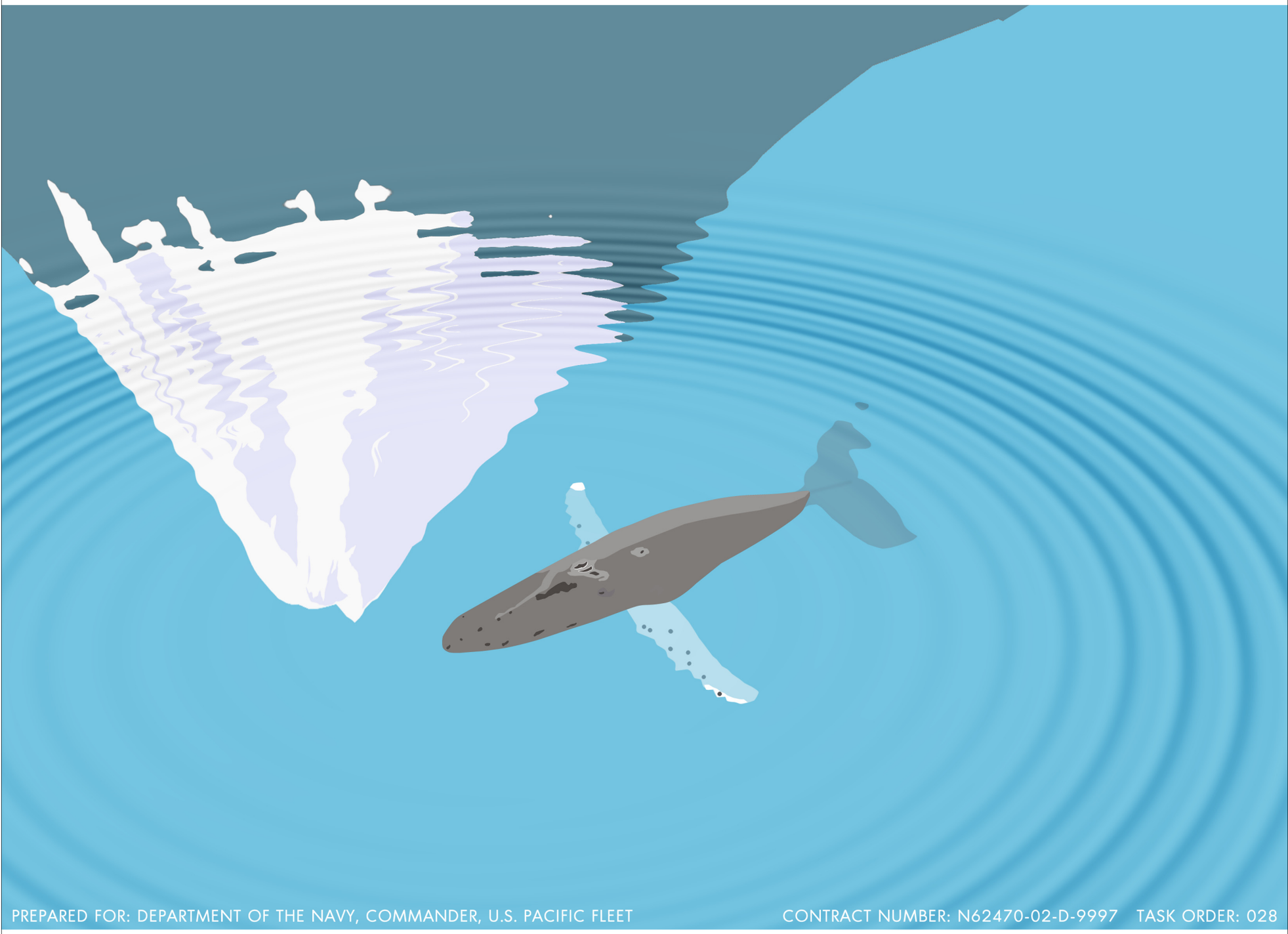
MARINE RESOURCES ASSESSMENT FOR THE JAPAN AND OKINAWA COMPLEXES OPERATING AREA



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For more information contact:
Naval Facilities Engineering Command, Pacific
Attn: Ms. Vanessa Pepi, Code EV2VP
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860
vanessa.pepi@navy.mil

FINAL REPORT
DECEMBER 2005

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Naval Facilities Engineering Command, Pacific
Attn: Ms. Vanessa Pepi, Code EV2VP
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134
vanessa.pepi@navy.mil

Prepared by:
Geo-Marine, Inc.
550 East 15th Street
Plano, TX 75074

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EXECUTIVE SUMMARY

The Department of the Navy (DoN) is committed to demonstrating environmental stewardship while executing its national defense mission. The United States (U.S.) Navy (Navy) is responsible for compliance with a suite of U.S. federal environmental and natural resources laws and regulations that apply to the marine environment, including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and Executive Order (EO) 12114 on Environmental Effects Abroad of Major Federal Actions. In addition, several Japanese environmental laws and agencies are recognized when conducting overseas operations. The Navy Commander, U.S. Pacific Fleet (COMPACFLT) implemented the marine resources assessment (MRA) program to develop a comprehensive compilation of data and literature concerning the protected and managed marine resources found in its various operating areas. The information in this MRA is vital for planning purposes and for various types of environmental documentation such as biological and environmental assessments that must be prepared in accordance with the NEPA, MMPA, and ESA.

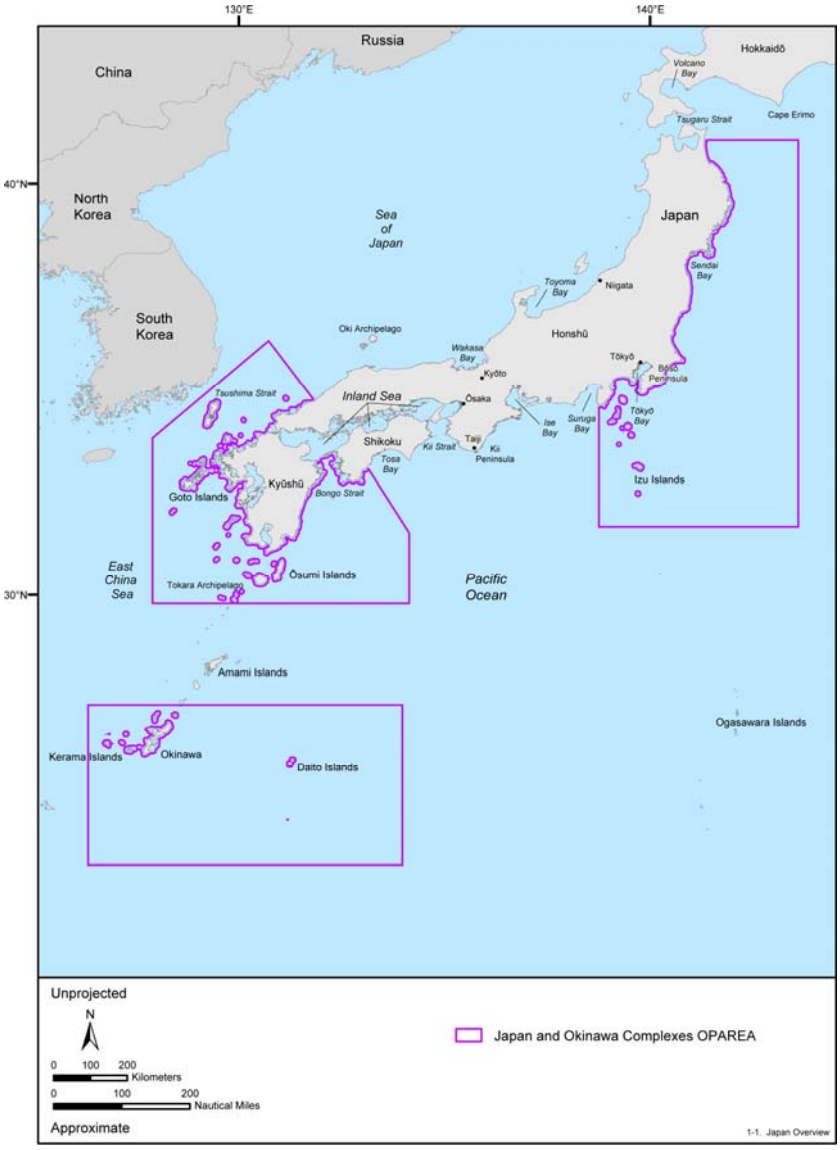

Figure ES-1. The Japan and Okinawa Complexes OPAREA consists of the East Japan, West Japan, and Okinawa study areas. Source data: DoN (2003) and SRS Technologies (2005a, 2005b).

This MRA documents and describes the marine resources within the Japan and Okinawa Complexes Operating Area (OPAREA) and vicinity (**Figure ES-1**). An overview of marine environments found in the western North Pacific Ocean illustrates the important physical parameters that may affect the occurrence and distribution of protected marine species. Detailed information is included on the characteristics and life history of protected marine mammals and sea turtles that may occur in the Japan and Okinawa Complexes OPAREA and vicinity. Seasonal variations in protected species occurrence patterns have been identified, mapped, and described along with the likely causative factors (behavioral, climatic, or oceanographic). The probable distributions of marine habitats, such as coral reefs, chemosynthetic communities, and artificial habitats, have also been assessed. Convention on International Trade in Endangered Species of Wildlife Flora and Fauna (CITES)-listed fish species and commercial fishing activities are briefly discussed in terms of their location and prevalence in the OPAREA. Finally, information is provided on additional

considerations that may potentially impact Navy activities in the OPAREA. These include maritime boundaries, major trade routes, marine protected areas (MPAs), self contained underwater breathing apparatus (SCUBA) diving sites, whaling, and whale watching cruises.

A thorough and systematic literature search was conducted, providing as much relevant information as possible for this assessment. Predictions of the areas of occurrence for marine mammals and sea turtles are based on both scientific literature and expert opinion.

The geographical representation of marine resource occurrences in the Japan and Okinawa Complexes OPAREA and vicinity is a major constituent of this MRA. A geographic information system (GIS) was used to store, manipulate, analyze, and display the spatial data and information accumulated for the MRA. Over 70 GIS-generated map figures are included in this assessment; data layers associated with these maps comprise bathymetry, sea surface temperature (SST), protected species' occurrences, Navy operating area grids, and maritime boundaries in addition to many others. Metadata (documentation of the GIS data) were also prepared for each GIS file associated with this MRA report. The MRA report for the Japan and Okinawa Complexes OPAREA is provided in both paper and electronic form.

REPORT ORGANIZATION

This report consists of eight chapters and two appendices:

Chapter 1 Introduction—provides background information on this project, an explanation of its purpose and need, a review of relevant environmental legislation, and a description of the methodology used in the assessment;

Chapter 2 Physical Environment and Habitats—describes the physical environment (e.g., marine geology [physiography, bathymetry, and bottom sediments], physical oceanography [circulation and currents], hydrography [temperature], biological oceanography [plankton and primary productivity], and habitats (e.g., nearshore and oceanic) of the Japan and Okinawa Complexes OPAREA and vicinity;

Chapter 3 Species of Concern—covers protected marine mammals and sea turtles found in the vicinity of the Japan and Okinawa Complexes OPAREA, with detailed narratives of their morphology, status, habitat preferences, distribution, behavior, life history, acoustics, and hearing;

Chapter 4 Fish and Fisheries—investigates CITES-listed fish species and commercial fishing activities that occur within the Japan and Okinawa Complexes OPAREA;

Chapter 5 Additional Considerations—provides information on maritime boundaries, major trade routes, marine protected areas, SCUBA diving locations, whaling, and whale watching cruises;

Chapter 6 Recommendations—suggests future avenues of research that are necessary to fill the data gaps identified in this project and prioritizes research needs from a cost/benefit approach;

Chapter 7 List of Preparers—lists all individuals who helped prepare the Japan and Okinawa Complexes OPAREA MRA report;

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

Appendix A—contains marine mammal occurrence maps discussed in Chapter 3.1; and

Appendix B—contains sea turtle occurrence maps discussed in Chapter 3.2.

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percent
°	Degree(s)
°C	Degree(s) Celsius
µs	Microsecond(s)
2D	Two-dimensional
3D	Three-dimensional
ASM	Asian Summer Monsoon
ASP	Amnesiac Shellfish Poisoning
AVHRR	Advanced Very High-resolution Radiometer
C	Carbon
CCC	Caribbean Conservation Corporation
CCL	Curved Carapace Length
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
chl *a*	Chlorophyll *a*
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	Centimeter(s)
cm/yr	Centimeter(s) Per Year
COMFLEACT	U.S. Commander Fleet Activities
COMPACFLT	Commander, U.S. Pacific Fleet
COTS	Crown-of-Thorns Starfish
CZCS	Coastal Zone Color Scanner
d	Day(s)
dB re 1 µPa-m	Decibel(s) with a Reference Pressure of One Micropascal at One Meter
dB	Decibel(s)
DCM	Deep Chl Maximum
DoD	Department of Defense
DoE	Department of Energy
DoN	Department of the Navy
DSL	Deep-Scattering layer
DSP	Diarrhetic Shellfish Poisoning
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
ENSO	El Niño Southern Oscillation
EO	Executive Order
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
FAD	Fish Aggregating Device(s)
FAO	Food and Agriculture Organization
FGS	Final Governing Standards
Fleet	U.S. Pacific Fleet
FM	Frequency Modulated
g	Gram(s)
$gC/m^2/d$	Gram(s) of Carbon Per Square Meter Per Day
GIS	Geographic Information System
GMI	Geo-Marine, Inc.
GPS	Global Positioning System(s)
ha	Hectare(s)
HAB	Harmful Algal Bloom(s)
hr	Hour(s)
HTML	Hypertext Markup Language
Hz	Hertz

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

IUCN	International Union for the Conservation of Nature and Natural Resources
IWC	International Whaling Commission
JEGS	Japan Environmental Governing Standards
kg	Kilogram(s)
kg/m^2	Kilogram(s) Per Square Meter
kg/m^3	Kilogram(s) Per Cubic Meter
kHz	Kilohertz
km	Kilometer(s)
km/hr	Kilometer(s)/hour
km^2	Square Kilometers
L	Liter(s)
M	Magnitude
m	Meter(s)
m/s	Meter(s) Per Second
m^2	Square Meter(s)
m^3	Cubic Meter(s)
MCSST	Multi-channel Sea Surface Temperature
mg	Milligram(s)
MHI	Main Hawaiian Islands
min	Minute(s)
mm	Millimeter(s)
mm/d	Millimeter(s) Per Day
mm/yr	Millimeter(s) Per Year
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MOI	Monsoon Index
MPA	Marine Protected Area(s)
MPPRCA	Marine Plastic Pollution Research and Control Act
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRA	Marine Resources Assessment
ms	Millisecond(s)
MSL	Mean Sea Level
mt	Metric Ton(s)
NAF	Naval Air Facility
NASA	National Aeronautic and Space Administration
Navy	United States Navy
NEC	North Equatorial Current
NEPA	National Environmental Policy Act
NM	Nautical Mile(s)
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
NPIW	North Pacific Intermediate Water
NPSG	North Pacific Subtropical Gyre
NPTW	North Pacific Tropical Water
NRHP	National Register of Historic Places
NSP	Neurotoxic Shellfish Poisoning
NWHI	Northwestern Hawaiian Islands
OCONUS	Outside of the Continental U.S.
OPAREA	Operating Area
PDF	Portable Document Format
PDO	Pacific Decadal Oscillation
PIFSC	Pacific Islands Fisheries Science Center

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

ppm	Parts Per Million
ppt	Parts Per Thousand
PSP	Paralytic Shellfish Poisoning
psu	Practical Salinity Unit
s	Second(s)
S.D.	Standard Deviation
SCUBA	Self Contained Underwater Breathing Apparatus
SEC	South Equatorial Current
SLP	Sea Level Pressure
SSH	Sea Surface Height
SST	Sea Surface Temperature
STMW	Subtropical Mode Water
Sv	Sverdrup
TIN	Triangular Irregular Network
TTS	Temporary Threshold Shifts
TZCF	Transition Zone Chlorophyll Front
U.S.	United States
U.S.C.	United States Code
UN	United Nations
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USMC	United States Marine Corps
USVI	United States Virgin Islands
WIDECAST	Wider Caribbean Sea Turtle Conservation Network
WPRFMC	Western Pacific Regional Fishery Management Council
WWII	World War Two
XML	Extensible markup language
yr	Year(s)

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1.0 INTRODUCTION

The COMPACFLT contracted this MRA to initiate a comprehensive compilation of existing information on the protected and commercial marine resources found in U.S. Pacific Fleet (Fleet) military ranges and training areas located in and around the waters of Japan. For the purposes of this MRA, the military areas assessed as a whole will be considered together and referenced as the Japan and Okinawa Complexes OPAREA. This OPAREA is further divided into three study areas that will be considered distinct entities and referred to as the East Japan, West Japan, and Okinawa study areas. Unless otherwise stated within this report, the extent of coverage lies from the outer boundaries of the study areas to within three nautical miles (NM) of any coastline.

1.1 PURPOSE AND NEED

The goal of this MRA is to provide a compilation of the most recent information and expert opinion on the occurrence of marine resources in the Japan and Okinawa Complexes OPAREA. This MRA report includes a discussion of the physical environment, habitats (coastal and oceanic), and protected species found in the OPAREA and surrounding western North Pacific Ocean. Fish and fisheries, MPAs, and other areas of interest (e.g., SCUBA diving sites, oil and gas structures, and whale watching locations) are also addressed. The identification of data gaps and the prioritization of recommendations for future research in the OPAREA are additional components of this report.

The DoN is responsible for organizing, training, and equipping Naval forces for combat. The mission of the Japan and Okinawa Range Complexes is to support Navy and U.S. Marine Corps (USMC) tactical training by maintaining and operating facilities, and providing services, arms, and material to support the Fleet, USMC Forces Pacific, and other operating forces. Section 4.1.1 of Department of Defense (DoD) Instruction 4715.3, “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” (DoD 1996). The information assembled in this MRA will serve as a baseline from which the Navy may evaluate its operations and their potential impacts on the marine environment while balancing the requirement to provide trained and ready forces with the obligations of sound resource stewardship. This assessment will contribute to the Fleet’s integrated long-range planning process and represents an important component in the Fleet’s ongoing compliance with U.S. federal mandates that aim to protect and manage resources in the marine environment. All species and habitats potentially affected by the Navy’s maritime exercises and protected by U.S. federal resource laws, EO, and Japanese wildlife laws are considered in this assessment.

A search and review of relevant literature and consultations with regional experts were conducted to provide information on important features of the marine environment, the occurrence patterns of protected species, and other Navy concerns in the Japan and Okinawa Complexes OPAREA. To describe the physical environment and habitats of the OPAREA, physiographic, bathymetric, geologic, hydrographic, and oceanographic data for the study region were compiled. Marine mammal and sea turtle areas of occurrence have been identified, mapped, and described along with the likely causative factors (behavioral, climatic, or oceanographic). Fish species listed under the CITES were also identified and addressed in this assessment. Biological characteristics, such as habitat preferences and life history patterns, were researched for all marine mammals, sea turtles, and CITES-listed fish species potentially occurring within the OPAREA. Also reviewed were commercial fishing activities, maritime boundaries, major trade routes and seaports, MPAs, SCUBA diving sites, oil and gas structures, and whale watching.

1.2 LOCATION OF THE JAPAN AND OKINAWA COMPLEXES OPAREA

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 (**Figure 1-1**). The bow-shaped archipelago is over

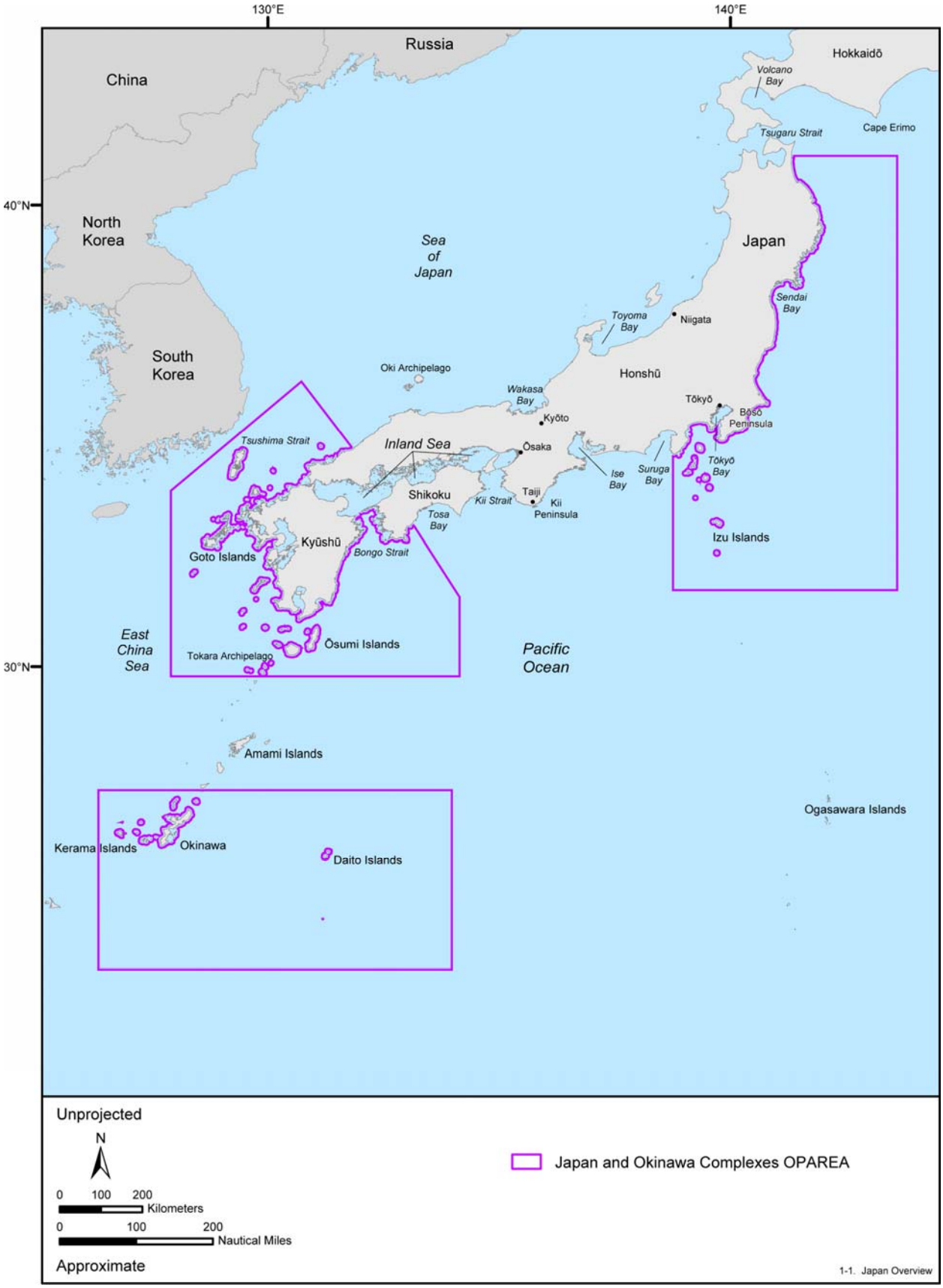

Figure 1-1. Overview of the major geographic features of Japan.

3,800 kilometers (km) long with total land area approximating 380,000 square kilometers (km^2). There is no point within the island chain that exceeds a distance of 150 km from sea (Dolan and Worden 1994; Petry 2003). Japan formed as a result of tectonic movements of the earth's crust beneath the sea, creating mountain ridges that surfaced near the outer ridge of the continental shelf within the Pacific Ocean. Throughout the archipelago, Japan's terrain consists of coastal plains, mountains, basins and volcanic plateaus that sit atop the summits of the underwater mountain ridge (Caraway 2005).

The Japan and Okinawa Complexes OPAREA contains three distinct regions of land and seas that surround the two complexes. These include the West Japan study area, the East Japan study area, and the Okinawa study area (**Figure 1-2**). Covering 863,360 km^2 of land and ocean, the OPAREA consists of specific ranges designated for military training including weapons firing, bombing, and maneuver of ground, sea and air elements (DoN 2003).

The northernmost island of Japan is Hokkaidō, a body of land that encompasses approximately 22 percent (%) (83,452 km^2) of the total land area of Japan. The island is bordered by the Pacific Ocean, the Sea of Japan, and the Okhotsk Sea. To the southwest of Hokkaidō is Honshū, the 'mainland' island of Japan. Honshū is located across the Tsugaru Strait and is connected to Hokkaidō by the Seikan Tunnel (Wikipedia 2005). 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% of Japan's total land area. Both Naval Air Facility (NAF) Atsugi and Yokosuka Naval Complex are located on the eastern coast of Honshū, south of Tōkyō. The landward boundary of the East Japan study area begins just slightly south of the northern apex of Honshū and descends along its eastern coast, excluding Tōkyō Bay, ending at the southern tip of the Izu Peninsula. This study area encompasses 310,250 km^2 of ocean area and begins 3 NM beyond the Japanese coastline.

Shikoku is the smallest of the four Japanese islands (18,800 km^2) and lies south of the easternmost portion of Honshū. Southwest of both Honshū and Shikoku lies the third largest Japanese island, Kyūshū (35,640 km^2). U.S. Commander Fleet Activities (COMFLEACT) Sasebo installations and facilities are concentrated along the Sasebo Harbor on Kyūshū. The eastern edge of the West Japan study area begins 3 NM from the coast just south of Ogata on the island of Shikoku. The study area boundary remains 3 NM from shore as it extends around the southern tip of Shikoku to Kyūshū and continues to parallel its southern, western, and northern borders, terminating on the northwest extension of Honshū. Although several small islands lie within the West Japan study area off the coast of Kyūshū, their nearshore environments will not be discussed in this report. The northwest boundary of the study area extends through the Tsushima Strait, 15 km from the southeast coast of South Korea. The West Japan study area covers a total area of 220,570 km^2 within the Pacific Ocean, East China Sea, and the Tsushima Strait.

The Ryukyu archipelago arcs from the southern tip of Kyūshū through the western Pacific Ocean, stretching towards 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 to be the administrative rule in each section for the nation, a concept similar to that of city and state in the U.S. 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 the exchange between nations. Due to its propinquity to potential trouble spots in the Pacific, Okinawa has been favored to serve as a location in 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 Okinawa study area consists of 332,540 km^2 of land and seas and is the only study area that includes a discussion of nearshore habitats surrounding four specific islands. Barring these four islands,

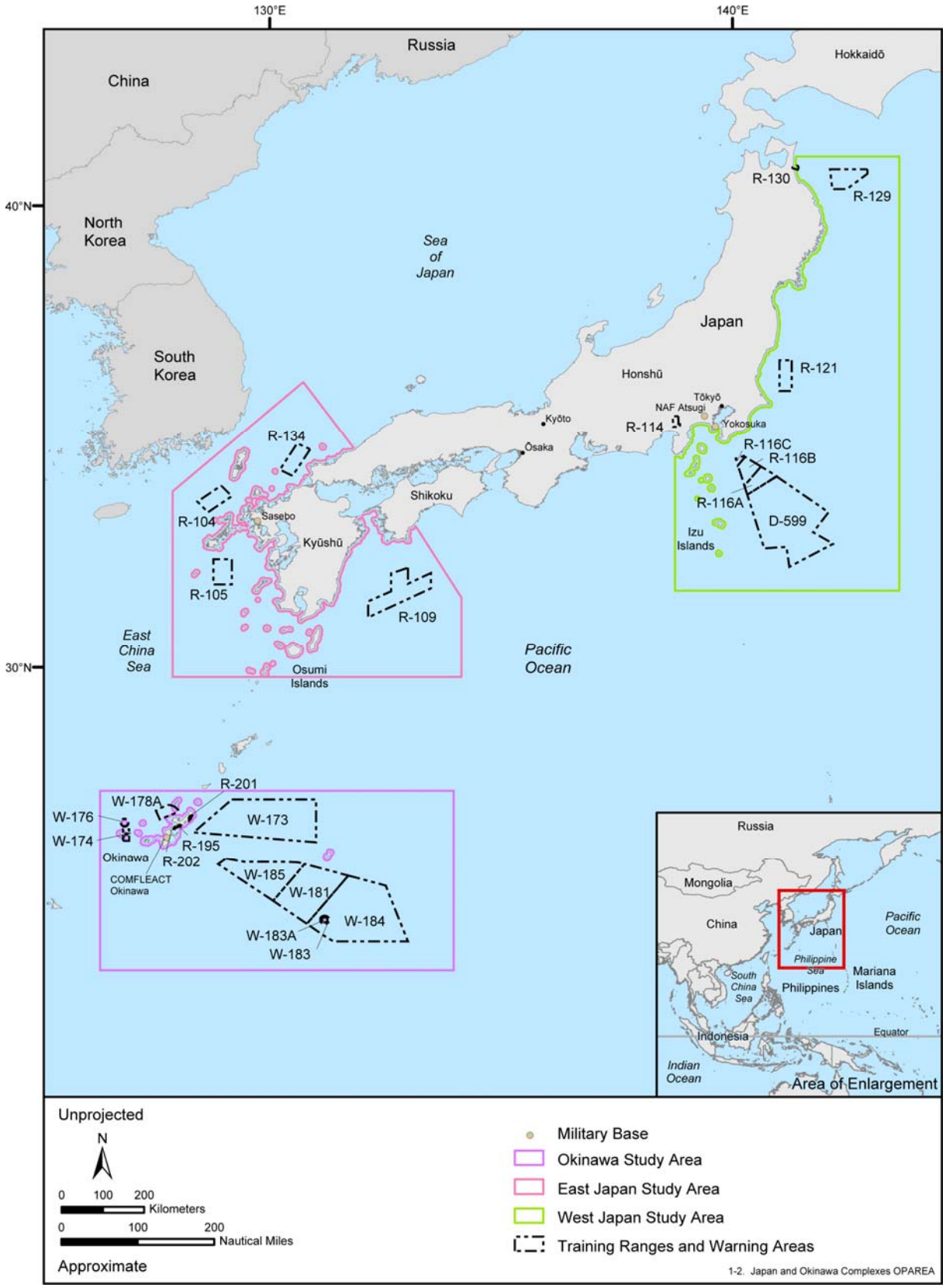

Figure 1-2. The Japan and Okinawa Complexes OPAREA is located in the western North Pacific Ocean and consists of Navy training areas adjacent to mainland Japan and Okinawa. Three study areas (East Japan, West Japan, and Okinawa) comprise the OPAREA. Source data: DoN (2003) and SRS Technologies (2005a, 2005b).

the boundary will cease 3 NM from shore for all adjacent islands, including the largest, Okinawa (**Figure 1-3**). The military training areas for which coastal and oceanic habitats are addressed include: Idesuna Jima Range (Warning Area W-174), Tori Shima Range (Warning Area W-176), Ie Shima Range (Warning Areas W-178 and W-178A), and Okino Daito Jima Range (Warning Areas W-183 and W-183A). The Idesuna Jima Range includes a water surface area contiguous to the land in a 2 NM arc centered on the island. A circular water surface area contiguous to the 2.7 km wide landmass of Tori Shima, out to a distance of 5 NM, represents the Tori Shima Range Warning Area. Although the northeast portion of the Ie Shima Range traverses Izena Island, the only island within this military range in which the nearshore habitats are addressed is that of Ie Shima. The northwest coastal extent of Ie Shima lies along the southern boundary of the warning area. The water surface area centered at 26°43'41"N, 127°45'41"E within an arc of 5 NM defines the limits of the Ie Shima Range. Warning areas W-183 and W-183A contain the waters surrounding Okino Daito Jima, an island approximately 200 NM southeast of Okinawa, in a circular outline from the coast to 3 NM seaward.

The U.S. military uses each range for air-to-ground bombing and gunnery training with ship-to-shore maneuvers being conducted in the Okino Daito Jima Range. COMFLEACT Okinawa installations and operations are located on the southwest coast of Okinawa. In addition, several U.S. military training ranges extend throughout the Japan archipelago and are discussed in great detail in *COMNAVFORJAPAN Instruction 3500.3T* (DoN 2003). The Senkaku Islands lie southwest of the Okinawa Prefecture in the East China Sea and contain warning areas in the regions of Kobi-sho and Sekibi-sho, the two largest islands within Senkaku. The Navy has been prohibited from using W-175 (Kobi-sho) and W-182 (Sekibi-sho) since 1979 due to political sensitivities with the People's Republic of China, Taiwan, and Japan (DoN 2003).

The *Integrated Natural Resources Management Plan: Commander Fleet Activities (COMFLEACT) Okinawa* (DoN 2004), *Natural Resources Management Plan: COMFLEACT Sasebo* (DoN 1998), *Natural Resources Management Plan: Naval Air Facility, Atsugi* (DoN 1997a), and *Natural Resources Management Plan*: *Yokosuka Naval Complex* (DoN 1997b) provide an abundance of information on the coastal environments and Naval activities found in and around each installation. DoN (2003) also provides detailed environmental information for Navy training areas and installations located throughout the Japan archipelago.

1.3 APPLICABLE LEGISLATION

The primary environmental laws that govern Navy activities in marine environments and address international concerns include the NEPA, the MMPA, and the ESA. In addition to these U.S. federal acts, EO 12114 is a statute describing the actions that must be initiated before military activities that may potentially disrupt, disturb, or destroy marine environments take place in foreign waters. Furthermore, several Japanese environmental laws and agencies enforce resource conservation and management in territorial waters.

The Environmental Agency, established in 1971, typically administers Japanese environmental conservation and protection laws. U.S. military activities and installations in Japan are required to recognize the 2004 Japan Environmental Governing Standards (JEGS) to ensure compliance of environmental regulation. The JEGS, also known as the Final Governing Standards (FGS), are a comprehensive set of environmental principles, specific to Japan, used by the DoD to direct operations with the intent of minimizing potential environmental impacts (DoD 2002). The environmental guidelines in Chapter 13 of the JEGS (DoD 2004) states that any species (flora or fauna) considered to be in jeopardy under either U.S. law, Japanese wildlife law, or a treaty in which the U.S. is a party, is afforded the proper protection and management. All domestic and foreign nation species deemed threatened or endangered that could be adversely affected by DoD activities will be protected and enhanced. In instances where the JEGS do not apply to military operations and/or personnel, international environmental protection legislation or Japanese national or prefectural regulations are recognized (DoN 1997a).

The following are U.S. and international laws and regulations that the Navy must consider when conducting maritime operations in Japan.

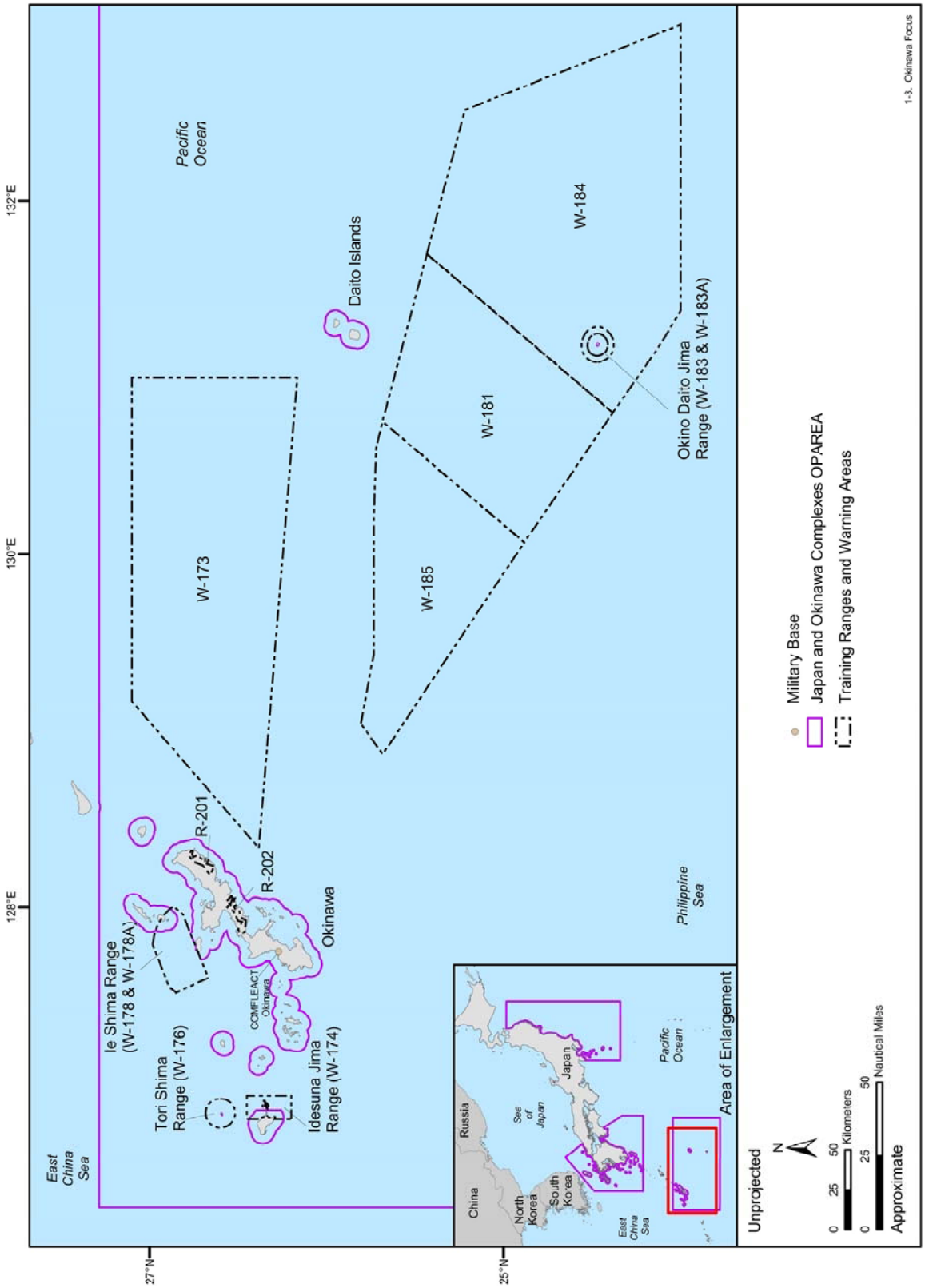

Figure 1-3. A zoom-in view of the Okinawa study area and the Navy training areas located around the island. Four ranges within the study area include a coastal component: W-174, W-176, W-178, and W-183/W-183A. Source data: DoN (2003) and SRS Technologies (2005b).

1.3.1 U.S. Federal Resource Laws

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

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

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

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

- The **Marine Mammal Protection Act** (MMPA) of 1972 (16 U.S.C. §§ 1361 et seq.) established a moratorium on the “taking” of marine mammals in waters or on lands under U.S. jurisdiction. Marine mammals include cetaceans (whales, dolphins, and porpoises), pinnipeds (seals and sea lions), sirenians (manatees and dugongs), sea otters, walruses, and polar bears. 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[13]). It also prohibits the importation into the U.S. of any marine mammal or parts or products thereof, unless it is for the purpose of scientific research or public display, as permitted by the Secretary of the Interior or the Secretary of Commerce. In the 1994 amendments to the MMPA, two levels of “harassment” were defined. Harassment is defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild (Level A), or any act that has the potential to disturb a marine mammal or marine mammal stock in the wild by disrupting behavioral patterns, including, but not limited to migration, breathing, nursing, breeding, feeding, or sheltering (Level B). In 2003, the National Defense Authorization Act for Fiscal Year 2004 altered the MMPA’s definition of Level A and B harassment in regards to military readiness and scientific research activities conducted by or on behalf of the federal government. Under these changes, Level A harassment was redefined as any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment was redefined as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered.

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

level). Section 101(a)(5)(A) also specifies that the Secretary has the right to deny permission to take marine mammals if, after notice and opportunity for public comment, the Secretary finds: (1) that applicable regulations regarding taking, monitoring, and reporting are not being followed, or (2) that takes are, or may be, having more than a negligible impact on the affected species or stock.

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

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

  The major responsibilities of the NMFS and USFWS under the ESA include: (1) the identification of threatened and endangered species; (2) the identification of critical habitats for these species; (3) the implementation of research programs and recovery plans for these species; and (4) the consultation with other federal agencies concerning measures to avoid, minimize, or mitigate the impacts of their activities on these species (Section 7 of the ESA). Further duties of the 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).

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

  There are 48 marine mammals (39 cetaceans, eight pinnipeds, and one sirenian), five sea turtles, and a number of fishes with known or potential occurrence in the Japan and Okinawa Complexes OPAREA. Of these, nine marine mammals and five sea turtles are listed as either an endangered or threatened species (**Table 1-1**). For the marine mammals, the NMFS has jurisdiction over cetaceans and pinnipeds. For the sea turtles, the NMFS has jurisdiction over them while they are in the water and the USFWS has jurisdiction over them while they are on land (including eggs, hatchlings that are on the beach, and nesting females).

1.3.2 Executive Orders

- **EO 12114 on Environmental Effects Abroad of Major Federal Actions** (32 CFR 187) was passed in 1979 to further environmental objectives consistent with U.S. foreign and national security policies by extending the principles of the NEPA to the international stage. Under EO 12114, federal agencies that engage in major actions that significantly affect a non-U.S. environment must prepare an environmental assessment (EA) of the action's effects on that environment. This is similar to an

Table 1-1. The federally protected marine mammal and sea turtle species with known or potential occurrence in the Japan and Okinawa Complexes OPAREA and surrounding region.

Taxon Group	Scientific Name	ESA Status
Marine Mammals		
North Pacific right whale	*Eubalaena japonica*	Endangered
Bowhead whale	*Balaena mysticetus*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Steller sea lion	*Eumetopias jubatus*	Threatened
Dugong	*Dugong dugon*	Endangered
Sea Turtles		
Green turtle	*Chelonia mydas*	Threatened[1]
Hawksbill turtle	*Eretmochelys imbricata*	Endangered
Loggerhead turtle	*Caretta caretta*	Threatened
Olive ridley turtle	*Lepidochelys olivacea*	Threatened[1]
Leatherback turtle	*Dermochelys coriacea*	Endangered

[1] Although both species as a whole are listed as threatened, the Eastern Pacific nesting stock of the green turtle and the Mexican Pacific nesting stock of the olive ridley turtle are listed as endangered (NMFS and USFWS 1998a, 1998b, 1998c). Since the nesting areas for green and olive ridley turtles encountered at sea often cannot be determined, a conservative approach to management requires the assumption that some greens and olive ridleys found in the OPAREA may be endangered.

environmental impact statement (EIS) or EA developed under the NEPA. Certain actions, such as intelligence activities, disaster and emergency relief actions, and actions that occur in the course of an armed conflict, are exempt from this order. Such exemptions do not apply to major federal actions that significantly affect an environment that is not within any nation's jurisdiction, unless permitted by law. The purpose of the order is to force federal agencies to consider the effects their actions have on international environments.

1.3.3 International Environmental Law

- Japan's **Law for the Protection of Cultural Properties** (1950) is designed to designate, preserve and manage national monuments in order to maintain their habitat, promote public awareness, and implement plans for their protection. Potential monuments can range from animals, various types of vegetation, to ecosystems that are potentially at risk of a status change due to alteration of habitat or other restricting events. The National Historic Preservation Act requires the U.S. government to prepare an EA before undertaking any overseas activities that may potentially impact a cultural resource listed on the equivalent to the U.S. National Register of Historic Places (NRHP); in Japan, The Law for the Protection of Cultural Properties is equivalent to the country's NRHP. In 1955, the Japanese government designated the dugong (*Dugong dugon*) a national monument due to its endangered status and deep cultural significance to Okinawa (STRP 2003).

- The **Convention on International Trade in Endangered Species of Wild Fauna and Flora** (CITES) is an international conservation agreement between countries/states that aims to protect certain species by regulating and monitoring their international trade. The convention acts to maintain

sustainability of the traded plant or animal species. Each participating party (e.g., U.S.: 1975 and Japan: 1980) voluntarily agrees to ensure that CITES is implemented through independently created domestic legislation; CITES does not take the place of any existing national legislation (CITES 2005). Appendices I, II, and III of CITES list all species (import, re-export, and introduction) according to the degree of protection needed to maintain a sustainable population. Species threatened with extinction are listed in Appendix I and only traded in extraordinary circumstances. Appendix II contains a list of species that are not necessarily threatened with extinction, although, trade would potentially limit their survival. Species listed and regulated by a party that requests additional assistance from other countries to ensure conservation of those species are contained in Appendix III (CITES 2005).

- The **International Union for the Conservation of Nature** (IUCN) Red List of Threatened Species provides taxonomic, conservation status, and distribution information on evaluated taxa. The IUCN determines the relative risk of extinction; the main purpose of the IUCN Red List is to document and emphasize those organisms that face an increased risk of extinction (IUCN 2004).

1.4 METHODOLOGY

1.4.1 Literature and Data Search

Prior to the production of this report, a thorough and systematic search for relevant scientific literature and data was conducted. Information, data, and literature that were deemed vital to the production of this MRA were identified, obtained, reviewed, and then catalogued. Of the available scientific literature (both published and unpublished), the following types of documents were utilized in the assessment: journals, periodicals, bulletins, monographs of scientific and professional societies, theses, dissertations, project reports, conference proceedings, endangered species recovery plans, stock assessment reports, EAs, EISs, Navy natural resource management plans, and other technical reports published by government agencies, private businesses, or consulting firms. A multitude of individuals, agencies, and databases were consulted during the search for data and information on the occurrence of marine resources in the Japan and Okinawa Complexes OPAREA (all of which are mentioned below).

To investigate the physical environment and habitats of the OPAREA; summarize the occurrence patterns of protected species; describe the region's fish species and commercial fisheries; and ascertain the distribution of maritime boundaries, major trade routes, MPAs, and other concerns, information was collected from the following sources:

- Academic and education/research institutions (Australian Institute of Marine Science, Comstock/Cornell University Press, Institute of Cetacean Research, Los Angeles County Museum of Natural History, Sea Turtle Association of Japan, SRS Technologies, Inc., Teikyo University of Science and Technology, University of California at San Diego [Scripps Institute of Oceanography], University of Hawai'i, University of Ryukyu Islands, Whale and Dolphin Conservation Society, Wider Caribbean Sea Turtle Conservation Network [WIDECAST])

- The Internet, including various databases and related websites (Allen Press, Associated Press, Blackwell-Science, dbSEABED, Department of Energy [DoE], divejapan.com, Elsevier, Federal Register, FishBase, Florida Museum of Natural History, Food and Agriculture Organization [FAO], globalsecurity.org, Integrated Coastal Management, Ingenta, MPA Global, National Oceanic and Atmospheric Administration [NOAA], NMFS, outdoorjapan.com, ReefBase, seahorsetales.com, seaturtle.org, Sirenian International, Inc. online bibliography, Springer, The Dugong Network Okinawa, University of Florida Online Sea Turtle Bibliography, University of Rhode Island, USFWS, U.S. Geological Survey [USGS], U.S. Pacific Command, Wikipedia, World Database on Protected Areas)

- U.S. federal agencies (DoD, DoN, Marine Mammal Commission [MMC], National Aeronautic and Space Administration [NASA], NMFS: Alaska Fisheries Science Center – National Marine Mammal Laboratory [NMML], NOAA, Office of Protected Resources, Pacific Islands Fisheries Science Center

[NMFS-PIFSC], Western Pacific Regional Fishery Management Council [WPRFMC], U.S. Coast Guard [USCG])

- State/regional agencies (O'ahu Civil Defense Agency), and
- International agencies (CITES, Ministry of Land, Infrastructure, and Transport [Japan], Ministry of the Environment [Japan], United Nations [UN] Atlas of the Environment, International Union for the Conservation of Nature and Natural Resources [IUCN])

1.4.2 Spatial Data Representation—Geographic Information System

The geographical representation of marine resource occurrences in the Japan and Okinawa Complexes OPAREA and vicinity was a major constituent of this MRA report. The marine resources data and information accumulated for this project were accessed from a wide variety of sources, were in disparate formats, covered a broad range of time periods, and represented differing levels of accuracy as well as quality assurance.

A GIS was used to store, manipulate, analyze, and display the spatial data and information accumulated for the Japan and Okinawa Complexes OPAREA. For this project, Environmental Systems Research Institute, Inc.'s (ESRI) ArcGIS® version 8.3 GIS software was used to create the majority of the map figures, geospatial data, and metadata. ArcGIS® was chosen for this project due to its widespread use by the federal government and, the Navy, and its ability to create highly accurate and richly detailed maps.

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

The source type and associated references for all marine resource data presented in the map figures are listed in each figure's caption. The full reference citations for map source data or information may be found in the Literature Cited section of each MRA chapter. Aside from the protected species maps, the two primary types of spatial information used in the Japan and Okinawa Complexes OPAREA MRA were coordinate data and scanned maps. These two source types are associated with differing levels of data reliability or confidence (Section 1.4.2.1). Numerical or authentic data are associated with the highest level of reliability while data obtained by scanning source maps is less reliable.

GIS data are displayed as layers for which scale, extent, and display characteristics can be specified. Multiple themes are represented on an individual map figure. Throughout the project, data imported into ArcView® had to be maintained in the most universal, least transformed manner in order to reduce conflict between theme coordinate systems and projections. In the GIS, the most flexible spatial data format is the unprojected geographic coordinate system, which uses decimal degree latitude and longitude coordinates (Section 1.4.2.2). The decimal degree format is the only coordinate system format that allows

unlimited, temporary, custom projection and re-projection in all versions of ArcView® and is therefore the least restrictive spatial data format. The printed maps and electronic GIS map data for this MRA report are unprojected and are therefore not as spatially precise (in terms of distance, area, and shape) as a projected map. Consequently, the maps should not be used for measurement or analysis. For these tasks, an appropriate local/continental projection should be selected when using the GIS data.

Once the marine resource data were imported and stored in the GIS, maps were created representing multiple layers of either individual or combined data. The maps in this MRA report are presented in kilometers and nautical miles. The majority of maps in this report are presented in either of two forms: a display that includes two seasonal maps per page, and a display that includes one full-page map. Maps of each display type are often presented at the same approximate scale.

The ability to display and analyze multiple data themes or layers simultaneously is one of the advantages to using a GIS rather than other graphic software. Customizations were made to the software in ESRI's ArcObjects™ proprietary language to automate the more repetitive map-making tasks as well as the processing and analysis of large volumes of data. A customization was created to ensure consistent Geo-Marine, Inc. (GMI) field names and domains for each of the shapefiles. The attribute tables for each layer must contain at least two added fields: GMI_Data and GMI_Source. GMI_data is the field that contains the source type and GMI_Source contains the source citation. The ArcObjects™ script was used to create and with a GIS analyst's input via a user form, populate these fields automatically. Also, a customization to ArcCatalog® allowed for a metadata automation tool that greatly increased the efficiency and lowered the amount of errors of metadata generation.

1.4.2.1 Data Confidence

The level of data confidence is dependent upon three factors: precision, accuracy, and currency. Each of these three factors are in turn affected by all the variables involved in obtaining data and putting the data into a GIS in order to display the data on a map. Following is a brief description of the three main factors and some of the subsequent variables that figure into overall level of confidence. Details concerning the Japan and Okinawa Complexes OPAREA GIS maps are incorporated into **Table 1-2**.

- ***Precision***—Refers to whether or not the description of the data is specific or non-specific. It is possible to have data recorded very precisely but with very low accuracy. In other words we may say that 2 + 2 = 5.12546732, where the sum is given very precisely but inaccurately. Global positioning systems (GPS) offer the highest level of precision for recording locations.

- ***Accuracy***—Refers to how well the data reflect reality. There may be 10 records of cold seeps in an area, but they may actually have been hydrothermal vents. Even if the locations were precisely recorded, the data are still not accurate. Some variables that affect accuracy are who originally recorded the data (source reliability), how many people have processed/altered the data since it originated (number of iterations), and the method used to record the data.

- ***Currency***—Refers to how recently the data were obtained. Because recent developments in equipment and methods have improved precision and accuracy, confidence is higher for data that have been recorded more recently.

1.4.2.2 Map Projections

Since understanding the role map projections play in the creation of valid and usable maps is so critical, further explanation of this issue is provided. A geographic reference system (such as latitude and longitude) is based on the angles measured from the earth's center. A planar coordinate system, on the other hand, is based on measurements on the surface of the earth. To meaningfully transfer real world coordinates (in three dimensions) to planar coordinate (two dimensions), a transformation process has to be applied. This transformation process is called a projection. Such a transformation involves the distortion of one or more of the following elements: shape, area, distance, and/or direction. The user

Table 1-2. Japan and Okinawa Complexes OPAREA GIS maps.

Japan and Okinawa Complexes OPAREA Map Examples	Description of Map Data	Confidence Level
Bathymetry, Sea Surface Temperature, Chlorophyll, Benthic Habitats, Maritime Boundaries, Bottom Substrates	Data from original/reliable sources. Provided in a digital format with geographic coordinates given. Identified as "*source data*" in map captions.	**High** 10 maps (14% of total number of maps)
Corals, Major Trade Routes, Geological Features	First- or second-hand data sources. Locations obtained through scanning geo-referenced* maps. Identified as "*source map(s) scanned*" in map captions.	**Medium** 13 maps (17% of total number of maps)
Marine Mammal and Sea Turtle Occurrence Maps, Migration Maps	First- or second-hand data sources. Locations obtained by digitizing from written descriptions with no coordinate data or by altering and/or interpreting raw data. Identified respectively as "*source information*" or "*map adapted from*" in map captions.	**Low** 50 maps (69% of total number of maps)

* Geo-referenced–Refers to data, maps, and images with points that can be matched to real world coordinates so that the data can be accurately positioned in a GIS.

typically dictates the choice of a projection type to ensure the least distortion to one or more of the four elements. Choice of a particular projection is dictated by issues such as the location of the place on earth, purpose of the project, or user constraints.

The length of one degree of longitude will vary depending on what latitude on earth the measurement is taken. The geographic coordinate system measures the angles of longitude from the center of the earth and not distance on the earth's surface. One degree of longitude at the equator measures 111 km versus 0 km at the poles. Using a map projection mitigates this difference or seeming distortion when using geographic coordinates. However, when multiple data sources with multiple projection systems are used, the most flexible system to standardize the disparate data is to keep all data unprojected. Thus, the maps in this MRA are untransformed, meaning they are shown unprojected on the map figures and their associated geographic data are delivered unprojected.

Since the measurement units for unprojected, geographic coordinates are not associated with a standard length, they cannot be used as an accurate measure of distance. Since the maps in this assessment are in geographic coordinates, the map figures should not be used for measurement and the scale information only provides approximate distances. The map scales and reference datum used on all maps in this MRA are presented in kilometers and nautical miles.

1.4.2.3 Maps of the Physical Environment—Oceanography and Habitats

Bathymetric data from Sandwell et al. (2004) were sampled at two minute (min) resolution and were acquired as geographic coordinates giving depth below mean sea level. Depth data were imported into the Spatial Analyst module of ArcView®, which interpolated and contoured the data at 50 meter (m)

intervals for waters shallower than 100 m and at 500 m intervals for waters deeper than 500 m. Selected isobaths from the resulting two-dimensional contours are shown on the bathymetry figures and on various maps throughout the MRA report.

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

Seasonal averages of SST were obtained from the NASA and compiled from weekly averaged Advanced Very High-resolution Radiometer (AVHRR) images, which contain multi-channel sea surface temperature (MCSST) pixel data for the years 1981 to 2001. Seasonal averages of chlorophyll *a* concentrations were also obtained from the NASA and compiled from monthly averaged Coastal Zone Color Scanner (CZCS) images taken from 1978 to 1986 to provide a proxy of primary productivity for the study area. Seasons are defined as winter (December through February), spring (March through May), summer (June through August), and fall (September through November) for the oceanography and habitat chapter of this MRA.

Multiple sources of data and information were used in the creation of maps for the oceanic and coastal habitats located in the MRA study area and vicinity. Habitats that were incorporated into the Japan MRA include coral reef communities, chemosynthetic communities, and artificial habitats (**Figures 2-9** through **2-14**). These maps were created using scanned images, coordinate data, GIS shapefiles, and other information available in the scientific literature and technical reports.

1.4.2.4 Biological Resource Maps—Species of Concern

Marine mammal and sea turtle areas of occurrence within the Japan and Okinawa Complexes OPAREA and vicinity were drawn with the assistance of and insights from regional protected species experts, using published literature, gray literature, and their knowledge of the species' occurrence patterns and habitat preferences. Published information on habitat preferences and distribution patterns in the western North Pacific Ocean (and other locales) was reviewed. However, occurrence data for these species (e.g., sighting, stranding, incidental fisheries bycatch, tagging, and nesting/haulout records) were not systematically collected or plotted.

Seasonal shifts in distribution are known for a number of marine mammal and sea turtle species in the area, but quite often the occurrence maps did not capture this since the published literature generally did not show the shifts with the required periodicity noted. It should be noted that the species occurrence maps presented in Appendices A and B would likely need to be revised if occurrence data were plotted for the OPAREA and vicinity. An underlying premise used during the map creation process was that a conservative approach to delineating occurrence patterns was necessary, since all five sea turtle species and nine of the marine mammal species with confirmed or possible occurrence in the OPAREA are listed as either threatened or endangered under the ESA.

Four types of occurrence information may be displayed on each marine mammal or sea turtle map: areas of **expected occurrence** (areas encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and documented occurrence records), areas of **concentrated occurrence** (subareas of a species' expected occurrence where there is the highest likelihood of encountering that species; this designation is based primarily on areas of concentrated sighting/nesting records and preferred habitat), areas of **low/unknown occurrence** (areas where a species is believed to be rare or the likelihood of encountering that species is not known), and areas labeled **occurrence not expected** (areas within the protected species data extent where a species encounter is not expected to occur). In the species of concern chapter of this MRA, seasons are defined

as winter-spring (December through May) and summer-fall (June through November). Occurrence maps may be presented on either a seasonal or year-round basis, depending on the type and detail of information available.

1.4.2.5 Maps of Additional Considerations

Information regarding the locations of maritime boundaries and major trade routes in the Japan and Okinawa Complexes OPAREA were gathered from various sources. Maps displaying maritime boundaries were created using GIS shapefiles produced by privately owned companies. Major trade routes in the OPAREA and vicinity were depicted using a scanned map from a U.S. Pacific Command document detailing the economic status of the Asian Pacific.

1.4.2.6 Metadata

The creation of metadata (or information about the GIS data) documentation files was a large component of the GIS work completed for this assessment. Every GIS file used in the creation of the map figures within this MRA has a metadata file associated with it. When possible, metadata were obtained along with GIS data used in this MRA; those data are included in the metadata documentation. Often documentation information, especially on the accuracy or reliability of the associated data, was not available.

Metadata for geographical data should include the data source, creation date, format, projection, scale, resolution, accuracy, and reliability with regard to some standard. Metadata also consists of properties and process documentation. Properties are derived from the data source, while documentation is entered manually. ESRI ArcCatalog® creates metadata in extensible markup language (XML) format, so the same metadata can be viewed in many different ways using different styles. Metadata created to accompany this MRA report are provided in both XML and hypertext markup language (HTML) formats, so that the metadata can be viewed in many types of viewers and are accessible within the GIS environment by other users.

1.5 REPORT ORGANIZATION

This report consists of eight major chapters and two associated appendices. Chapter 1—Introduction provides background information on this project, an explanation of its purpose and need, a review of relevant environmental legislation, and a description of the methodology used in the assessment. Chapter 2—Physical Environment and Habitats describes the physical environment of the study areas, including the marine geology (physiography, bathymetry, and bottom sediments), physical oceanography (circulation and currents), hydrography (surface temperature and salinity), biological oceanography (plankton), and habitat complexity. It also discusses the distribution of marine habitats including marine and estuarine wetlands (e.g., salt marsh, lagoons, mangroves), intertidal habitat (e.g., tidal pools, anchialine ponds, beach), subtidal benthos (e.g., kelp, seagrass, coral reefs), water column (e.g., neritic, pelagic), deep benthic (e.g., deep-sea corals, abyssal plain, seamounts), chemosynthetic ecosystems (e.g., hydrothermal vents, cold-seeps, and whale falls), CITES-listed coral species, and artificial substrates (e.g., artificial reefs, shipwrecks, and fish aggregating devices [FADs]) in the Japan and Okinawa Complexes OPAREA and vicinity. Chapter 3—Species of Concern covers all protected marine mammal and sea turtle species found in the Japan and Okinawa Complexes OPAREA. For these species, detailed narratives of their morphology, status, habitat preferences, distribution (including migratory patterns), behavior, life history, and acoustics and hearing (if known) have been provided. Chapter 4—Fish and Fisheries describes fish distributions, CITES-listed species, and commercial fishing activities that occur within the OPAREA. Chapter 5—Additional Considerations provides information on maritime boundaries, major trade routes, MPAs, SCUBA diving sites, oil and gas structures, and whale watching. Chapter 6—Recommendations suggests future avenues of research that may fill the data gaps identified in this project and prioritizes research needs from a cost-benefit approach. Chapters 7 and 8 are the List of Preparers and Glossary, respectively. Appendices A and B contain occurrence map figures that are described or referenced in the marine mammal and sea turtle sections (3.1 and 3.2, respectively) of Chapter 3.

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

1.6 LITERATURE CITED

Caraway, B. 2005. Japan, Land of the Rising Sun: Geography. Accessed 18 August 2005. http://www.koreanhistoryproject.org/Jta/Jp/JpGEO1.htm.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). 2005. CITES. Accessed 20 June 2005. http://www.cites.org.

DoD (Department of Defense). 2004. Japan environmental governing standards. Pearl Harbor, Hawaii: Naval Facilities Engineering Command, Pacific Division.

DoD (Department of Defense). 1996. DoD Instruction 4715.3, Environmental Conservation Program. Washington, D.C.: Secretary of Defense.

Dolan, R.E. and R.L. Worden, eds. 1994. Japan: Composition, topography, and drainage. Accessed 27 July 2005. http://lcweb2.loc.gov/cgi-bin/query/r?frd/cstdy:@field(DOCID+jp0052).

DoN (Department of the Navy). 1997a. Natural resources management plan, Naval Air Facility, Atsugi. Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii by Belt Collins Hawaii, Honolulu, Hawaii. 111 pp.

DoN (Department of the Navy). 1997b. Natural resources management plan, Yokosuka Naval complex. Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii by Belt Collins Hawaii, Honolulu, Hawaii. 170 pp.

DoN (Department of the Navy). 1998. Natural resources management plan, COMFLEACT Sasebo, Japan. Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii by Belt Collins Hawaii, Honolulu, Hawaii. 114 pp.

DoN (Department of the Navy). 2003. COMNAVFORJAPAN Instruction 3500.3T. Commander U.S. Naval Forces, Japan.

DoN (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.

Fuqua, J. 2001. Understanding Okinawa's role in the U.S.-Japan security agreement. Japan Digest. Accessed 29 July 2005. http://www.indiana.edu/~japan/Digests/okinawa.html.

IUCN (International Union for Conservation of Nature and Natural Resources). 2004. The 2004 IUCN red list of threatened species. Accessed 3 February 2005. http://www.redlist.org.

NMFS (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.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998a. Recovery plan for U.S. Pacific populations of the green turtle (*Chelonia mydas*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998b. Recovery plan for U.S. Pacific populations of the East Pacific green turtle (*Chelonia mydas*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998c. Recovery plan for U.S. Pacific populations of the olive ridley turtle (*Lepidochelys olivacea*). Silver Spring, Maryland: National Marine Fisheries Service.

Petry, A.K. 2003. Geography of Japan. Japan Digest. Accessed 29 July 2005. http://www.indiana.edu/~japan/Digests/geo.html.

Sandwell, D.T., W.H.F. Smith, S.M. Smith, and C. Small. 2004. Global topography: Measured and estimated seafloor topography. Accessed 15 August 2005. http://topex.ucsd.edu/marine_topo/mar_topo.html.

SRS Technologies. 2005a. GIS shapefiles for western Pacific Navy bases. Received 3 August 2005 from Ryan Heitz (GIS Manager) via Vanessa Pepi (NAVFAC Pacific). Arlington, Virginia: SRS Technologies-Washington Group.

SRS Technologies. 2005b. GIS shapefiles for Navy bases, stations, and supporting sites worldwide. Received 3 August 2005 from Ryan Heitz (GIS Manager) via Vanessa Pepi (NAVFAC Pacific). Arlington, Virginia: SRS Technologies-Washington Group.

STRP (Sea Turtle Restoration Project). 2003. Lawsuit filed to save Okinawan dugong from extinction. Accessed 18 August 2005. http://www.seaturtles.org/press_release2.cfm?pressID=178.

Wikipedia. 2005. Hokkaidō. Accessed 21 July 2005. http://en.wikipedia.org/wiki/Hokkaido.

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2.0 PHYSICAL ENVIRONMENT OF THE JAPAN AND OKINAWA COMPLEXES OPAREA

2.1 INTRODUCTION

The islands of Japan form an arc between the western Pacific Ocean and the east of the Asian continent. The land is comprised of four large islands named (in decreasing order of size) Honshū, Hokkaido, Kyūshū, and Shikoku; additionally, there are numerous smaller islands. To the east of Japan lies the Pacific Ocean while the Sea of Japan and East China Sea separate the islands from the Asian continent. Southwest of the main Japanese islands in the East China Sea lies the Ryukyu archipelago, which includes Okinawa. The Japan and Okinawa Complex OPAREA is located within a dramatic geological setting possessing several climatic regimes, making it home to a wide variety of habitats and marine organisms.

2.2 CLIMATE/WEATHER

The islands of Japan and Okinawa are located within the Asian temperate monsoon climatic region and span over 25 degrees (°) latitude (Isobe 1998; Web Japan 2005). This expansive region creates climate regimes from subtropical and humid in the south to temperate and rainy in the north. Hokkaido, the northernmost of the main Japanese islands, experiences a subarctic weather pattern in which the annual temperature averages 8 degrees Celsius (°C) and annual rainfall averages 1,150 millimeters (mm) (Web Japan 2005).

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 (DoN 1997a; Web Japan 2005). Winters are cold with average temperatures declining to 4.5°C in January (DoN 1997a). Relative humidity ranges from a low of 55% in the winter months to approximately 80% during the rainy seasons. Precipitation (1,000 to 2,500 mm 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 (DoN 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 2005).

The island of Kyūshū experiences a subtropical humid climate (DoN 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 (DoN 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 1,610 mm along the northwestern coast and up to 2,520 mm along the southwestern coast (DoN 1997b, 1998).

The southwestern islands of Okinawa also experience a subtropical climate with average temperatures often exceeding 22°C; the region receives over 2,000 mm of precipitation annually (DoN 2004; Web Japan 2005). Approximately 60% of the rainfall occurs during the months of May through September (DoN 2004). The local subtropical climate keeps Okinawa warm during the winter months (DoN 1997b). Despite the high humidity that prevails throughout much of the year, high winds result in substantial evaporation rates during the wet season and winter months (DoN 2004).

2.2.1 Seasons

The climate of Japan is characterized by clear-cut temperature changes and climatic patterns that occur between the four seasons (Web Japan 2005). When winter comes to an end (February), cold seasonal breezes that blow from Siberia become weaker and more intermittent (Lonely Planet 2003; JTBUSA 2005; Web Japan 2005). Meanwhile, low-pressure systems that reside over China migrate into the Japan Sea and give rise to strong, warm, southerly winds that originate in the Pacific Ocean (Web Japan 2005). The first of these strong winds, the "*haru ichiban*" signals the arrival of spring.

Prior to the onset of summer, 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 (DoN 2004; Web Japan 2005). Following 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, and the country experiences hot weather (Lonely Planet 2003; JTBUSA 2005; Web Japan 2005).

Beginning in late summer and extending through the month of September, Japan is often struck by typhoons (see below; DoN 2004; Web Japan 2005). Following mid-October, Japan experiences clear weather and predominantly mild temperatures (Web Japan 2005). For Okinawa, the typhoon season spans from late May through November with peak storms in August and September (DoN 2004).

Near the end of November, cold seasonal winds begin to blow over Japan from the Asian continent. These northwesterly winds pick up moisture from the Japan Sea and drop rain or snow along the western coast of Japan (Web Japan 2005). In contrast, the eastern regions of Japan experience relatively clear conditions throughout the winter (December through February).

2.2.2 El Niño

El Niño (the little boy or Christ Child in Spanish) was originally defined by fisherman from the western coast of South America. The El Niño Southern Oscillation (ENSO) results from interannual changes in sea level pressure (SLP) between the eastern and western hemispheres of the tropical Pacific (Conlan and Service 2000). These events can initiate large shifts in global climate, atmospheric circulation, and oceanographic processes (Jacobs et al. 1994). El Niño conditions typically last 6 to 18 months although they can persist for longer periods of time (Barber and Chavez 1983; Lynn et al. 1998; Durazo et al. 2001; Schwing et al. 2002); they are the main signs of global change over time scales of months to years (Philander 1983).

El Niño conditions occur when unusually high atmospheric pressure develops over the western tropical Pacific and Indian Oceans and low SLPs develop in the southeastern Pacific (Trenberth 1997; Conlan and Service 2000). 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 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 (sometimes extreme) rainfall across the southern U.S. and Peru and drought conditions in the western Pacific (Conlan and Service 2000). Historically, strong El Niño events have been documented in 1940, 1958, 1983, 1992, and 1997 to 1998 (Hayward 2000).

La Niña is the opposite phase of El Niño in the Southern Oscillation cycle (NOAA 2005a). La Niña is characterized by strong trade winds that push the warm surface waters back across to the western Pacific (Schwing et al. 2000). Under these conditions and due to 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 along the equatorial Pacific. Often with La Niña, the climatic effects are the opposite of those encountered during an El Niño warming event (e.g., higher SST in the western equatorial Pacific, high production along Pacific upwelling coasts, and heavy rainfall in Australia and Indonesia; NOAA 2005a).

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 (~0.5 m sea surface height [SSH] difference between Indonesia and Ecuador; Conlan and Service 2000; NOAA 2005a, b). Under these normal conditions, rainfall is low in the eastern Pacific and is high over the warm waters of the western Pacific.

The North Pacific atmosphere-ocean system fluctuates with periods of 2 to 6 years in response to the southern oscillation (Nakamura et al. 1997). The Japan and Okinawa Complexes OPAREA has recently experienced nine El Niño years (1963, 1965, 1969, 1972, 1982. 1987, 1991, 1994, and 1997) and six La Niña years (1964, 1971, 1973, 1975, 1988, and 1999) (Trenberth 1997; Wu et al. 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; Wang et al. 2000). These shifts result in a weaker than normal winter monsoon along the East Asian coast. Consequently, during an El Niño winter and the ensuing spring, the climate along East Asia is warmer and wetter than normal.

2.2.3 Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) is a long-term climatic pattern capable of altering the SST, surface winds, and SLP (Mantua 2002; Mantua and Hare 2002). The PDO is linked to the 10 to 20 year 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 et al. 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; Minobe 1997, 1999; Hare and Mantua 2000; Mantua and Hare 2002). Second, climatic effects of the PDO are more prominent in ecosystems outside the tropics. Third, the mechanisms controlling the PDO are unknown, while those forces creating ENSO variability have been well resolved (Mantua and Hare 2002).

Warm phases of the PDO coincide with anomalously cool and dry conditions along the western Pacific (including Japan; Mantua and Hare 2002; Gordon and Giulivi 2004). In addition, SST 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 et al. 1997); during a positive PDO (warm phase), a large pool of cold water is centered northwest of Hawaii 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, which is weaker during a negative PDO. The decrease in flow from the Kuroshio enhances the Tsushima Current, which can affect the SSH in the Japan Sea (Gordon and Giulivi 2004).

2.2.4 Winds

From late fall to early spring the Aleutian Low, a semi-permanent subpolar area of low pressure located in the Gulf of Alaska near the Aleutian Islands, produces strong westerly winds in the mid latitudes (35 to 40°N) that flow from Siberia to Japan (Rienecker and Ehret 1988; Trenberth et al. 1990; Sugimoto et al. 1995; Web Japan 2005). The warmth of spring begins as the *haru ichiban* flows over Japan from the south. This wind mass is often responsible for exceptionally hot and dry weather, avalanches, and large fires (Web Japan 2005). During the summer, the North Pacific basin is dominated by the northward extension of the Subtropical High, a semi-permanent high-pressure region ranging from 10 to 40°N latitude. As a result, winds from the Pacific Ocean blow over Japan creating an anticyclonic circulation throughout the region (Trenberth et al. 1990; Web Japan 2005).

Over the course of a year, there is approximately a four-fold variability in the magnitude of the wind stress overlying the southern subtropical waters of the OPAREA and a seven-fold variability over the more northern Oyashio waters (Limsakul et al. 2002). Minimum wind stresses occur in May for winds overlying subtropical waters and in July for winds overlying Oyashio waters. Wind stresses overlying the subtropical waters are generally lower than those over Oyashio waters, except during typhoon season (Limsakul et al. 2002).

Interannual variations in wind stress for the region can be attributed to the intensity of the winter-time East Asian Monsoon. The monsoon is a global circulation system caused by the contrast of SLP over land and sea (Krishnamurti 1985; Lau et al. 1988). Monsoons dominate the large-scale circulation over many regions; the Asian Summer Monsoon (ASM) defines the rainy period of the region from India to northeast Asia (Lim 2004). Due to the large geographical extent of the ASM, it is further divided into regional

monsoons based on their occurrence locations, including the East Asian Monsoon (Lau et al. 1988; Kang et al. 1999; Lim et al. 2002). The onset of the East Asian Monsoon usually takes place during June and is geographically divided into Mei-yu (China), Baiu (Japan) and Changma (Korea), and the onset of the East Asian regional monsoons is associated with the movement of the major rain band (Lau et al. 1988; Ronghui and Fengying 1992; Kang et al. 1999).

Strength of the East Asian Monsoon can be represented by the winter-time Monsoon Index (MOI) (Yasuda and Hanawa 1999; Limsakul et al. 2001). When the MOI index is high, the winter-time East Asian Monsoon is strong and horizontal pressure gradients steepen in the western North Pacific, especially over Japan, leading to more frequent outbreaks of cold dry air from the Asian continent (Hanawa et al. 1989a; Bingham et al. 1992). Mid-latitude westerly winds strengthen the winter East Asian Monsoon over Japan shifting the monsoon to the south during colder winters; however, during warmer winters the winter-time East Asian Monsoon is weakened over Japan and moves northward (Hanawa et al. 1989a, b).

2.2.5 Storms

The geographical location of Japan is prone to numerous seaborne natural disasters including tropical cyclones, typhoon-induced flooding, high waves, and large tsunamis (Isobe 1998).

2.2.5.1 Tropical Cyclones

Tropical cyclones occur in the Japan and Okinawa Complexes OPAREA in the form of tropical depressions, tropical storms, or typhoons. Tropical depressions are an organized system of clouds and thunderstorms with defined circulation patterns and maximum sustained winds of 61 kilometers per hour (km/hr) or less. Tropical storms are an organized system of strong thunderstorms with a defined circulation and maximum sustained winds of 63 to 118 km/hr. A typhoon, known as a hurricane in the Atlantic, is defined as an intense tropical weather system with well defined circulation, maximum sustained winds of 118 km/hr or higher, and a diameter that spans hundreds of miles over warm ocean water (Thurman 1997; OCDA 2003).

Typhoons rank as the most expensive and deadly natural catastrophe affecting Japan, South Korea, Taiwan, and the Philippines; 51 severe typhoons reached mainland Japan from 1955 through 1994 (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 over 680,000 wooden houses and caused damages that amounted to $5 billion U.S. (Fujii 1998). In the western Pacific, typhoon season extends from late spring through October (Limsakul et al. 2002). Typhoons impacting Japan originate from large masses of tropical low-pressure air in the North Pacific near Guam between 5 and 20°N; the time of formation is closely related to the interannual variations of monsoons (Lander 1994; DoN 1997a; Kadena 2005; Web Japan 2005). When a typhoon begins to develop it gradually begins to move north towards Taiwan and Okinawa before turning to the northeast (DoN 1997a). Annually, approximately 30 typhoons form in the Pacific, four of which reach Japan (Web Japan 2005). These typhoons are a threat to all of Japan due to flooding and high waves (DoN 1998; Isobe 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 2005).

The impacts of ENSO events on tropical cyclone activity in the western North Pacific have been reviewed by Chan (1985), Lander (1994), and Chan (2000) as well as others; the alteration of life spans and tracks of tropical storms in the North Pacific during strong ENSO events have been reviewed by Wang and Chan (2002). The number of tropical cyclones making landfall along the western North Pacific coastlines is significantly reduced during El Niño years when compared to neutral years, except along the Japan and Korean Peninsula where no difference is found (Lander 1994; Saunders et al. 2000; Wu et al. 2004; **Table 2-1**).

Table 2-1. Average number of landfalling tropical cyclones in the western North Pacific during El Niño, La Niña, and neutral years (adapted from Wu et al. 2004).

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

2.3 MARINE GEOLOGY

2.3.1 Geologic Setting

The western Pacific Ocean is a deep basin that is bordered on the western and southwestern edges by deep trenches that extend to nearly 7,000 m depth (DoN 1994). During the Cretaceous through to the Tertiary periods, Japan was a typical arc-trench system along the continental margin of Asia (Imaoka and Itaya 2004). However, a rise in sea level approximately 20,000 years ago submerged the low areas between the mountain peaks to create the Japanese Islands (DoN 1998). Today, Japan is a mountainous island chain of volcanic origin consisting of four main islands and thousands of smaller islands and islets; it is located on the marginal area between the continental and oceanic hemispheres of Asia and the Pacific Ocean (DoN 1998; Niitsuma 2004; **Figures 2-1** and **2-2**).

2.3.2 Physiography and Bathymetry

The islands of Japan mark the subduction zones of both the Pacific sea plate in the northeast and the Philippine plate in the southwest (**Figure 2-3**). This region is responsible for the destructive earthquakes and tsunami 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 et al. 1990).

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 centimeters per year (cm/yr) (von Huene et al. 1982; Niitsuma 2004). The subduction of the Pacific Plate has resulted in the creation of the Kuril Trench off the coast of Hokkaido, the Japan Trench off of Honshū, and the Izu-Ogasawara (Izu-Bonin) Trench southeast of Japan (Seno 1999; Niitsuma 2004). The Japan Trench, approximately 800 km long, and 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 (Kopf et al. 2003; Hayashi 2004). This active subduction generates many large earthquakes along the northern Japan Trench (Itou et al. 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 Boso Triple Junction, forming a trench–trench–trench type triple junction of the Pacific, Philippine Sea and North American Plates (**Figure 2-3**).

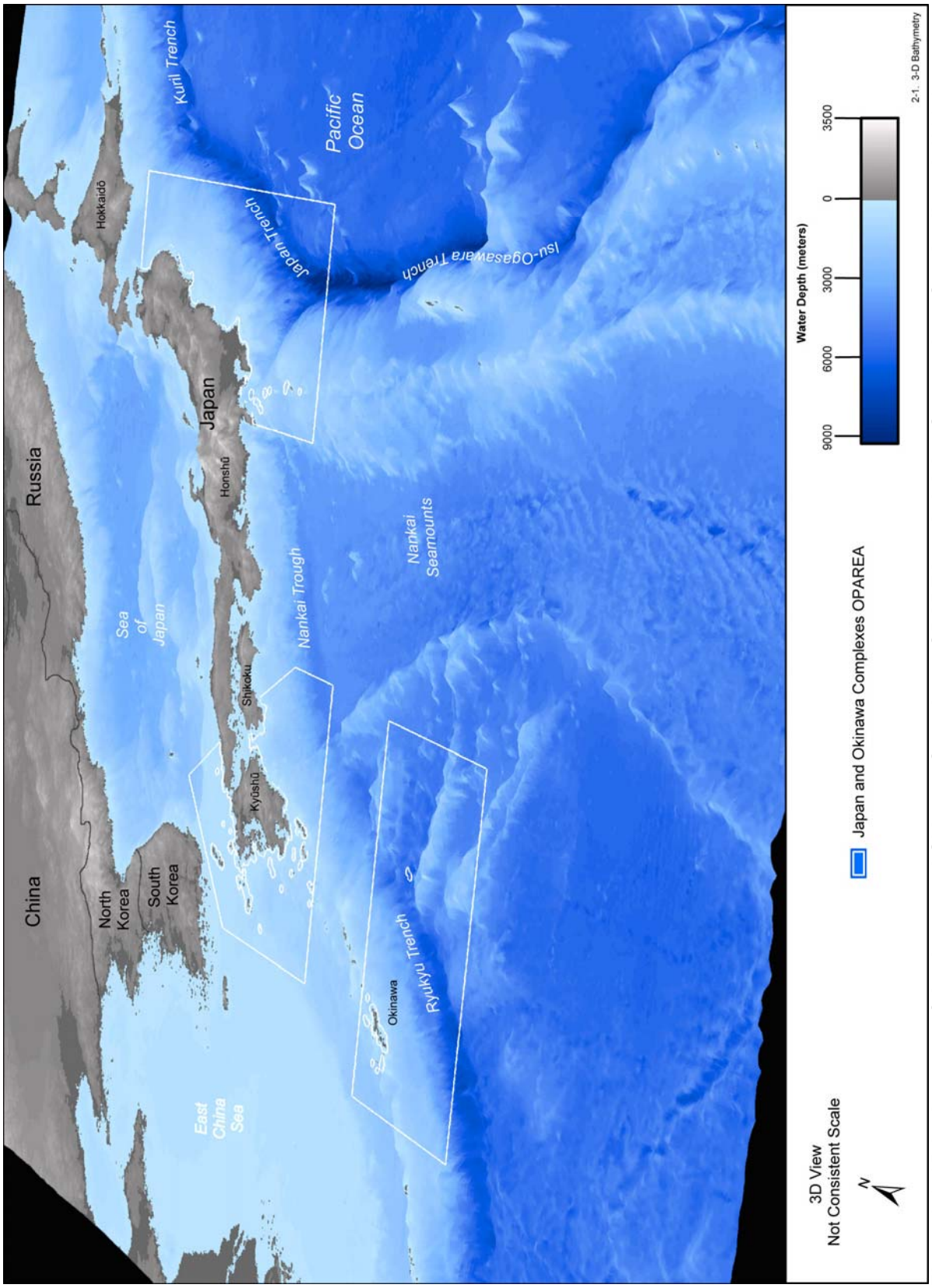

Figure 2-1. 3D bathymetry of the Japan and Okinawa Complexes OPAREA and vicinity. Source data: Sandwell et al. (2004).

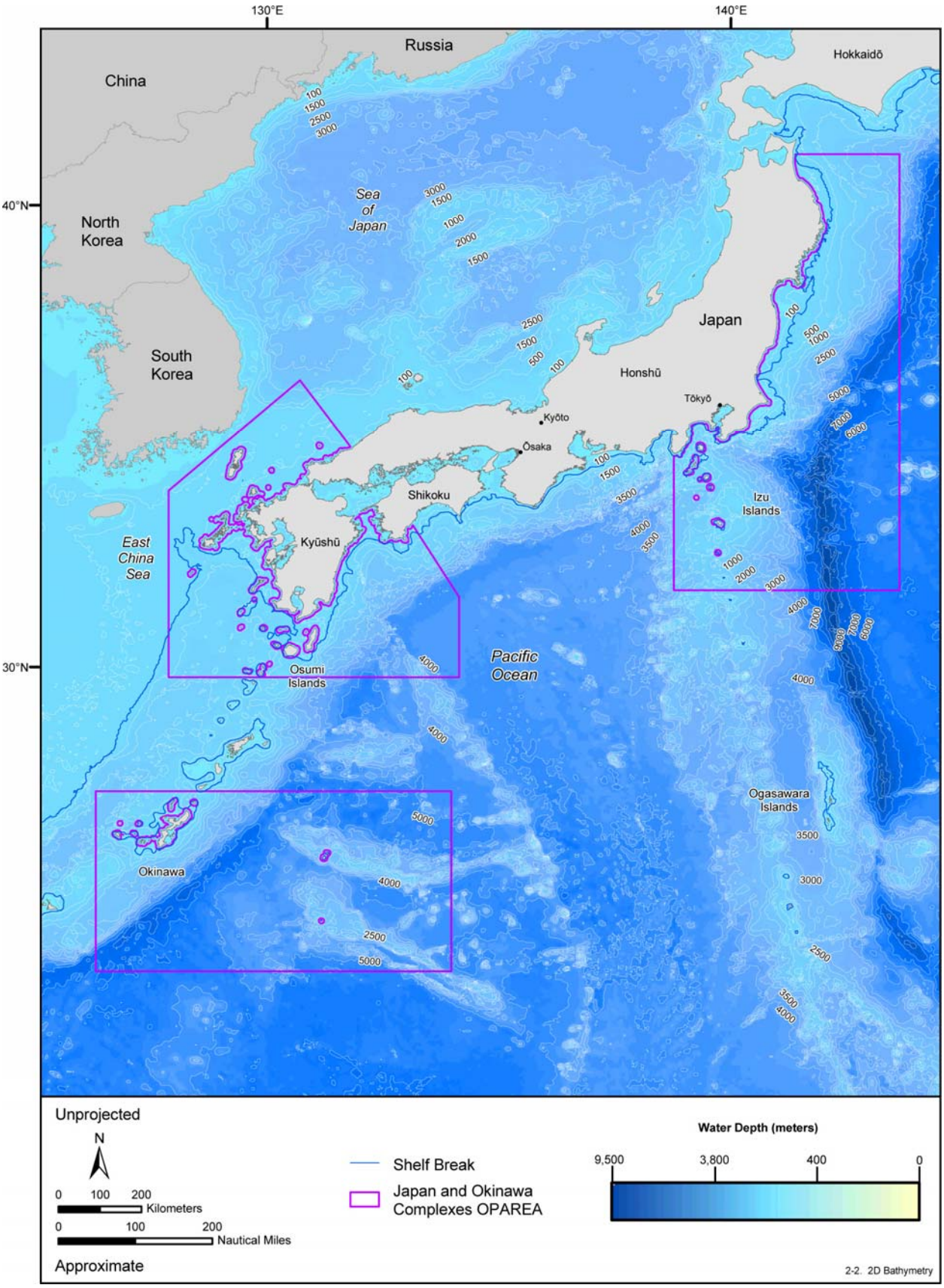

Figure 2-2. 2D bathymetry of the Japan and Okinawa Complexes OPAREA and vicinity. Source data: Sandwell et al. (2004).

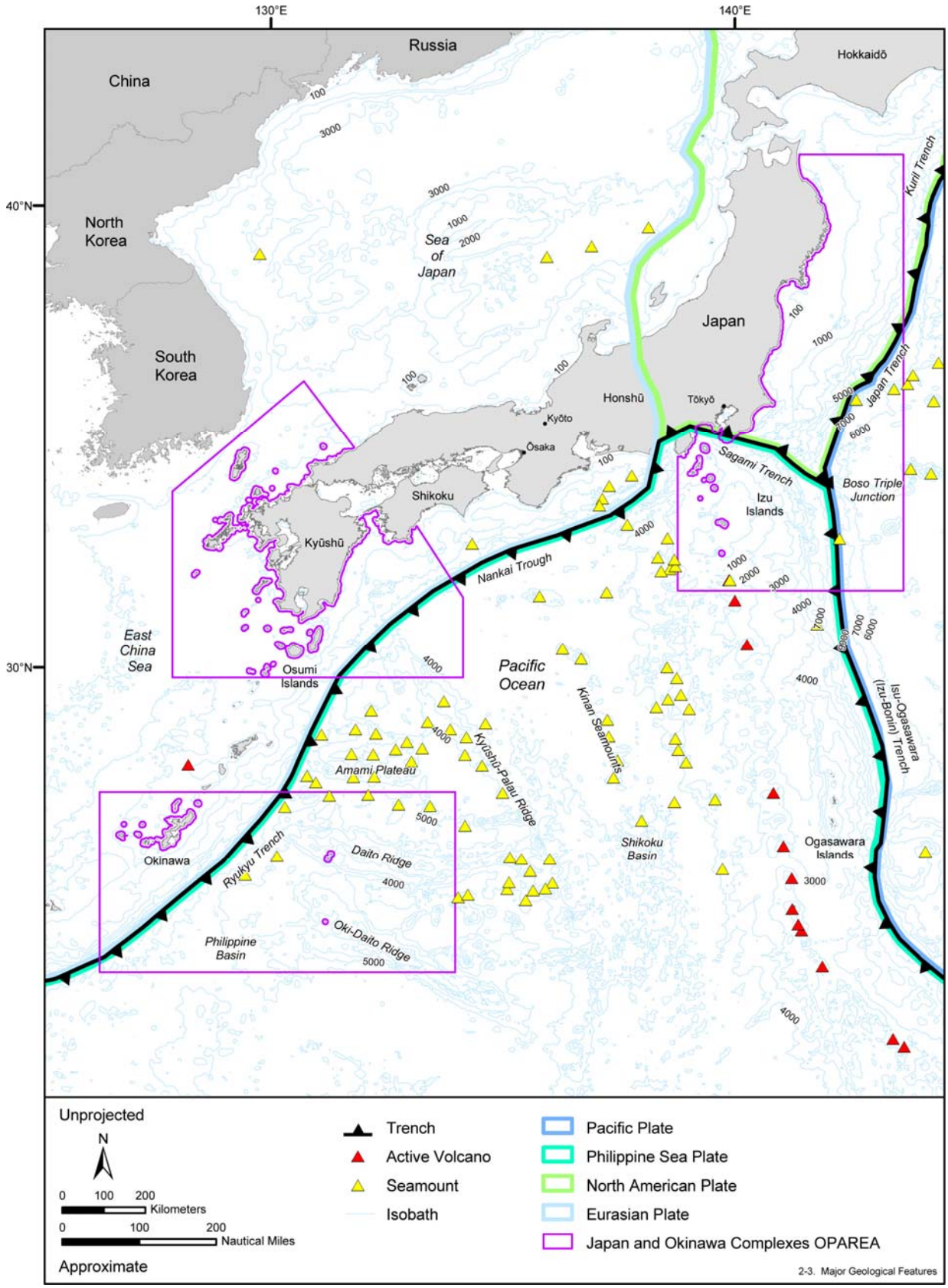

Figure 2-3. Major geological features of the Japan and Okinawa Complexes OPAREA and vicinity. Source data: Naganuma et al. (1996), Earthref (2005), and TEMIS (2005). Source maps (scanned): Isozaki et al. (1990), Seno (1999), and Seno and Yamasaki (2003).

The Philippine Sea Plate is subducting under the Eurasia Plate to the northwest along the Sagami Trench, Nankai Trough, and Ryukyu Trench (Ando 1975; Seno et al. 1993; Seno 1999; Niitsuma 2004; **Figure 2-3**). 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 et al. 1987a, b, c). Subduction in the region began approximately 10 Ma and continues today at a rate of approximately 2 to 4 cm/yr (Le Pichon et al. 1987a, b, c). 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 (see Section 2.8.13 for further review; Le Pichon et al. 1987a; Tsunogai et al. 2002).

Okinawa is the exposed crest of a large, curved submarine volcanic ridge located within the Ryukyu island arc system (DoN 2004). This typical trench-arc-backarc 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 island 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).

2.3.2.1 Continental Margins

The boundary 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 along coastlines 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 are considered stable because they are not associated with seismic or volcanic activity.

Unlike passive margins, active margins mark the boundary between two crustal plates; the collisions at these converging plate boundaries play an important role in the tectonics of active margins (Kosuga et al. 1988). 70% of all of the main oceanic subduction zones are located in the Pacific Ocean. The continental margin along Japan is referred to as a Mariana-type, or island-arc, margin, which exhibits a shallow marginal basin that separates the continent from an island-arc and trench system (Kennett 1982). Japanese island arcs are located at the boundaries between the Pacific Plate, Philippine Sea Plate, North American Plate (or Okhotsk Plate; Seno and Sakurai 1996) and Eurasian Plate (or Amurian Plate and South China Plate; Heki et al. 1999; **Figures 2-1**, **2-2**, and **2-3**) (Niitsuma 2004; Heuret and Lallemand 2005). This results in a rapid transition from shelf to slope to deep trench (Kennett 1982). In the Japan and Okinawa Complexes OPAREA the shelf is narrow, spanning only 5 to 40 km from the coastline (Okada 1980).

2.3.3 Bottom Substrate

Limestone sediments within the Japan and Okinawa Complexes OPAREA are often found in collaboration with reef complexes in shallow waters or on the top of seamounts (e.g., Tatsumi et al. 2000). These limestone sediments form in high energy environments (Tatsumi et al. 2000). The majority of deep-sea sediments in the region are composed of silts, diatomaceous ooze and clay (**Figure 2-4**); interbedded with these silts is a thin layer of volcanic ash (Kanamatsu and Matsuo 2003; McGuire and Acton 2003; Jenkins et al. 2005). The sediments associated with the trenches in the region also contain a high percentage of diatomaceous clays, silts and ooze (Le Pichon 1987c; Kanamatsu and Matsuo 2003; 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, indicative of anaerobic environments (Okada 1980; Boulégue et al. 1987).

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; Itou 2000). These phenomena have the potential to carry large quantities of terrestrial and marine particulate materials from the coastal region to floor of the deep sea (e.g., Heezen and Ewing 1952; Prior et al. 1987; Garfield et al. 1994; Thunell et al. 1999).

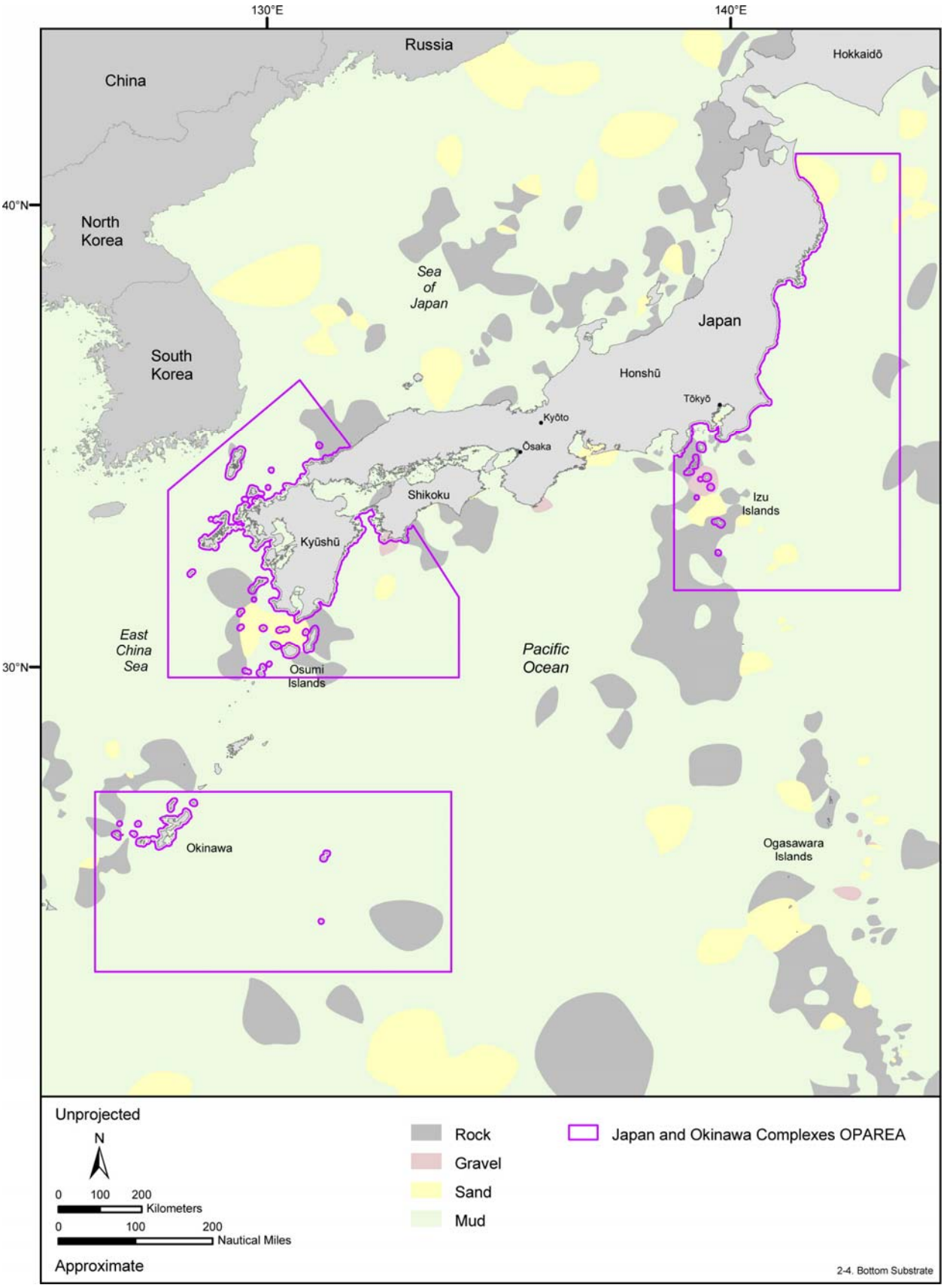

Figure 2-4. Distribution of bottom sustrates in the Japan and Okinawa Complexes OPAREA and vicinity. Source data: Jenkins et al. (2005).

2.3.4 Seismic Activity

Active trenches surround all of Japan, including Okinawa (Kasahara et al. 1998); this region is considered to be a seismically energetic region (DoN 1997a, 2004; **Figure 2-3**). Over 1,400 earthquakes with an epicenter near Tōkyō have been recorded since the late 1930s. Of these, over 600 possessed a magnitude (M) of 4.0 to 4.9 (DoN 1997a, b). Over 1,200 earthquakes have affected western Kyūshū during the same period; of these, over 600 were of an M between 4.0 and 4.9 (DoN 1997b, 1998).

In general, seismic activity associated with subduction-related plate-boundary faults is weak and aseismic (Davis et al. 1983; Byrne et al. 1988); 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 along a regular schedule (Rydelek and Sacks 1990); these recurrence intervals have been documented since the seventh century (Kanaori et al. 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 (M ≥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 (Kanamori 1972; Ando 1975; Bangs et al. 2004). Many large earthquakes have occurred near the northern Japan Trench area; however, no significant periodicity has yet been found for the Japan Trench (Mori and Shimazaki 1984; Itou et al. 2000). In this region large earthquakes (M ≥7.0) have occurred recently in 1989, 1992, and 1994 (Seno 2002).

2.3.4.1 Volcanism

While seismology is concerned primarily with the study of earthquakes (sudden, transient disturbances) there are also non-transient seismic processes. 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 observed only near active volcanoes and are often accompanied by evidence of subterranean magma motion (Shimozuru et al. 1966; Julian 1994). Volcanic tremor frequently precedes eruptions although it can also occur without an associated eruption (e.g., Kubotera and Otsuka 1970). Vibrations persisting for minutes or weeks have been observed 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” making the region one of the most volcanically active areas on the planet. Several submarine volcanoes are located to the southeast of the Japanese Islands (**Figure 2-3**). The most recent eruption to occur in the waters surrounding Japan occurred on 3 July 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 (AP 2005). The volcano, Fukutoku-Okanoba, was last known to erupt over a period of three days in 1986.

2.3.4.2 Tsunami

Tsunami, Japanese for harbor wave, is a series of waves most commonly caused by violent movements of the sea floor (NERC 2000; Marris 2005). It is characterized by high speed (up to 950 kph), long wavelengths (up to 193 km), long periods between successive crests (varying from 5 min to a few hours [generally 10 to 60 min]), and low wave amplitude in the open ocean (less than 0.3 m) (Curtis 1998; Fletcher et al. 2002). Seafloor movements that generate tsunami may include faulting (earthquakes), landslides, submarine volcanic eruptions, or anthropogenic sources. Undersea earthquakes around the Pacific Rim, where colliding plates lead to an unusually high level of seismic activity, generate more than 80% of the tsunami worldwide (NERC 2000; Koenig 2001). Most tsunamis, like the majority of earthquakes, are small and are only observed instrumentally. Earthquakes causing tsunami are generally characterized by slow faulting (Kanamori 1972; Kanamori and Kikuchi 1993; Polet and Kanamori 2000). Landslides may also generate tsunami; 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). The characteristics of tsunami are dependent upon 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).

The Pacific is by far the most active zone for tsunami generation and Japan is one of the most tsunami-battered islands in the Pacific Ocean (Koening 2001). Tsunami 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; however, two tsunamis impacted the coastline along the Sea of Japan in 1983 and 1993 (Isobe 1998). Historically, 11 of the 23 most damaging tsunami worldwide (1600 to 1999) impacted the island of Japan (USGS 2004; **Table 2-2**). Furthermore, at least four tsunamis were related to coastal volcanism; of those, two impacted Hokkaido in northern Japan (Nishimura et al. 1999). In 1640, after more than 1,000 years of dormancy, Mt. Komagatake, southern Hokkaido erupted and the resulting summit collapse and avalanche initiated a tsunami. Part of the avalanche flowed eastward from the summit, entered into the sea, and created a large tsunami. In 1741, a tsunami impacted 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 et al. 1999). A highly destructive tsunami that impacted 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 used to rebuild harbors (NERC 2000).

Table 2-2 Most damaging tsunami to impact Japan (1600 to 1999). Adapted from USGS (2004).

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

2.4 HYDROGRAPHY

2.4.1 Sea Surface Temperature

Japan experiences relatively high SST and a warm climate given its high northern latitude (Isobe 1998; **Figure 2-5**). However, from October through March, strong wind stress, decreased solar irradiation, and surface water mixing lead to a decrease in SST; on average, temperatures drop below 19.5°C in the southern subtropical waters and 3°C for the more northern Oyashio waters (Limsakul et al. 2002). In

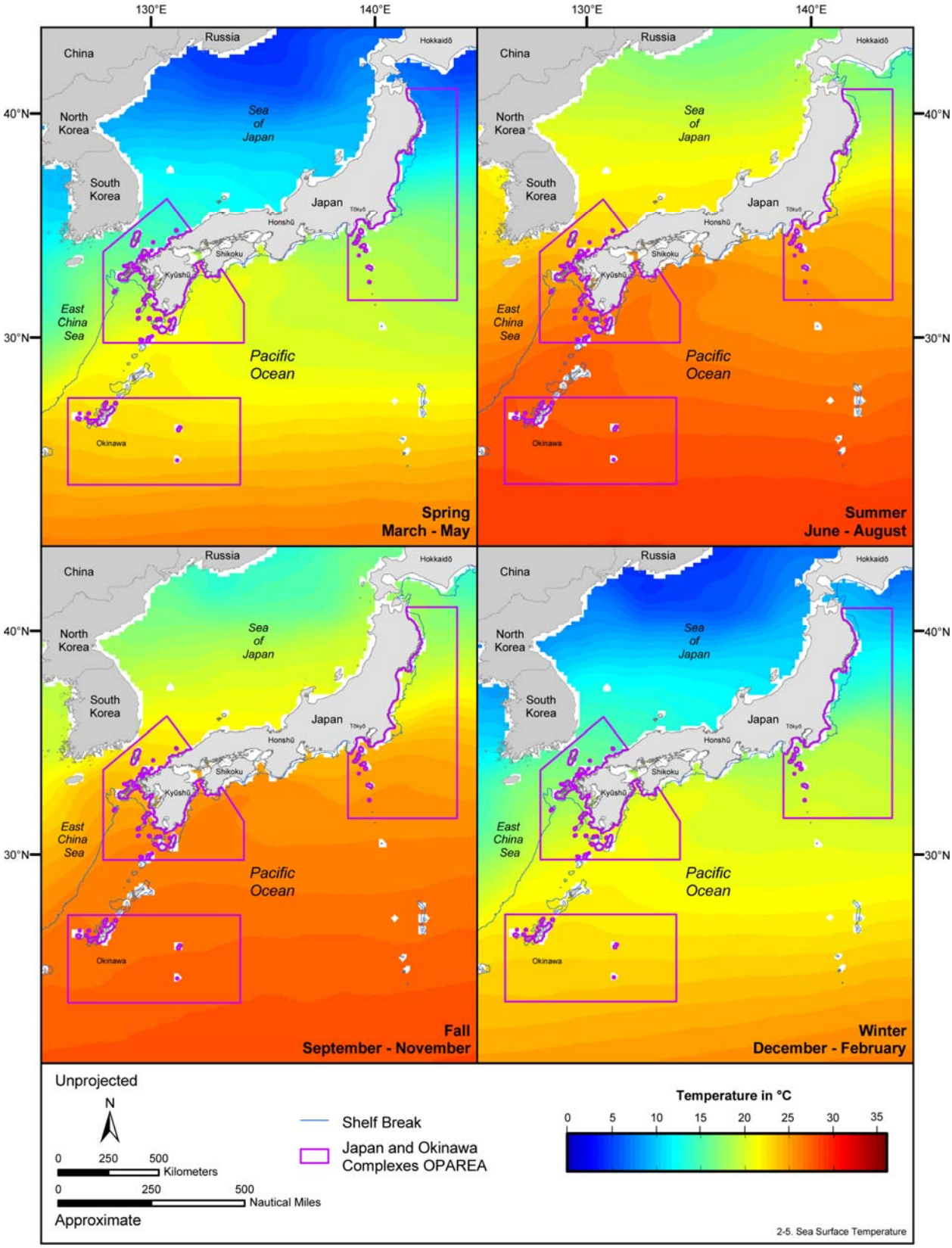

Figure 2-5. SST of the Japan and Okinawa Complexes OPAREA and vicinity during the spring (March through May), summer (June through August), fall (September through November), and winter (December through February) seasons. Source data: NASA (2000).

addition, the confluence of the warm Kuroshio and cold Oyashio 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 less than less than 37 km. In addition, 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).

2.4.2 Salinity

Waters of the western Pacific Ocean tend to have low salinity (Ballabrera-Poy et al. 2002). This low salinity is due to the low SST of the North Pacific which prevents high rates of evaporation in the region (Open University 1995). The surface salinity in the Japan and Okinawa Complexes OPAREA is also relatively fresh with salinities less than 32 practical salinity units (psu) in the northern regions to more than 34.5 psu south of Japan (Tomczak and Godfrey 2001). 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).

2.5 PHYSICAL PROCESSES

2.5.1 Water Masses, Currents, and Circulation

Ocean circulation, driven by the difference in solar heating between low and high latitudes and the earth's rotation, regulates various physical oceanic regimes which determine what types of organisms develop and how much production occurs in any part of the world oceans. In the western North Pacific, two western boundary currents, the Kuroshio (part of the subtropical anticyclonic gyre) and the Oyashio (part of the subarctic cyclonic gyre) dominate the oceanography (DoN 1994; Limsakul et al. 2002). The Kuroshio marks the western boundary of the North Pacific Subtropical Gyre (NPSG), the largest circulation system on the planet (Karl 1999). The convergence of the warm Kuroshio and the cold Oyashio along the east coast of northern Japan results in a "perturbed zone" of complex frontal systems and mixing of water masses known as the Kuroshio-Oyashio confluence region (Hanawa and Mitsudera 1987; DoN 1994; Limsakul et al. 2002).

2.5.1.1 North Pacific Subtropical Gyre

The NPSG encompasses 2 X 10^7 km^2 of ocean and is bounded by the North Pacific Current to the north, the Northern Equatorial Current (NEC) to the South, the California Current to the East, and the Kuroshio Current to the west (**Figure 2-6**); these boundaries have existed since the Pliocene (10^7 years ago) (McGowan and Walker 1985). The NPSG is a very old ecosystem that is considered a climax community where the climate affects the seascape, community structure, and community dynamics of the Pacific (Karl 1999). The center of the gyre is located at approximately 20°N and tilts poleward. The Japan and Okinawa Complexes OPAREA is located on the western boundary of the NPSG (**Figure 2-6**).

Despite being the largest contiguous ecosystem on the planet, the NPSG is remote, poorly sampled, and not well understood (Karl and Lukas 1996; Karl 1999); it is considered to be analogous to a terrestrial desert, comprised of warm (>24°C) nutrient depleted surface waters with low standing stocks of living organisms and a persistent deep-water chlorophyll maximum (Karl et al. 1995; Karl 1999). Surface circulation in the gyre is wind driven and the overall anti-cyclonic rotation of the NPSG restricts the exchange of water and nutrients with adjacent current systems (Karl and Lukas 1996; Karl 1999).

The NPSG is thought to be a semi-enclosed, stable, and relatively homogenous habitat with weak seasonal changes (Karl and Lukas 1996); however, increasing evidence suggests that the NPSG exhibits substantial physical, chemical, and biological variability with time and space (Karl 1999). During winter months, tropical cyclones pass through the NPSG deepening the mixed layer and injecting nutrient rich water into the surface waters fueling ephemeral phytoplankton blooms (Karl 1999). Over longer time scales, the NPSG is affected by El Niño conditions. 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).

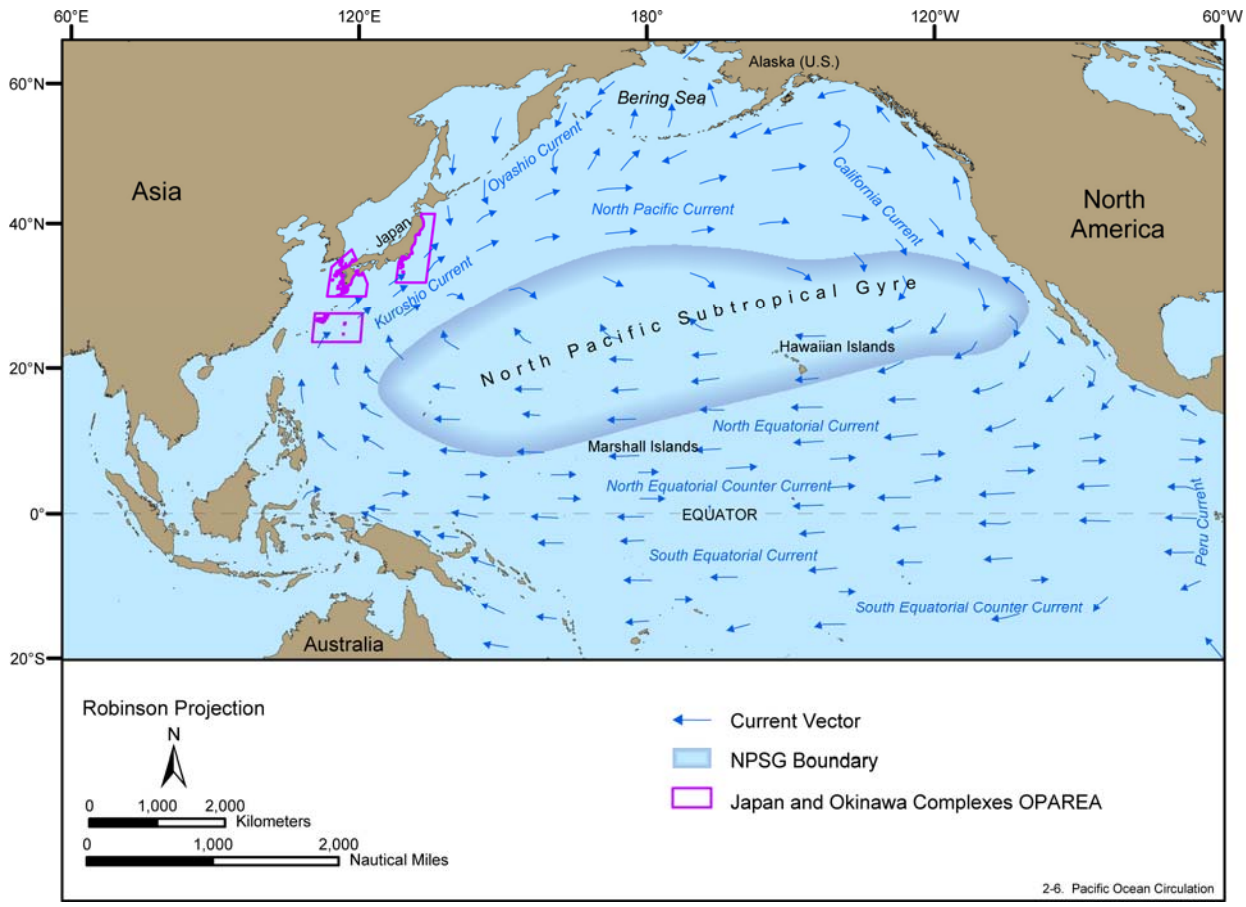

Figure 2-6. Surface circulation of the Pacific Ocean and outline of the NPSG. Source maps (scanned): Pickard and Emery (1982) and Karl (1999).

2.5.1.2 Surface Currents/Water Masses

The oceanography of the western North Pacific is dominated by two opposing current systems, the Kuroshio and the Oyashio (**Figure 2-7**). The strong ocean current system of the region is unlike any other in the world although the Kuroshio is often compared to the Gulf Stream of the Atlantic Ocean (DoN 1994). Because the Kuroshio and Oyashio Currents transport large amounts of water and heat, recently, there has been heightened interest in understanding the dynamic of the Kuroshio and Oyashio Currents in influencing climate through SST. Large-scale changes in the Kuroshio and Oyashio current systems can affect the SST through warm/cold water advection, upwelling, changes in the current paths, and mesoscale eddy variability (Qiu 2001). Outside of the eastern equatorial Pacific Ocean, the Kuroshio Extension and the Oyashio Current exhibit the largest SST variability (interannual to decadal) in the North Pacific.

2.5.1.2.1 Kuroshio

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 stems from the fact that the downwelling-dominant subtropical North Pacific Ocean is low in biological productivity making the surface waters devoid of detritus and other organic material (Qiu 2001). The flow of the Kuroshio also influences the global ocean climate variations and the regional climate of East Asia (Guo et al. 2003).

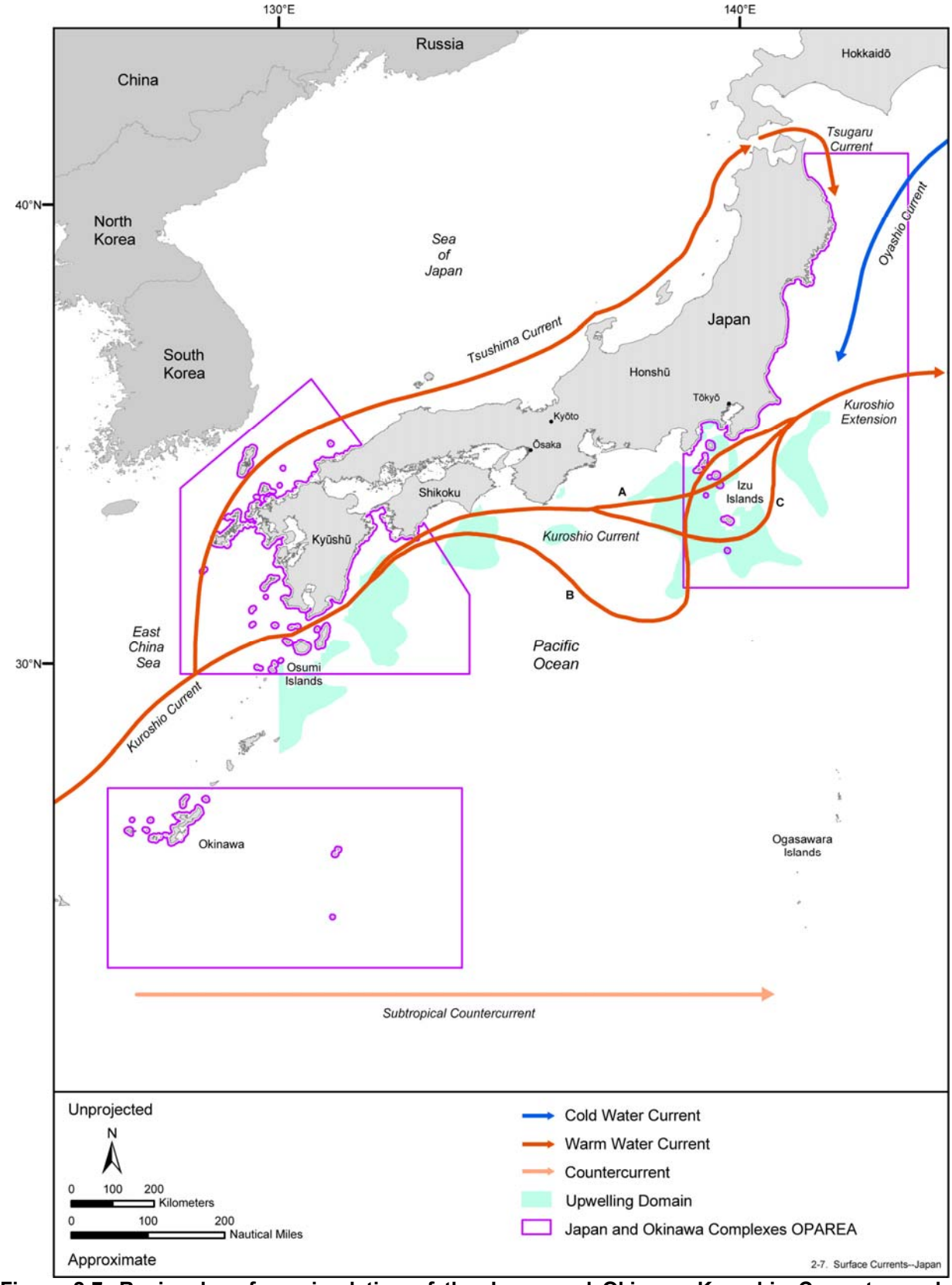

Figure 2-7. Regional surface circulation of the Japan and Okinawa Kuroshio Current are also represented (A: straight path, B: large-meander path, C: transitional path). Source maps (scanned): Takahashi et al. (1980), Furuya et al. (1986), Qiu (2001), Hayashi (2004), and Miyazawa et al. (2004).

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 (DoN 1994; Qiu and Lukas 1996; Qiu 2001). 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 (Toole et al. 1990; Qiu and Lukas 1996; Qiu 2001). Below the sea surface, the bifurcation tends to shift northward with increasing depth due to the fact that 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 meters per second (m/s). Minimum transport (approximately 19 Sverdrup [Sv] [1 Sv = 10^6 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 and Lukas 1996; Qiu 2001). 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 (DoN 1994; Qiu 2000; Qiu 2003). 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 (Wyrtiki et al. 1976; Qiu 2002). East of the dateline, there is little distinction between the Kuroshio Extension and the northern Subarctic Current; together they form the broad, eastward-moving North Pacific Current (Qiu 2001, 2002; **Figure 2-6**).

Inter-annually, the Kuroshio Current is known for its bimodal path fluctuations (Qiu 2001; Guo et al. 2003; **Figure 2-7**. The 'straight path' denotes the flow of the Kuroshio is close to the Japan coast (Qiu and Miao 2000; Qiu 2001); 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 and Miao 2000; Qiu 2001).

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

2.5.1.2.2 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 2-7**). The Tsushima Current is the only major warm current in the Sea of Japan (Onishi and Ohtani 1997). Currents in the strait have considerable variation in current velocity, 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 with maximum summer flows of 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 (DoN 1994; Lee et al. 2000). Flow of the Tsushima Current is out of phase with the Kuroshio; it delivers more subtropical water to the Sea of Japan when the 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 are formed off of the Tsushima Current due to the complexity of the currents in the Sea of Japan (DoN 1994). Flow of the Tsushima Current is enhanced during negative phases of the PDO and depressed during positive PDO conditions (Gordon and Giulivi 2004).

2.5.1.2.3 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 Hokkaido to the north. The mechanism responsible for the 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 (Oguma et al. 2002; Hayashi 2004; Kojima et al. 2004). The Tsugaru Current in the strait is strong during the summer and in autumn but almost disappears in winter as transport decreases (Oguma et al. 2002); transport of water from the Tsugaru Strait ranges from 1.0 to 4.1 Sv but is highly variable (Onishi and Ohtani 1997).

2.5.1.2.4 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. It originates in the Bering Sea and flows southward to the southeast coast of Hokkaido (DoN 1994; Kono 1997; Limsakul et al. 2002). 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 (e.g., Kasai et al. 1997; Taniguchi 1999).

At least two branches of the Oyashio develop along the northeastern coast of Hokkaido (DoN 1994, Qiu 2001). The first path veers offshore and contributes to the east-north-eastward-flowing Subarctic Current along 42°N, southeast of Hokkaido. 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 further 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 (DoN 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).

2.5.1.2.5 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 (DoN 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 Hokkaido 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 Hokkaido. 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). At this confluence, currents are deflected eastward and large-scale (≥200 km) anticyclonic eddies regularly detach from the Kuroshio

Current. 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 (DoN 1994; Qu et al. 2001).

2.5.1.3 Tides

Tides are the most predictable oceanic motions; the gravitational pull of the moon (and to a lesser extent of the sun) creates "bulges" of water on opposite sides of the earth (Thurman 1997). Each region of the earth passes through these bulges twice a day, resulting in semi-diurnal (half daily) components to the tidal cycle. Furthermore, the moon and the sun do not generally lie over the equator; this displacement creates one tidal bulge larger than the other, thus leading to a diurnal (daily) component to the tides.

Deviations between tidal ranges result from the relative position of the moon and the sun; when the moon is in new and full phases, the moon and the sun act together to produce larger "spring" tides. When the moon is in its first or last quarter, smaller than average "neap" tides occur. The cycle of spring to neap tides and back is half of the 29 day lunar cycle and is known as the fortnightly cycle. Tidal circulation around the Japanese islands can contribute significantly to overall flow in some regions (Teague et al. 2001).

The difference in tidal amplitude ranges from 1.5 m along the Pacific coast of Japan to 3 m in the Tsushima Strait and inland seas (Isobe 1998; Teague 2001; Yokoyama and Ishishi 2003; Yamamoto et al. 2004). Tidal range within the Sea of Japan is low (<1 m) (Isobe 1998). Despite the low tidal ranges, storm conditions combined with high tides can cause severe damage to coastlines. High tides in three major bays (Tōkyō, Ise, and Osaka) can be amplified by storm winds. For example, during a typhoon in 1953 maximum tide deflection was 3.9 m in Tokyo Bay; in 1959; Ise-Bay experienced a tidal deflection of 3.4 m resulting in over 5,000 deaths and damage to almost one million buildings (Isobe 1998).

Along with contributing to the flow in some regions, tidal fluctuations can also create dramatic circulation patterns such as the Naruto Strait whirlpools located between Honshū and Shikoku (Chanson 2002). A whirlpool (also known as Maelstroms, after the Norwegian current, or uzu-maki in Japanese) is a vertical axis vortex with a downward velocity component near its center. In coastal zones, whirlpools are produced by the interaction of rising and falling tides and are often observed at the edges of straits with large tidal currents. The Naruto Strait connects the Awaji and Shikoku islands, Japan. The strait is 1.3 km wide and the tide is semidiurnal. Tidal range in the strait may be up to 1.7 m with differences in tidal levels across the strait reaching 1.5 m. Current speeds exceeding 4.6 m/s in the Northern part of the strait are not uncommon. The whirlpools take place on the Southern side of the Strait at the peak of the flood and ebb currents (Chanson 2002). These whirlpools are capable of trapping and grounding large freighters and other ships which become stranded until the next high tide.

2.5.1.4 Subsurface Currents/Water Masses

2.5.1.4.1 North Pacific tropical water

North Pacific Tropical Water (NPTW) is characterized by a subsurface salinity maximum flowing in the NEC. It supplies the main source of salt for the North Pacific (Suga et al. 2000). NPTW is thought to form at the surface in the central North Pacific roughly along the Tropic of Cancer (20 to 30°N) where evaporation rates exceed precipitation (Cannon 1966; Suga et al. 2000). NPTW is advected westwards in the NEC forming a subsurface salinity maximum (Qu et al. 1999). Along the western boundary, part of NPTW flows northward in the Kuroshio while the remainder flows southward in the Mindanao Current (Cannon 1966; Qu et al. 1999). Remnants of NPTW in the Kuroshio are recognizable as the subsurface salinity maximum to the south of Japan; this contributes to the formation of the broad subsurface salinity maximum typical in the northwestern regions part of the NPSG (Emery and Dewar 1982).

NPTW can be regarded as the saline counterpart of the North Pacific Intermediate Water (NPIW) (see below). Thus, NPTW is a major source of ‘salt’ in the North Pacific while NPIW is a major source of ‘fresh water’. Wong et al. (1999) recently detected concurrent increases in salinity in NPTW and a freshening of

NPIW along with similar change in the South Pacific. This relationship is also related to an intensification of the global hydrological cycle. This suggests that NPTW is not only important for salinity distribution but also the climate system. Thus, the variability of the NPTW carries useful information for the detection and research of climate change.

2.5.1.4.2 North Pacific intermediate water

NPIW can be regarded as the fresh counterpart of the NPTW. NPIW is characterized as the intermediate salinity minimum in the subtropical gyre; the most likely source of low salinity for the NPIW is the Oyashio winter mixed layer. The NPIW is considered to be a major source of fresh water in the Pacific (Suga et al. 2000; Talley and Yun 2001). Both NPTW and NPIW are important for salinity distribution within the Pacific Ocean and are sensitive components of the climate system (Suga et al. 2000).

2.5.1.4.3 North Pacific subtropical mode water

North Pacific Subtropical Mode Water (STMW) is identified by a temperature region ranging from 16 to 19°C lying just above and within the permanent thermocline of the western NPSG at a depth of 300 to 365 m (Masuzawa 1969; DoN 1994; Oka and Suga 2003). It is formed in late winter in the deep mixed layer immediately south of the Kuroshio and the Kuroshio Extension (between 30 and 35°N and as far to the east as 175°E) and spreads through advection over the Kuroshio recirculation region (Hanawa and Mitsudera 1987; Suga and Hanawa 1990; Bingham et al. 1992; Suga and Hanawa 1995; Limsakul et al. 2001). The mixed layer becomes colder, fresher, and denser toward the east, leading to the formation of warmer, saltier, and lighter STMW in the western part of the region (Oka and Suga 2003). Following formation, mesoscale eddies retain STMW during their southwestward movement from the formation region contributing substantially to the STMW transportation (Uehara et al. 2003). Underlying the STMW is the main thermocline of the region (DoN 1994).

2.5.1.4.4 Thermocline

The thermocline is located between the surface and deepwater circulation zones; it is the transition region where water temperatures change rapidly from warmer surface waters to colder deep waters. Varying in temperature from 18 to 8°C, the thermocline in the Japan and Okinawa Complexes OPAREA tends to lie between the STMW and the underlying Subarctic Water (DoN 1994). Variations in the depth of the mixed layer are primarily governed by wind stress. During the winter, strong wind stress, reduced solar radiation, and a positive air to water temperature gradient leads to cooling of the ocean and the mixing of surface water to depth. This causes the mixed layer to deepen (Limsakul et al. 2001, 2002). Despite the stronger wind stress and lower solar radiation, the mixed layer in the Oyashio is shallower than that in the southern subtropical waters in the winter due to a shallow (100 to 200 m) permanent halocline found over most of the subarctic North Pacific. This condition does not allow deep convective mixing in the northern regions of the OPAREA despite the relatively high wind stress in winter (Evans and Parslow 1985; Kono 1997). South of the Kuroshio Current, the deep thermocline allows convection to penetrate substantially during the winter (Suga and Hanawa 1990; Bingham et al. 1992). As the climate warms, increased solar radiation and reduced wind stress lead to rapid thermal stratification and shallow mixed layers; the shallowest mixed layers (<25 m) occur in the summer months (Limsakul et al. 2002).

2.5.1.4.5 Deep Pacific waters

Below the intermediate depth layers, between approximately 2,000 and 4,000 m, lies the nearly homogeneous deep water layer. Deep Pacific water is formed from the upwelling of the southern source bottom waters (sometimes known as Circumpolar Water; Open Ocean 1995). This is the oldest deep water in the world ocean and is fairly well mixed.

There are indications of slight warming on the bottom of the North Pacific due to gentle geothermal heating (Fukasawa et al. 2004). A vertical deep silica maximum (its origin is in the northeastern Pacific) is characteristic of the Pacific Deep Water. It is separated from the deep Antarctic Bottom Water (also known as Lower Circumpolar Water) by a “benthic front” in the southern and western North Pacific.

2.5.1.5 Upwelling

Upwelling is a wind driven, dynamic process that brings nutrient-rich deep water to the surface and nutrient-poor surface waters offshore through the interaction of currents, density, or bathymetry (Mann and Lazier 1991). In wind driven upwelling, warmer surface waters are transported perpendicular to the direction of the wind. Deep, cold water moves vertically into the euphotic zone to replace the nutrient-poor surface water that was transported offshore. Off of Japan, increased levels of production, ranging from phytoplankton to fish, often accompany these patches of upwelled water (Toda 1989; Takahashi and Kishi 1984; Yanagi and Nakajima 1991).

In the area off the central part of Japan, where the Kuroshio flows east-northeastward through the Izu island chain, regional upwelling occurs around the islands along frontal eddies of the meandering Kuroshio Current stimulating the growth of local phytoplankton (Furuya et al. 1986; Chiang et al. 1997; Nakata et al. 2000; Yoo et al. 2004). Regional upwelling has been repeatedly observed near the Izu Islands (**Figure 2-7**); upwelled regions along the islands tend to be wind-driven resulting in ephemeral upwelling episodes lasting only several days (Takahashi et al. 1980; Takahashi and Kishi 1984; Atkinson et al. 1987; Toda 1989). In the Izu islands, upwelling tends to occur on the lee side of the islands (Takahashi et al. 1980), suggesting the island effect (turbulence created by winds and water passing by the islands) may play a role in the upwelling (e.g., Doty and Oguri 1956; Simpson et al. 1982)

In addition, several bays along the Pacific Japanese coast can be regions of localized upwelling. During summer in Tokyo Bay, northerly winds create regions of upwelling along the eastern coast and near the bay head. The water brought to the surface is anoxic; this anoxic water greatly damages the eggs and larvae of fish and shellfish (Suzuki and Matsuyama 2000). At the mouth of Tokyo Bay, Sugami Bay can also be an area of upwelling (Takahashi et al. 1980; **Figure 2-7**). During summer months, prevailing winds in Volcano Bay, Hokkaido promote upwelling along the west coast of the bay (Takahashi et al. 2004).

Japan has also initiated a program in which man-made structures are placed at depth to promote upwelling in an attempt to enhance local fishery productivity (Yanagi and Nakajima 1991). For additional information on these structures, see Section 2.9.

2.6 BIOLOGICAL OCEANOGRAPHY

2.6.1 Primary Production

Primary production is the rate at which the biomass of organisms changes and is defined as the amount of carbon fixed by organisms in a fixed volume of water through the synthesis of organic matter using energy derived from solar radiation or chemical reactions (Thurman 1997). Photosynthesis is the major process through which primary production occurs. The intensity and quality of light, the availability of nutrients, and seawater temperature all influence primary productivity as generated through photosynthesis (Valiela 1995). However, chemosynthesis is another significant form of primary production that occurs in the Japan and Okinawa Complexes OPAREA. Chemosynthetic communities that are common in the Japan and Okinawa Complexes OPAREA include hydrothermal vent, cold seep, and whale fall ecosystems (discussed in Section 2.8.13). Primary production in the region has been estimated at 0.2 to 1.0 milligrams (mg) C $m^{-2}d^{-1}$ (Furuya et al. 1998; Shiomoto et al. 1998).

2.6.1.1 Photosynthesis

Photosynthesis is a chemical reaction that converts solar energy from the sun into chemical energy stored within organic molecules by combining water, carbon dioxide, and light energy to form sugar and oxygen. In the oceanic system, the majority of photosynthesis is carried out by phytoplankton utilizing a suite of light harvesting compounds to convert solar energy into chemical energy, the most common being chlorophyll *a* (chl *a*) (Thurman 1997; **Figure 2-8**). Rates of photosynthetic production can vary from

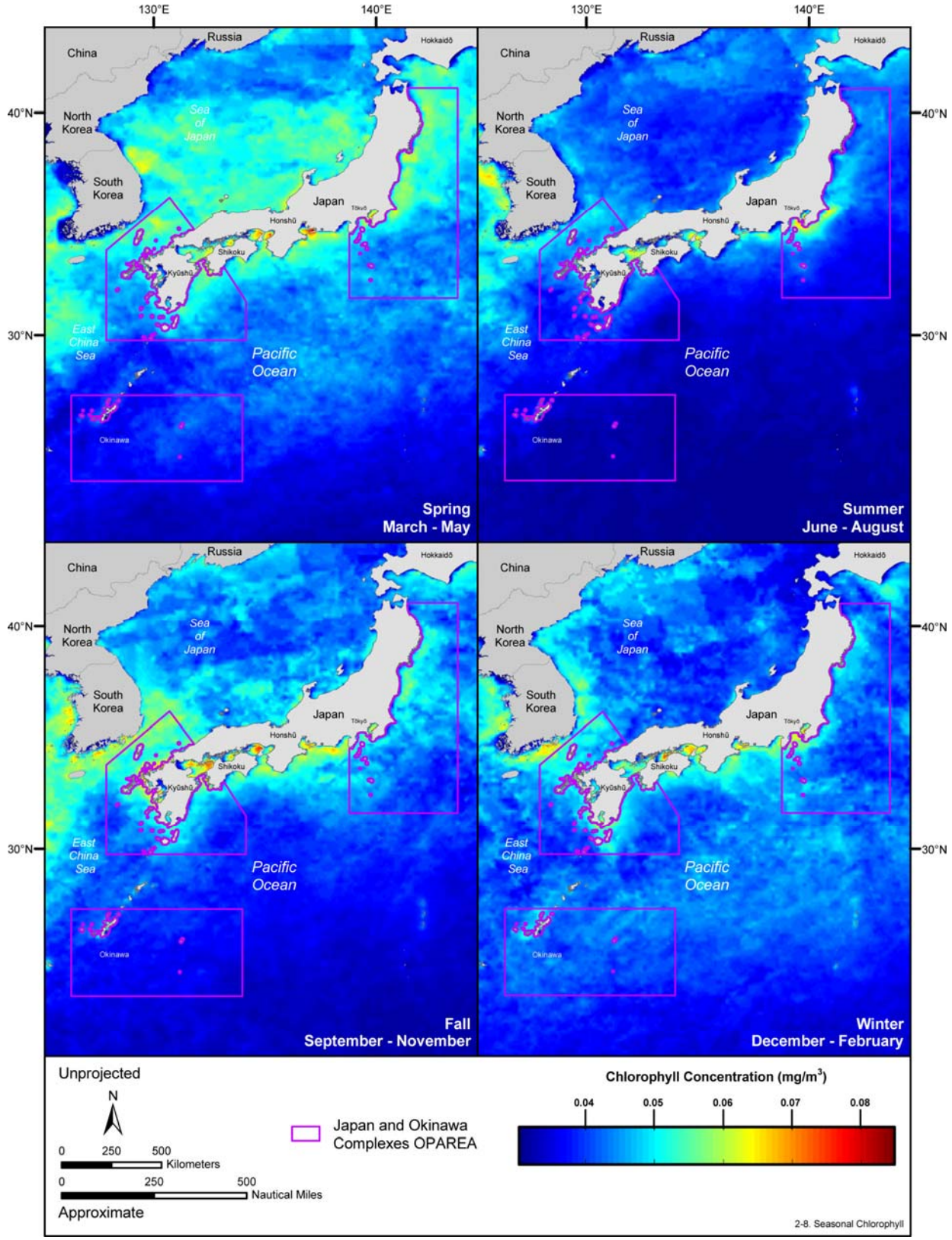

Figure 2-8. Seasonal distribution of chlorophyll throughout the Japan and Okinawa Complexes OPAREA and vicinity during the spring (March through May), summer (June through August), fall (September through November), and winter (December through February) seasons. Source data: NASA (1998).

between less than 0.1 gram (g) of carbon (C) per square meter (m^2) per day (d) in oligotrophic regions, such as the western equatorial Pacific, to more than 10 $gC/m^2/d$ in highly productive areas (Thurman 1997).

2.6.1.1.1 Phytoplankton

Phytoplankton in the OPAREA can be divided into two distinct regions. The first grouping of phytoplankton is found in the subtropical waters of the southern regions of the Japanese Islands. The second group is found within the cooler, nutrient-rich waters of the Oyashio.

Subtropical waters—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 (NASA 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 m^{-3}) due to 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 the vertical mixing of nutrients that are essential for phytoplankton (Reid 1962; Aruga et al. 1968; Ondrusek et al. 1991; Ayukai and Hattori 1992; Sugimoto et al. 1995; Odate and Furuya 1998); this stratification is typical of plankton dynamics that occur in subtropical waters (Hayward et al. 1983; Hayward and McGowan 1985). In these regions of nutrient limitation, nitrogen-fixation may be an important source for new nitrogen (Karl 1999; Limsakul et al. 2002). Seasonal cycles in production are directly related to mixed-layer depth; during a deepening of the mixed-layer during the winter, nutrient supply is enhanced and phytoplankton populations rapidly respond to the higher nutrient flux (Limsakul et al. 2001, 2002). 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).

Although the subtropical waters possess low concentrations of surface chl, a subsurface region of enhanced chl concentration exists (the deep chl maximum [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 the reestablishment of the DCM until April. The depth of the DCM in the subtropical waters off Japan and Okinawa is dependant upon light irradiance and nutrient availability. Mean chl concentrations in the DCM range from 0.26 to 0.36 mg chl 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 and Marumo 1983; Furuya 1990). These phytoplankton are distinct from those occurring in shallower waters and adjacent regions (Furuya and Marumo 1983).

Oyashio waters—Oyashio waters are cold, nutrient-rich, and among the most productive waters in the world with a high abundance of phytoplankton and higher trophic levels (Aruga et al. 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 (e.g., Odate and Maita 1988; Shiomoto et al. 1994; Kasai et al. 1997). 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 comprise a large portion of phytoplankton biomass in the euphotic zone (Shiomoto et al. 1994; Kasai et al. 1997). Intense spring blooms with near surface chl *a* concentrations in excess of 5 mg m^{-3} were observed from 1972 to 1998. In April, the near-surface chl *a* concentrations range from <1 to 37.7 mg m^{-3} suggesting that the timing, magnitude, and duration of spring blooms undergo high levels of inter-annual variability. The initiation and development of the spring bloom in the Oyashio waters result from a combination of increased irradiance and a decrease in the depth of the mixed-layer (Yoshimori et al. 1995; Limsakul et al. 2001, 2002). Following the bloom in late spring, there is a sharp decrease in near-surface chl *a*; minimum concentrations occur in August and a small secondary bloom is observed 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 DCM. 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 chl in the Oyashio DCM are only 1.2 to 2 times greater than those found at the surface.

Climatic Variability—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 has a significant impact on the extent of vertical mixing, nitrate inputs into the euphotic zone, and concentrations of chl *a* in winter and the following 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, during this period, the spring chl *a* increased steadily. 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 that is necessary for growth. Thus, substantial amounts of nutrients are left unutilized. However, water column stratification in the spring allowed phytoplankton to take advantage of the enhanced ambient concentrations of nutrients (Limsakul et al. 2001).

In the upper stream of the Kuroshio, the 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 (Sugimoto et al. 2001; Nakata and Hidaka 2003). In El Niño years, average chl concentrations are almost twice as high as those measured during La Niña years (Sugimoto et al. 1995).

2.6.1.2 Chemosynthesis

Another potentially significant source of biological productivity does not occur in the euphotic zone but rather in specific habitats that supply the nutrients necessary for chemosynthesis. In some locations, including the Japan and Okinawa Complexes OPAREA, hydrothermal vents, cold seeps, and whale falls can support vast benthic communities (e.g., Hashimoto et al. 1989; Naganuma et al. 1996; Fujikura et al. 1999; Fujiwara et al. 2000, 2001; Tsunogai et al. 2000). It has been estimated that at any given time there may be in excess of 500,000 sulfide-rich whale skeletons on the deep-sea floor (Smith and Baco 2003). Many organisms live in association with bacteria capable of deriving energy from hydrogen sulfide that is dissolved in the hydrothermal vent, cold seep fluid, or supplied by the decaying whale carcasses of whales (Thurman 1997). Since these bacteria are dependant upon the release of chemical energy, the mechanism responsible for this production is called chemosynthesis. Little is known regarding the significance of chemosynthetic productivity on the ocean floor on a global scale. However, the best studied chemosynthetic communities in the world are located in the Japan and Okinawa Complexes OPAREA; communities associated with hydrothermal vents, cold seeps, and whale falls are described in further detail in Section 2.8.13.

2.6.1.3 Secondary Production

Secondary production refers to the production (change in biomass) of organisms that consume primary producers (i.e., the production of bacteria and animals through heterotrophic processes; Scavia 1988; Strayer 1988; Karl 1999). Detailed descriptions of protected species as consumers of primary production including marine mammals, sea turtles, corals, and fish are found in later sections of this chapter or later chapters of this MRA. In this section, secondary production from marine zooplankton (primarily associated with water masses) is discussed.

2.6.1.3.1 Zooplankton

In most marine ecosystems, including Japan, copepods are the dominant zooplankton (Toda 1989; Uye et al. 1996). They play a key role in the marine plankton food web by affecting primary productivity via

predation and providing food for animals in higher trophic levels (Chang and Fang 2004). In Japanese bays and the Sea of Japan, the nauplii of copepods (cyclopoids and calanoids) are the most abundant food resource for higher trophic levels (Hirakawa et al. 1997; Chang and Fang 2004).

Much like phytoplankton, zooplankton can be divided into two distinct populations: those in subtropical waters and those in Oyashio waters. In the subtropical waters, seasonal variations in mesozooplankton are constrained within narrow bounds due to high levels of stratification. Monthly maximum and minimum biomass ranges from 23 to 54 mg m^{-3} (Limsakul et al. 2002). In the Kuroshio area, small sized copepods are the most abundant mesozooplankton (Ayukai and Hattori 1992). However, in the Oyashio waters, larger copepods are numerically dominant (Tsuda and Sugisaki 1994; Mackas and Tsuda 1999; Tsuda et al. 1999; Kobari and Ikeda 1999; Tsuda et al. 2001). Mesozooplankton in Oyashio waters exhibit considerable seasonal variation compared to subtropical waters; minimum and maximum monthly means range from 22 to 183 mg m^{-3}, respectively. Maximum values tend to occur in April in coordination with the 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).

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 et al. 1995, 2001).

2.6.1.4 Harmful Algal Blooms

Two types of harmful algal blooms (HABs) are known in Japan. The first is a noxious algal bloom associated with the mass mortality of marine organisms, especially fish in aquaculture cages and shellfish grown from rafts. Although most of these noxious blooms result in a discoloration of local waters, fewer than 20% of the blooms cause harmful effects within people. The second type of bloom is a toxic algal bloom causing the contamination of shellfish via either paralytic shellfish poisoning (PSP) or diarrhetic shellfish poisoning (DSP). In this case, the closure of aquaculture areas for the harvesting and marketing of shellfish is dependant upon the concentration of toxin not on the abundance of toxic plankton (Fukuyo et al. 2002).

From 1900 to 1950 the number of reports of harmful blooms averaged between 10 and 25 per decade. Following 1950, the numbers increased. By the 1970s, the number jumped drastically to more than 200 cases reported each year. After 1970, a massive effort was devoted to the elucidation of the biology and ecology of red tide organisms (Fukoyu et al. 2002).

Almost all microalgae responsible for various types of fish and shellfish poisoning of humans, including PSP, DSP, amnesiac shellfish poisoning (ASP), neurotoxic shellfish poisoning (NSP), and ciguatera are present in Japanese coastal waters. The most hazardous species are *Chattonella marina*, *C. antiqua*, and *Gymnodimium mikimotoi* (now *Karenia mikimotoi*); these species kill finfish and have caused damage to fisheries in excess of 100 million yen ($1 million U.S.). In addition, 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 (Fukoyu et al. 2002; Wazniak et al. 2004).

Among the HAB species in Japan, those causing PSP and DSP contaminations have been officially monitored since 1995 at over 170 sampling stations (Fukoyu et al. 2002). *Alexandrium tamarense* and *A. catenella*, two species known to cause PSP, 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 10^3 to 10^4 cells/liter (L) in April and May (Itakura 2002).

Japan is one of the most highly affected areas for cases of DSP (Wazniak et al. 2004); dinoflagellates in Japanese waters responsible for DSP contamination include *Dinophysis fortii* and *D. acuminate*. Affected

areas are primarily found in northern Japan. Mysteriously, *D. fortii* has never caused DSP toxin contamination in Japanese shellfish; *D. mitra* and *D. tripos* also produce DSP toxins but the accumulation of toxins in shellfish produced by these dinoflagellates is less than the quarantine level of the market (Fukoyu et al. 2002).

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. Within blooms of *P. multiseries*, *P. delicatissima*, and *P. pseudodelicatissima* domoic acid is produced; domoic acid has been linked to ASP in North America. However, domoic acid contamination has not yet been detected in wild and aquaculture shellfish in Japan despite intensive surveys. Currently, no monitoring program is in place for NSP and ciguatera although *Gymonodimium breve* (now *Karenia brevis*) and *Gambierdiscus toxicus*, causative organisms for these types of poisonings respectively, are found in western Japan (Fukoyu 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 (Fukoyu et al. 2002; Wazniak et al. 2004).

2.7 HABITAT

The majority of the Japan and Okinawa Complexes OPAREA is located 3 NM offshore. However, there are four nearshore areas located in the Okinawa study area including the Idesuna Jima, Tori Shima, Ie Shima, and Okino Daito Jima ranges. There is very little information regarding the coastal habitats of these nearshore areas; therefore, a general description of all habitats that are found in the Japanese Islands is given. Information pertaining to the specific area of the Japan and Okinawa Complexes OPAREA and vicinity is discussed where data was available.

2.7.1 Marine and Estuarine Wetlands

Wetlands can be subdivided into five major systems: marine, estuarine, riverine, lacustrine (lake), and palustrine (freshwater marsh; Cowardin et al. 1979). Of these five major categories, only the marine and estuarine systems are relevant to the Japan and Okinawa Complexes OPAREA. These areas are subject to tidal influence, characterized by strong salinity gradients, and include habitats such as tidal salt marshes, mudflats, salt flats, mangroves, seagrass beds, and coastal lagoons (MMS 2001). For all marine and estuarine wetlands, salinity varies with season, time, precipitation, location, and water depth. The USFWS defines wetlands as having one or more of three attributes: 1) the area supports predominantly hydrophytes, at least periodically; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or submerged by shallow water at some time during the growing season of each year (Cowardin et al. 1979).

Wetlands form the transition zone between terrestrial and marine systems and help to prevent shoreline erosion, reduce flood damage, and improve water quality (Carlisle et al. 2002). Pollutants from terrestrial runoff are filtered through wetlands where 1) particulates settle to the substrate, 2) excessive nutrients (i.e., the nitrogen and phosphorous found in fertilizers) are taken-up by vegetation and microorganisms (Bertness 1999), 3) contaminants are removed and broken down, 4) excess carbon from the burning of fossil fuels is absorbed, and 5) nitrogen and sulfur are re-cycled (Mendelssohn 1979). In addition, estuarine and marine wetlands are among the most productive natural systems on earth, producing more food per acre than the richest farmland (RAE/ERF 1999). They support essential habitat for 80% of the world's fish and shellfish species and provide feeding, nesting, shelter, high tide refuge, spawning grounds, nursery habitat, and other benefits for thousands of commercially and recreationally important fish, birds, mammals, and invertebrates. Per unit surface area, wetlands are more diverse than any other marine habitat (Bertness 1999).

Japan's coastlines are physically and geologically diverse resulting in a multitude of marine and estuarine habitats in Japan's nearshore areas; wetlands cover approximately 50,000 hectares (ha) in Japan (NACS-J 2003). Bays, estuaries, and nearshore areas form a variety of wetlands including salt marsh, lagoon, mangrove, intertidal sand and mud flats, beach, and rocky intertidal habitats (the three largest localities are Tōkyō Bay, the Ise Bat, and the Ariake Sea). However, the majority of Japan's wetlands are damaged and under threat from water pollution and land reclamation for agricultural, industrial and

commercial use. During the last 2 decades, 7% of Japan's wetlands have been lost, mainly to land reclamation (NACS-J 2003). In Japan, coastal wetlands close to urbanization areas often become developed because they can be reclaimed, at relatively low cost, and they are convenient for industrial use (Sohma et al. 2004). Japan currently has nine sites registered under the Convention on Wetlands of International Importance for the preservation of waterfowl habitat (Ramsar Convention). However, the current level of wetland protection is not adequate to prevent future loss of habitat (NACS-J 2003).

The most common coastal wetland found within in the Japanese Islands is intertidal habitat (PICES 2004). For example, intertidal regions of the Yellow Sea encompass more than 1,000 islands and 1,600 species including 400 phytoplankton, 300 marine macroalgae, 50 halophytes, 500 marine invertebrates, and approximately 389 vertebrate species (PICES 2004). Intertidal ecosystems consist of several different types of wetlands including mudflat with salt marsh, sand flat with gravel beach, sand dunes, rocky intertidal areas, and seagrass beds. These environments exhibit high levels of productivity and support important food resources, an ecological niche for diversity, good nursery and fishing grounds, and feeding, wintering, and summering grounds for migratory birds.

2.7.1.1 Coastal Salt Marsh

Coastal salt marshes are temperate wetlands bordered by land on one side and water on the other; they are regularly inundated by seawater at high tide and contain elements of both terrestrial and marine communities. They form in protected, low energy environments and occur along coastlines in middle and high latitudes worldwide (Wiegert et al. 1981; Tiner 1984). Salt marshes have three distinct zones designated according to the salinity and inundation tolerance of vegetation communities; the zones are defined as low marsh, middle marsh, and upper marsh (Carlisle et al. 2002).

Low Marsh—The low marsh is located along the seaward edge from mean sea level (MSL) to mean high tide (Leet et al. 2001); the region is flooded at every high tide and exposed at every low tide (Tiner 1993; Bertness 1999). Cordgrass (*Spartina* spp.) is the characteristic vegetation associated with most low marsh habitats (Zedler 1982). The low marsh is fundamental to the estuarine food web and is one of the most productive, self-sustaining habitats (Ursin 1972; Patrick 1994). In Japan (e.g., Tōkyō Bay), the low marsh is commonly composed of *Phragmites australis*, *Carex pumila*, and *Suaeda maritima* communities (Nohara et al. 2004). *P. australis* generally dominates the low salt marsh (e.g., the salt marshes in the Yoshino River Estuary; Kuroda et al. 2005).

Middle Marsh—The middle marsh is located between low and upper marsh, from mean high tide to mean higher high tide (Leet et al. 2001); the middle marsh is flooded only during higher than average tides (Tiner 1993; Bertness 1999). In general, it has low plant diversity (usually less than 25 species) and is dominated by pickleweed (*Salcornia* spp.). In Tōkyō Bay it is common to see *Phacelurus latifolus* communities associated with this zone (Nohara et al. 2004).

Upper Marsh—The upper marsh is located at the upland edge and in areas of high elevation from the mean higher high tide to extreme high tide (Leet et al. 2001); it is only flooded during extremely large tides and during storm surges or wind-driven tidal inundations (Tiner 1993; Bertness 1999). In general the upper marsh has a high diversity of herbs, shrubs, and trees and is dominated by salt grass (*Distichlis* spp.) (Nixon 1982).

Benthic fauna are present in high abundances and diversities in salt marsh habitat (Furota 1981). Similar to vegetation zonation, the occurrence of macrobenthic fauna in salt marshes is governed by tidal fluctuations. The abundance and distribution of macrobenthic fauna is affected by interstitial water level, predation, and interspecific competition (Furota 1981). In general, salt marsh benthic fauna are characterized by polychaetes, crustaceans, bivalves, and gastropods (Furota 1981). In Japan, grapsoid crabs are common in the middle marsh zone in bays and estuaries (Kuroda et al. 2005). In addition, fauna inhabiting the low marsh were also found subtidally; these populations were primarily affected by predation and interspecific competition (Furota 1981).

2.7.1.2 Lagoons

A lagoon is a semi-enclosed bay formed when a sandbar (or reef) is built up parallel to the coastline and cuts off the inland waters to the sea, creating a shallow region of water capable of collecting the freshwater from the land (Nybakken 1997, NCCOS/NOAA 2005). Lagoons typically contain three distinct zones: freshwater zone, transitional zone, and saltwater zone (Thurman 1997). The freshwater zone is located near regions of freshwater input (e.g. near the mouths of rivers emptying into the lagoon). The transition zone is a region of brackish water where freshwater entering the lagoon mixes with oceanic water and the saltwater zone is located near the oceanic entrance of the lagoon. The overall size of each zone will vary between lagoons due to differences in climatic conditions, major river flow into the lagoon, and the extent to which the barrier restricts water exchange with the ocean (Nybakken 1997). As such, during periods of extended rainfall, lagoons tend to contain increased amounts of fresh water as rivers and runoff deliver more fresh water. During more arid periods, lagoons become more saline and can turn hypersaline if evaporation exceeds the inflow of seawater from the ocean (Thurman 1997).

A few examples of significant coastal lagoons located in the Japanese Islands and vicinity include Shinji, Hamana, Abashiri, and Saroma lagoons. Shiniji, a brackish lagoon, is located along the coast of the Sea of Japan; two small channels (Ohashikawa channel and Sakai channel) link the lagoon with the sea. The salinity of the surface waters of Shinji Lagoon ranges from 5 to 10 psu. Hamana is one of the largest lagoons in Japan (pacific coast of Honshū). The salinity of the surface waters of Hamana lagoon is approximately 30 parts per million (ppm). It connects with the Pacific Ocean through a narrow sill called Imakire-Guchi. Two coastal lagoons, Abashiri and Saroma, are located along the eastern coast of Hokkaidō and connect with the Ohotuku Sea. These lagoons contain high quantities of fresh water with salinities ranging from 5 to 10 psu (Kashima 2000).

2.7.1.3 Mangrove

Mangroves are small tropical trees with salt-tolerant roots that grow in wetlands at the edge of the ocean. They often grow in patches to form mangrove forests that are essential habitat for many fishes and animals. Mangrove forests are the tropical equivalent of salt marshes; they line the shores of coastal embayments and the banks of rivers to the upper tidal limits (Myers 1999). Mangroves have large roots that spread laterally and the extensive roots systems can consolidate sediments efficiently, eventually transforming surrounding mudflats into dry land (Myers 1999). Mangrove forests provide the surrounding ecosystem with nutrient rich waters, making them among the richest nursery grounds for marine life (Scott 1993; Myers 1999). In addition, mangroves act as a buffer between land and sea, filtering pollutants and sheltering the land against strong tidal motion (Anonymous 1999).

Mangroves are mainly restricted to the tropics but some mangroves are found in subtropical areas like Japan (Field 1995). Japan is one of the few regions that support both the tropical mangrove habitat and the temperate salt marsh habitat. Approximately 400 ha of mangrove forest exist in the southern regions of Japan; they are found scattered throughout the Ryukyu Archipelago and reach as far north as Kiire on southern Kyūshū (Spalding et al. 1997; Simard 1995). The current distribution of mangroves is largely concentrated on the islands of Ishigaki and Iriomote in the Okinawa prefecture. The mangroves on Iriomote Island are the largest and most diverse (eleven species) in the region (Spalding et al. 1997). The large mangrove communities that previously inhabited Okinawa have diminished due to increased pollution. Mangroves are still abundant near the Nakama and the Urauchi rivers in Iriomote, the Miyara River in Ishigaki, the Gesashi River in Higahi Village, and the Kanna River in Ginoza Village (Anonymous 1999). Generally, the smaller islands of the Okinawa study area do not have the extensive estuaries necessary to support mangrove forests (Simard 1995).

A few strong typhoons pass over the Ryukyu Islands every year; these storms can cause damage to mangrove forests and typically restrict the canopy height to 10 to 15 m (Spalding et al. 1997). Many mangrove forests have been destroyed for urban development. However, the Okinawa prefectural governments, Okinawa local governments, and a few non-governmental organizations have initiated activities in an attempt to conserve and restore local mangrove ecosystems (Spalding et al. 1997). To

assist in the preservation efforts, in 1992, scientists from around the world established the International Association for Researching the Ecology of the Mangrove in Okinawa (Anonymous 1999).

2.7.1.4 Tidal Flat

Tidal flats are relatively broad, flat intertidal habitat that are submerged during high tide and are located along protected coastal intertidal areas (DoN 2000) throughout the Japanese Islands. Tidal flats can be classified into sand flat and mud flat habitats according to sediment composition. They can also be categorized into coastal tidal flat and estuarine tidal flat based on their location. The physical characteristics of an area determine sediment composition; this, in turn, influences the biological diversity and the productivity of the habitat. Sand flats are comprised of sand particles that are approximately 0.2 to 0.7 mm in diameter with low organic matter content (1 to 2%) (UN 2001). They form in areas of higher current and wave energy than mud flats and are usually no more than 1 km in width. Mudflats form in more protected areas of slow current and wave energy and are usually at least 5 km in width. They are comprised of smaller silt/clay sediments that are approximately 0.031 mm in diameter; this small sediment size makes for a tightly compacted sediment bed (UN 2001). Well-developed mudflat sediments are anaerobic, stable, and harbor substantial amounts of organic matter and microorganisms (DoN 2000)

Bacteria play an essential role in the tidal flat ecosystem; they decompose organic material to make nutrient-rich detritus. Abundant macrofauna, such as clams, mussels, isopods, amphipods, gastropods, crabs, and polychaete worms, utilize this detritus (DoN 2000). Tidal flats also support vegetation that is typically found in bays and estuaries. In turn, the macrofauna and macroflora supported by tidal flats serve as the food base for fishes and birds. Seasonally, many tidal flats serve as essential stopovers for migrating birds to rest, feed and breed (UN 2001). For example, migratory water birds utilize the extensive algal cover and resident invertebrates present in mudflats (DoN 2000).

In addition, the sediments of tidal flats purify waters by filtering out excess nutrients and absorbing pollutants that are discharged from the land into the sea. The macrofauna and macroflora are also involved in this purification process directly or indirectly; thus, the greater the biological diversity of the tidal flat habitat, the greater the stability and purification of the ecosystem (UN 2001).

2.7.1.5 Beach

Beaches provide extensive benthic habitat for sand-dwelling crustaceans, mollusks, and fish; they also supply resting and nesting sites for seabirds, sea turtles, and some marine mammals. Beaches are found throughout the Japanese Islands, are generally associated with adjacent coral reefs, and are composed mainly of carbonate sediments. Carbonate sediments support diverse invertebrate assemblages; the specific assemblage structure is based upon the mean grain size and wave exposure of the site (De Felice and Parrish 2001). In general, the number of individuals and diversity increases with increased mean grain size and decreased wave exposure (De Felice and Parrish 2001). Beach sand tends to be coarser off wave-exposed and windy reaches of islands, and finer within lagoons, embayments, mangroves, and harbors (Maragos 2000); wave action and biological and chemical erosion determine the composition and longevity of beaches (Juvik and Juvik 1998).

There are a variety of beaches from white to black sands and from fine sand to large pebbles found throughout the Japanese Islands (Simard 1995). Four kinds of beaches have been recognized. White sand beaches are the most common; they are formed from the breakdown coralline algae and corals producing white carbonate sand, black sand beaches are derived from recent lava flows, when molten lava flows into the sea and tiny tephra particles are formed, pink sand beaches from the breakdown of iron-rich coastal cinder cones, and green sand beaches consist of olivine crystals that have eroded from lava rock (Maragos 2000; Juvik and Juvik 1998). There are famous dunes in Tottori, on the southwestern coast of Honshū on the Sea of Japan side and also near Tianjin in the Bohai Sea (Simard 1995). Also, with numerous coral reefs located offshore, it is likely that beach habitat is common in the nearshore areas of the Okinawa study area.

2.7.1.6 Rocky Intertidal

Biological assemblages common to rocky intertidal habitats are defined by extreme physical factors including exposure to air and potential desiccation, strong wave and surf exposure, rocky substrate, competition for living space, and the need to find food and shelter while avoiding predators. Cracks, crevices, and overhangs create microhabitats for organisms to elude predators, minimize wave shock, and avoid desiccation. These characteristics create strong vertical zonation in which the distribution of an organism is determined by its physiological tolerance to desiccation and competitive and predatory interactions with other species (MMS 2001). There are four zones in a rocky coast habitat: the upper intertidal, mid-intertidal, lower intertidal, and subtidal (Juvik and Juvik 1998).

Rocky intertidal habitat is found throughout the Japanese Islands; however, it is especially common in the islands of the Japan archipelago (Simard 1995). Rocky shores are likely to be one of the habitats encountered in the nearshore regions of the Okinawa study areas. In a study of a boulder shore habitat in Amakusa, Japan by Takada (1999), it was found the biological diversity of the organisms inhabiting the rocky intertidal environment increased as the shade and protection offered by the environment increased. A sample from the macrofauna of the rocky intertidal habitat in Amakusa, Japan included two carnivorous species (*Hemigrapsus sanguineus* and *Japeuthria cingulata*) and many herbivorous species (e.g., *Nerita japonica*, *Nipponacmea nigrans*, *Monodonta labio*, and *Littorina brevicula*; Takada 1999).

2.7.1.6.1 Tide pools

As the tide recedes, depressions between rocks can retain water. These areas form pools known as tide pools. Tide pools are flooded during rising tides and are continuous with the open ocean at the surface. Along the shores of the Japanese Islands, tide pools are formed by lava rock depressions that have subsided to sea level where wave action eventually breaks down the surface barriers exposing the area to open ocean. A variety of reef animals and plants occupy tidepools such as crabs, small fish, snails, and many types of algae (Juvik and Juvik 1998). The organisms that reside in a tide pool may be subjected to desiccation and drastic salinity and temperature changes; they are therefore uniquely adapted to survive under the harsh conditions of this habitat.

2.7.1.6.2 Anchialine pools

Anchialine pools are land-locked, marine or brackish pools of water that are located along the coasts of younger volcanic islands and where coral reefs have been uplifted (Maragos 2000) and are connected to the sea through underground caves, tunnels, or fissures (Frankel 2004). They are typically found along rocky coasts up to several hundred meters inland. Depending on the distance from the sea and the extent of groundwater input, pools range in salinity and water quality. The porous rock walls allow for subsurface connections with the sea. Anchialine pools in basalt rock are generally found where the lava rock is porous and creates broad shallow shelves near the coast. Limestone anchialine pools are found in karstic formations that consist of fossilized coral reefs; these formations have undergone extensive weathering and dissolution (Meier et al. 1993). Lava rock depressions that have subsided to sea level become flooded with seawater during tidal flow and anchialine pools are created; eventually these anchialine pools are eroded to form tide pools (Juvik and Juvik 1998).

Anchialine habitats are best known for their unique community assemblages, particularly invertebrate species such as the atyid shrimp living in an anchialine pool on Kuro-shima, Okinawa. Also, distinctive microorganisms' assemblages are present in the unique anchialine habitats. The microbial diversity of these habitats is important to assess because of the increasing threat posed by human activity; the majority of the ponds have been drastically impacted by human development (Meier et al. 1993).

2.7.2 Benthos

The bottom environment of the Japanese Islands is complex due the variety of bottom substrates and the complicated system of water circulation and temperature changes (Chikuni 1985). The distribution of the biota is determined by a vertical zonation pattern that is mainly a function of depth and substrate. Coastal

rocky shores are predominately defined by fouling fauna. Subtidally, mobile sestonophages begin to dominate the biota with an adjacent zone of detritivores (ex. Mollusks). With increased depth, mollusks are replaced by ophiuroids and polychaetes become the dominant fauna in the deep water. On the abyssal plains, sessile sestonophages also play a dominant role along with polychaetes (Chikuni 1985).

Detailed surveys of the benthos around Japan have been limited to a few specific bays and inlets. On the continental shelves of the Pacific coastline, the benthos biomass averages between 15 to 72 g/m^2. However, in the shallow areas of Tōkyō Bay this increases to 200 g/m^2 with a maximum of about 1,200 g/m^2 (Chikuni 1985). In general, benthic biomass decreases with increasing depth. Around the Japanese Islands, shallower waters of the shelf support about an order of magnitude more biomass and the shelf edge an order of magnitude less biomass on the average (Chikuni 1985).

2.7.2.1 Subtidal Colonized Hardbottom

Rocky substrate can provide support to extensive communities of marine plants and animals that require attachment for survival. For example, subtidal rocky substrates provide attachment sites for macrophytes (algae and surfgrass), which in turn provide habitat for a diverse ecosystem of fish and invertebrates including algae, sponges, octopus, feather stars, and the commercially valuable spiny lobster and abalone (Chess and Hobson 1997, Kanamori et al. 2004). Macrophytes provide shelter from predation; also, they act as a substrate for epiphytic microalgae and thereby provide food for smaller herbivores (Kanamori et al. 2004). These areas can also be termed live bottoms or live hardbottom habitat. Live bottoms or live hardbottom can be defined as areas that contain biological assemblages of sessile invertebrates (e.g., sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, and hard corals) living and attached to hard or rocky substrate with rough, broken, or smooth topography; these biological assemblages promote the congregation of turtles, pelagic and demersal fish. The distribution of subtidal benthic communities is determined by light penetration, temperature, wave action, availability of substrate, and sedimentation (Maragos 2000).

The subtidal rocky habitats of Japan consist of multispecific vegetation that creates habitat for many invertebrate populations (Kanamori et al. 2004). These benthic communities are found in depths of up to 50 m or more, on basalts and on consolidated limestones (e.g., reef carbonates and beach rock). In the temperate waters of Japan, macrophyte (seagrass and algal) biomass in subtidal hardbottom habitats fluctuates with season (Kanamori et al. 2004). After reaching a maximum in a season, the biomass decreases rapidly. A decrease in macrophytes correlates with a reduction habitat for many organisms. In turn, a seasonal change in the densities of small invertebrates often corresponds to that of macrophyte biomass. For example, when macrophyte biomass increases it is common for the organisms associated with this habitat to synchronize with the increase and begin recruiting. The response to seasonal fluctuation of habitat is specific to different macrophyte species and the preference of an organism's host species. On subtidal rocky shores in temperate waters of Japan, there are a wide variety of macrophyte species including seagrass (e.g. *Phyllospadix* spp.), large brown algae (e.g. *Sargassum*, *Laminaria*) and other smaller algae (Kanamori et al. 2004).

2.7.2.1.1 Flora

The fundamental component of the benthos habitat is the resident flora. Benthic floras are nearly ubiquitous in the photic zone. They occur from polar regions to the tropics and from depths ranging from the spray zone, well above high tide level, to depths of 268 m (Littler et al. 1985) They form a significant feature along most shorelines and shallow water environments (South 1993) and serve as an important food source, a means of substrate for attachment, and a source of shelter for many grazing invertebrates and vertebrates. The most abundant populations of benthic flora occur on hard substrates such as rock and corals, man-made structures, and roots of mangroves. They can also form extensive populations in sheltered, shallow habitats on soft substrates or grow completely unattached.

Algae (Chlorophycea, Phaeophycea, and Rhodophyceae) are a common type of benthic flora with approximately 8,000 species worldwide (South 1993). The highest diversity of algae occurs in temperate regions, more specifically Japan and southern Australia (South 1993). The Japanese Islands support

approximately 860 species of benthic flora, 310 of which are endemic. Subtropical species are the most common forms along the southern coasts of Japan (Chikuni 1985). For example, in the nearshore areas, Phaeophyceae (such as *Sargassum* and *Turbinaria*) are common and in the shallow lagoon habitats *Padina* species are common (South 1993).

In Japan, many types of algae are consumed in large quantities. There are approximately 600 species of algae in Japan (Simard 1995). Among those, the most common and important types are *Ulvales*, *Codium*, and *Caulerpa* for the Chlorophyta; *Nemacystus*, *Laminaria*, *Kjellmaniella*, *Eisenia*, *Ecklonia*, *Undaria*, *Hizikia*, and *Sargassum* for the Phaeophyta; *Helminthocladia*, *Scinaia*, *Gelidium*, *Gloiopeltis*, *Chondrus*, *Ceramium*, for the Rhodophyta. Nori (*Porphyra* spp.), Wakame (*Undaria pinatifida*), and Kombu (*Laminaria japonica*) are the more popular edible types (Simard 1995).

2.7.2.1.2 Fauna

The second component of benthos habitats is the biological community of fauna that utilize the resident flora (discussed above) to form a diverse ecosystem of fish and invertebrates. The marine benthic invertebrate assemblages of the Japanese Islands are extremely diverse and include representatives of nearly all phyla. In general, the nature of the bottom fauna depends on various local conditions and the highest densities of benthos occur at a depth of approximately 70 m. The benthos is extremely abundant in the eutrophic regions of the Japanese Islands. There is a eutrophic region that extends from west of Kyūshū in the Korea Strait and past the shelf of the southern Japan Sea. There is another, narrow, eutrophic region near the Tsugaru Strait (Chikuni 1985).

In Japan, there are about 6,000 species of Mollusca, 1,000 species of Brachyura, 480 species of Dendrobrachiata (shrimps and prawns), 320 species of Anomura (hermit crabs), and 50 species of Stomatopoda (mantis shrimp) (Simard 1995). Porifera (sponges) and Cnidarians are very common along the southern coast of Japan through West Kyushu, the Korea Strait, and the Tsugaru Strait along the coast of the Japan Sea; whereas, Annelida (segmented worms, predominantly sedentary forms) and Crustacea (crabs, shrimps, ascidians, and echinoderms; predominantly decapods) are widely distributed throughout the Japanese Islands (Chikuni 1985). Along the Pacific coasts in the sandy substrate habitats, Asteriodia (sea stars), Echinoidea (sea urchins and sand dollars), and Holothuroidea (sea cucumbers) are dominant. In the warmer waters of southern Japan, Ophiuroidea (brittle stars) are very abundant in the sandy substrate habitat of the Japan Sea coastline with offshore distributions as well; although, it is also found in muddy substrate habitats on the Pacific side. In the offshore waters of the southern Japan Sea, Mollusca (gastropods, bivalves, cephalopods) are dominant (Chikuni 1985). The benthos in the Yellow Sea and the East China Sea is very similar to the benthos of the southwestern coast of Japan. For example in the East China Sea, Holothuroidea, Macrura (decapods), Brachyura (crabs), and Cephalopoda (squids, octopus, cuttlefish, and nautilus) are abundant in the central part, Ophiuroidea are abundant in the northern part, and Macrura, Ophiuroidea, Brachyura, and Asteroidea are abundant in the southern part. The depth distribution of Ophiuroidea is 60 to 85 m, Asteriodea is 50 to 80 m and 100 to 150 m, Macrura is 50 to 110 m, and Gastropoda (cephalized mollusks) and Cephalopoda is about 50 m (Chikuni 1985).

Many of these species are commercially important; however, they are also considered to be threatened species in this region (Simard 1995). For example the pearl oyster, *Pinctada*, is a commercially fished genus in the Japanese Islands; the two species are the black-lip pearl oyster, *P. margaritifera*, and the gold-lip or silver-lip oyster, *P. maxima* (Sims 1993). *P. margaritifera* inhabits lagoons, bays, and sheltered reefs; they occur at up to 40 m depth but they are most abundant at the low tide mark. *P. maxima* are occasionally found on reef flats; but generally, they occur between 10 m and 60 m on the open shelf. *P. fucata martensii*, *P. chemnitzi*, *P. concinna*, and *P. simizuensis* are also common in the Japanese Islands although they are not commercially fished (Sims 1993). Giant clams, *Tridacna gigas*, typically prefer coral reef habitats but in general, they can live in any coralline substrate of tropical waters. *T. gigas*, the largest species, is now extinct in the Taiwanese and Japanese waters; however, the small rock-boring giant clam, *T. crocea*, has occasionally been found in southern Japan (Munro 1993). For the past 100 years, the marine snail, *Trochus niloticus*, has been harvested commercially. They have a very specific habitat and are restricted to intertidal and shallow subtidal habitats on the oceanic margin of coral reefs;

therefore, they are prone overfishing. They are found in the tropical and subtropical waters of southern Japan in the Ryukyu Islands (Nash 1993). The green snail, *Turbo marmoratus*, has been commercially exploited since the 1880s throughout the southern Ryukyus Islands. *T. marmoratus* inhabits coral reef environments and can extend down reef slopes to at least 20 m (Yamaguchi 1993). The spiny lobster, *Panulirus penicillatus*, is another commercially harvested fishery in the Japanese Islands. *P. pencillatus* mainly inhabits the oceanic side of reefs where the water is clean, clear, and well-oxygenated, with minimal terrestrial influence (Pitcher 1993).

2.7.2.1.3 Seagrass

Seagrasses are submerged aquatic vegetation that form extensive underwater meadows (or beds) and create important habitats. They are a group of about 60 species and are found in shallow-water depths and various temperatures and salinity ranges throughout many parts of the world (Phillips and Meñez 1988). Most seagrasses have flattened leaves that help them adjust to light restrictions and slow rates of gas diffusion within the water column (Thayer et al. 1984). Their extensive rhizome (root) system forms dense and tough belowground mats that function in anchorage and the absorption of nutrients from the sediments. The leaves are capable of transporting oxygen to the rhizomes allowing seagrasses to grow in anoxic sediments (Thayer et al. 1984).

Seagrass beds are among the most productive habitats in the ocean and provide a substantial element in the sustainability of coastlines, fisheries, benthic invertebrates (e.g., shrimp, juvenile lobster), marine mammals (e.g., manatees, dugongs), reptiles (e.g., green sea turtles), and waterfowl. Seagrasses play an important role in nutrient regeneration and recycling, water quality, primary production, and carbon sequestration. They also sustain ecosystem productivity by trapping detrital material and sustaining detrital-feeding pathways (Phillips and Meñez 1988; Nybakken 1997). Seagrass beds slow currents and waves and assist in the prevention of coastline erosion by stabilizing sediments and promoting sedimentation. In addition, seagrass meadows improve water quality by filtering sediments and sediment borne pollutants, excess nutrients, and dissolved and particulate pollutants from terrestrial run-off. However, primary production is probably the most essential function of the seagrass ecosystem (Brouns and Heijs 1986). As perennial structures, seagrasses are one of the few marine ecosystems that store carbon for relatively long periods. This carbon can be bound into sediments or transported to the deep ocean and play an important role in long-term carbon sequestration (Phillips and Meñez 1988).

Seagrass ecosystems promote biodiversity by providing a variety of unique niches and have been found to parallel that of adjacent high diversity ecosystems (e.g., coral reefs, mangroves, salt marshes, and bivalve reefs; Green and Short 2003). Seagrasses can grow up to 10 millimeters per day (mm/d); this high rate of growth sustains the feeding pathways of many herbivores and detrital-feeders. Seagrass meadows are usually among the highest biological production areas of shallow waters and provide nursery grounds for fish. Thus, these areas are important in terms of maintaining sustainable fisheries. Given these benefits and uses of shallow waters, mitigation of reclaimed seagrass beds is urgently required in Japan (Sohma et al. 2004). Short et al. (2000) and Green and Short (2003) have surveyed documented sources and determined that, worldwide, between the mid 1980s and the mid 1990s, 1,200,000 ha of seagrass habitat have been lost. Coastal modifications causing shading, resuspension of sediment (via dredging, recreational watercraft, ferries, tankers, and freighters), deposition of upland soils, and oil spills may reduce the transmission of light to and/or bury seagrasses.

Geographic distributions of seagrasses are based upon individual species tolerances to hydrological and atmospheric conditions (i.e., water temperature, salinity, irradiance, depth, substrate, and exposure; Phillips and Meñez 1988). Of the 12 genera of seagrasses, eight are present in Japan with seven occurring in Okinawa (*Zostera*, *Phyllospadix* [mainland Japan only], *Halodule*, *Cymodocea*, *Syringodium*, *Enhalus*, *Thalassia*, and *Halophila*) (den Hartog 1970; NACS-J 2002). In Atsumi Bay, Japan, the biomass of seagrass is highest in June (Sohma et al. 2004).

In Japan, seagrass beds cover extensive areas surrounding coral reef communities. In the Ryukyu Islands, monitoring studies have been conducted on two seagrass beds surrounding coral reefs. On the western side of Iriomote Island, the seagrass bed extended along the coastline between 40 and 160 m

from the shore; this bed was dominated by *Enhaulus acoroides*. On the northern side of Ishigaki Island, the seagrass bed extended along the coastline between 30 and 120 m from the shore; this bed was dominated by *Thalassia hemprichii* (Nakamura and Sano 2004).

In 2002, a seagrass-watch program was initiated in Okinawa. This program was tasked with addressing the impacts of the construction of a U.S. military airport on Okinawa's seagrass beds and dugongs (NACS-J 2003). In Okinawa, the largest seagrass bed is located along the coast from Henoko to Toyohara/Kushi in Nago-city; this seagrass bed is 1,500 m wide and 800 to 1,000 m long (NACS-J 2003). Continuous beds occur around Kayo and Abu in Nago-city, Matsuda and Kanna, and an area between the mouth of Oku-kubi River to Kin Cape. Seven species of seagrass inhabit the seagrass beds in Kayo, Henoko, and Toyohara *Thalassia hemprichii* has a broad distribution in the region while *Syringodium isoetifolium* and *Cymodocea serrulata* form mixed colonies and are restricted to shallow water. *Halophilia ovalis* is abundant in deep depths (NACS-J 2003).

2.7.2.1.4 Kelp

Kelp attaches to rocky substrate and can grow up to 50 m in length in nearshore areas of 2 to 30 m depth (Rodriguez et al. 2001). Several species of kelp occur throughout Japan. In North Japan (SW Hokkaidō, 39 to 46°N) *Laminaria* spp. are very common, especially *Laminaria japonica* (Steneck et al. 2002). In South Japan (West Honshū, 36-38°N) *Undaria pinnitifida* (Japanese name Wakame), *Eisenia bicyclis* (Japanese name Arame) *Ecklonia cava* are the most common species of kelp (Steneck et al. 2002).

Temperature, light, sedimentation, substrate, relief, wave exposure, and biological factors (i.e., grazing, competition with other species) determine the distribution and abundance of kelp. The highest densities are found on low relief substrate (Deysher et al. 2002). The most persistent beds occur on solid rock substrate with moderately low relief and moderate sand coverage; very low relief and abundant sand has less persistent kelp (Deysher et al. 2002). Wave exposure and interspecific competition affect both the temporal and spatial variability of kelp (Foster and Schiel 1985; Graham 1997). Kelp are sensitive to light irradiance; because of this, they are restricted from waters less than 2 m in depth (Graham 1997).

The stems and blades of kelp can form overlying canopies on the water's surface and provide unique habitat for plant and animal communities (Rodriguez et al. 2001). Kelp forests provide refuge, forage, and nursery areas for an abundance of animal and plant species in the Japanese Islands. In addition, kelp forests provide large quantities of drift kelp (detached kelp) to adjacent habitats; drift kelp provides an important resource to soft and rocky benthos, deep channel basins, sandy beaches, rocky shores, and coastal lagoons (Rodriguez 2003).

2.7.2.1.5 Coral communities and reefs

Coral communities occur throughout the Japan and Okinawa Complexes OPAREA (**Figure 2-9**). True coral reefs (hermatypic coral reefs) occur in the Okinawa study area and in the nearshore areas of the Okinawa study area, from the southern Ryukyu Islands to the Amami Islands (Veron 1995, 2000a; Tsuchiya et al. 2004). Closer to mainland Japan, in the West Japan study area, temperate non-reefal coral communities border the coastlines of Kyushu and Shikoku Islands, Goto Islands (Sea of Japan), and Iki Islands (Sea of Japan). High-latitude outlying coral communities fringe the Izu and Boso peninsulas in the East Japan study area (Veron 1995, 2000a; Tsuchiya et al. 2004; **Figure 2-9**).

There are three different types of coral communities in the Japanese Islands: true coral reefs, non-reefal communities, and outlying communities. The main factor differentiating the three different types of coral communities is the northward reduction in the number of tropical coral species (Veron 2000). Other factors influencing the regional distribution of corals of Japan include terrigenous runoff, the topography of coastal habitats, and seawater temperature (Veron 2000; Nishihira 2004). The southern and central Ryukyu Islands (Yaeyama, Miyako, Okinawa, and Amami islands) are isolated from terrigenous runoff originating from mainland China, have diverse coastal habitats, and compared to other coral-bearing locations of Japan are located within the warm waters of the Kuroshio Current (Nishihira 2004). Further, a

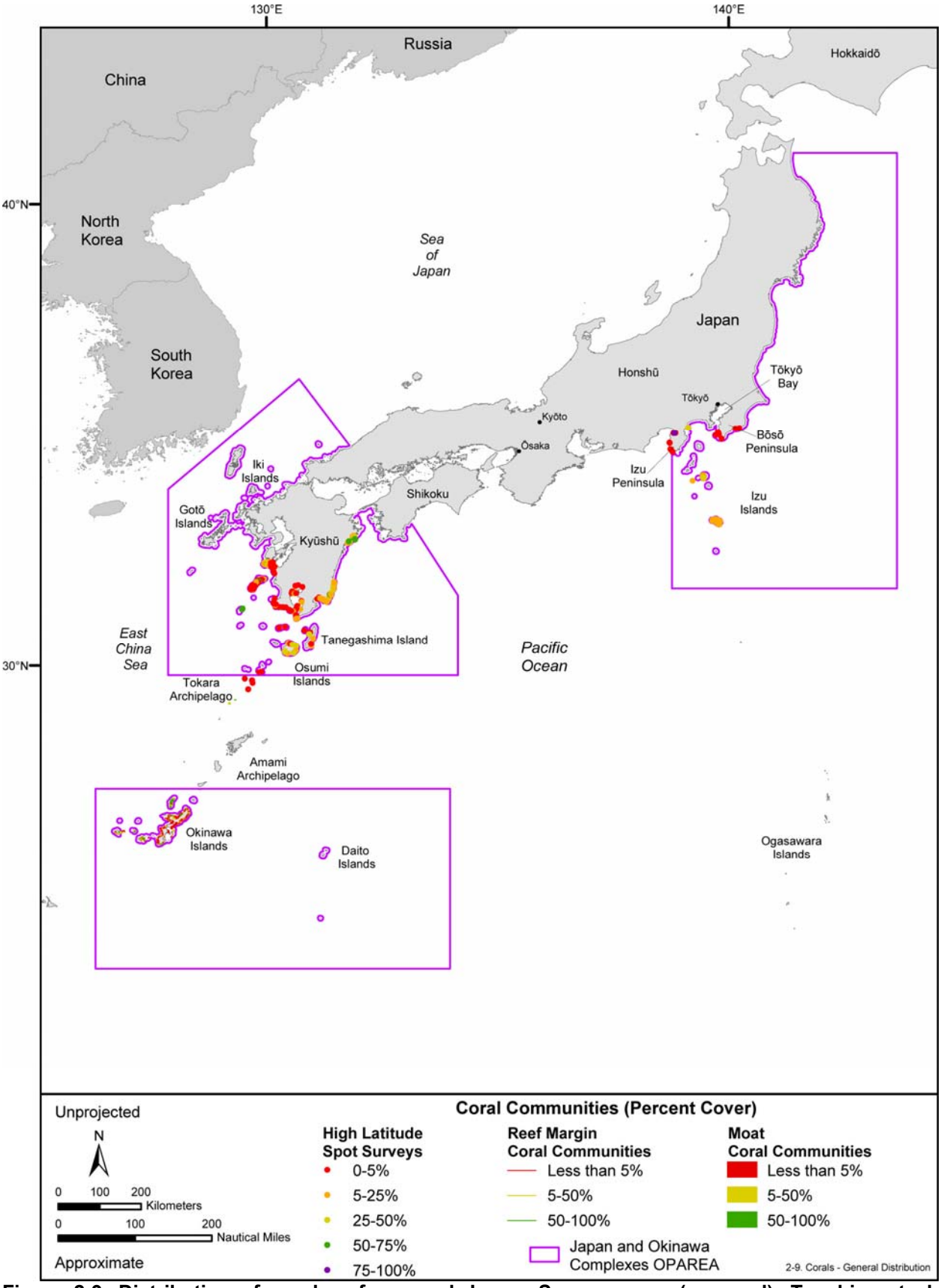

Figure 2-9. Distribution of coral reefs around Japan. Source maps (scanned): Tsuchiya et al. (2004).

major difference between hermatypic reefs and non-reefal communities is the ability of the hermatypic reefs to outcompete macroalgae. Corals in non-reefal communities are less capable of developing habitats suited for diverse coral communities (Veron 2000).

On Japanese coastlines, the number of coral species decreases with increasing latitude (Veron 2000). The true coral reefs of Japan contain 220 to 363 tropical coral species, the non-reefal communities contain 77 to 151 species, and the outlying communities contain 23 to 42 species (Veron 1995). For comparison, there are 59 coral species known in the Hawaiian archipelago (Maragos et al. 2004) and true coral reefs of the Western Atlantic contain 40 to 50 coral species (Liddell and Ohlhorst 1988). The number of tropical coral species in Japan decreases with decreasing SST; SST decreases with the poleward direction of the Kuroshio Current. In contrast to subtropical and temperate regions, SST in the tropicals is typically greater than 18°C and is suitable for the mass accretion of reefs. The Kuroshio Current disperses coral planulae from the tropical reefs of Japan to higher latitudes. Larvae that settle at higher latitudes form coral colonies that are genetically connected to the tropical locations. These corals subsequently form subspecies to which tropical species are not connected.

Regional Distribution, Composition, and Condition

Regional Distribution—Coral communities and reefs of Japan occur from sub-tropical to temperate areas (Iryu et al. 1995; Veron 1995, 2000a; Yamano et al. 2001; Nishihira 2004; **Figure 2-9**). True coral reefs of Japan are found between 24° and 33°N and hermatypic corals are found down to a depth of 100 m (Yamazato 1972; Yamano et al. 2001; Kayanne et al. 2004). True coral reefs are particularly abundant and speciose in the southern Ryukyu Islands (Irimote Island, Sekisei Lagoon, Ishigaki Island, Miyako Island, and Tarama Island; Nishihira 2004). The morphology of coral reefs changes with latitude from wide fringing reefs in the Ryukyu Islands (24° to 27°N), to patchy reefs and narrower reef flats further north in the Ogasawara Islands (27° to 31°N) (Kan et al. 1995; Kayanne et al. 2004).

Okinotorishima Island is the southern-most Japanese island that supports coral reefs. Minamitorishima Island is the eastern-most and Yonaguni Island is the western-most Japanese Islands that support coral reefs (Kayanne et al. 2004). The most diverse coral communities occur in the Yaeyama Archipelago (southern Ryukyu Islands; Nishihira 2004; **Figure 2-9**). With the exception of Iki Island, non-reefal communities are found north of Tanegashima Island and up to the Izu Peninsula (Veron 1995, 2000a; Yamano et al. 2001; Nishihira 2004). High-latitude outlying communities occur from the Izu Peninsula to Tokyo Bay (Nishihira 2004). The northern-most coral communities are found in Tokyo Bay (central Japanese mainland; Nishihira 2004).

Regional Composition—There are approximately 415 scleractinian (stony) coral species and approximately 10 non-scleractinian coral species in Japan (Veron 2000; Nishihira 2004). The most speciose stony coral genera in Japan are *Acropora* (82 species), *Montipora* (38), *Porites* (25), *Favia* (16), and *Fungia* (15). Three stony coral species are endemic: *Euphyllia paraglabrescens*, *Acropora tanegashimensis*, and *Porites okinawensis* (Nishihira 2004). All scleractinian and non-scleractinian corals are listed as CITES Appendix II species, i.e., “species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled” (CITES 2005).

In Japan, the fringing reef habitat is the most significant reef habitat that supports true coral reefs. A typical fringing reef of the Ryukyu Islands is characterized by the following successive areas: (1) a moat or trough-like depression found along the shoreline. The mote can be several hundreds of meters wide and up to 3 m deep. The seafloor of the moat is characteristically covered with seagrass close to shore and with sand/gravel further offshore; (2) an inner reef flat with a landward incline. Water depth on the reef flat is less than 1 m; (3) a reef crest that is less than 0.5 m deep; (4) an outer reef flat with a seaward incline that is less than 200 m wide. Water depth on the outer reef is 1 m; (5) a reef edge found at a 1 m depth. This reef edge marks the boundary between the outer reef flat and the reef slope; and (6) a reef slope on which spur and groove reefs can occur from 10 to 60 m water depth (Iryu et al. 1995).

Based on descriptions of fringing reefs in the Ryukyu Islands, Iryu et al. (1995) noted that before the mass bleaching of corals in 1998, all parts of the fringing reefs contained stony corals. Additionally,

seagrass beds and the sandy moat also harbored isolated coral colonies of *Acropora formosa*, *M. digitata*, *P. australiensis*, *P. cylindrica*, *Galaxaura* spp., and *Actinotrichia fragilis*. However, the inner reef flats supported the most abundant and diverse assemblages of branching and foliaceous stony corals; the dominant species were *Acropora pulchra*, *Montipora digitata*, *M. aequituberculata*, *M. informis*, and *Porites australiensis*. A reef crest emerging at low tide was covered by *Sargassum* and turf algae. Iryu et al. (1995) also noted that the thalli of *Sargassum* supported large benthic foraminifera, anon-emergent reef crest typically supported *A. pulchra*, *A. aspera*, and *M. digitata*, and the shallow outer reef flat supported *P. verrucosa*, *A. monticulosa*, *A. aspera*, *A. hyacinthus*, *Goniastrea retiformis*, and *Platygyra ryukyuensis (*wave-resistant, encrusting, and tabular forms of stony corals). On the reef slope, in a water depth of 1 to 5 m, the stony coral assemblage consisted of wave resistant forms of *A. humilis*, *A. hyacinthus*, *A. valida*, *Favia pallida*, *Favites abdita*, and *G. retiformis*. Deeper onto the reef slope from 5 to 25 m, there were hemispherical and encrusting forms of *P. verrucosa*, *A. cytherea*, *Favia stelligera*, *Echinophyllia aspera*, *Oxypora lacera*, and *Mycedium elephantotu*s. Also, there were fewer stony corals in water depths greater than 25 m which consisted mainly of foliaceous and encrusting forms of *Pachyseris speciosa* and *Leptoseris scabra* (Iryu et al. 1995).

Since the Iryu et al. (1995) assessment, the structure of stony coral communities on inner reef flats in the Ryukyu Islands has probably changed considering the mass mortality of branched stony corals that took place on reef flats of Okinawa during the 1998 mass bleaching event (Loya et al. 2001).

Regional Condition—Coral reefs of Japan are frequently impacted by typhoons, particularly in August and September (Kimrua et al. 2004). On average, 11 typhoons occur each year within 300 km of Japan. Typhoons cause recurrent physical impacts on coral communities and severe sedimentation (Kimrua et al. 2004). From October to April, north monsoons generate strong winds and large swells that impact reefs on a recurrent basis (Iwao 2004). In addition to the naturally-occurring impacts on reefs caused by typhoons and heavy wave action, coral reefs of Japan have been severely impacted by the coral predator *Acanthaster planci* (crown-of-thorns starfish [COTS]), particularly in the 1970-1980s and 2000s and coral bleaching in 1998, 2001, and 2003 (Yamazato 1997; Fujiwara et al. 2000; Loya et al. 2001; Kayanne et al. 2002; Akimichi 2004; Kimura et al. 2004; Nakano 2004; Yokochi 2004). Corallivorous gastropods (particularly *Drupella fragum*) have impacted high-latitude corals of Japan (Kimrua et al. 2004; Yokochi 2004). As of 2004, there have been few reports of coral diseases in Japan (Kimrua et al. 2004; Yamashiro 2004). In 2003, 30% of the sites monitored in Sekisei Lagoon, a prime location for coral reefs in Japan, contained diseased corals (Kimrua et al. 2004). Repeated physiological stresses on corals such as coral bleaching could decrease the resistance of corals to opportunistic diseases and promote mass mortality induced by disease outbreaks (Harvell et al. 1999).

The main human-induced factors that continue to impact coral reefs in the Ryukyu Islands include coastal development (dredging and reclamation) and sediment-laden terrestrial runoff (red soil pollution; Yamazato 1997; Omija 2004; Nakano 2004). Other human-induced impacts on coral reefs include physical impacts caused by anchoring and resource depletion caused by overfishing. Anchoring by large vessels off the port of Ishigaki in the southern Ryukyu Islands has caused severe structural damage to reefs (Akimichi 2004). Further, other reefs of the southern Ryukyu Islands have incurred substantial anchoring and grounding damages caused by the increased visitation of tour boats and increased physical impacts caused by tourist snorkellers and divers (Kimrua et al. 2004). Overfishing on shallow reefs is also a recognized impact on 70% of coral reef ecosystems of Japan (Kimrua et al. 2004).

Coral reefs of the Japan appear to be recovering from the effects of the mass bleaching that took place in 1998 (Kayanne et al. 2002; Kimrua et al. 2004). The bleaching affected coral communities in 97 municipalities from the Ryukyu Islands to southern Honshu (Fujiwara et al. 2000). In 1998, mass bleaching caused an 8% loss of total coral cover and 40% mortality of acroporids in the Sekisei Lagoon (Fujiwara et al. 2000). The same bleaching event caused a 62% decline in coral cover at Ishigaki Island.

From 2002 to 2003, average coral cover in the Sekisei Lagoon increased from approximately 36 to 46% (Kimrua et al. 2004). During the same time, mean coral cover on reefs of Ishigaki Island increased approximately from 27 to 29%. Further north, corals of Okinawa Island have not recovered from the 1998 bleaching and in 2003 average coral cover was 8.5%, lower than surrounding locations (e.g., Kerama

Islands, 31% coral cover; Fujiwara et al. 2000; Kimrua et al. 2004). As a result of the 1998 bleaching, the number of coral species at Sesoko Island located on the northwestern side of Okinawa Island declined from 81% in 1997 to 40% in 1999 and the live stony and soft cover dropped from 70.5% in 1997 to 10.8% in 1999 (Loya et al. 2001). Branched corals (mostly acroporids) constituted the bulk of the dead corals. Massive and encrusting corals survived the bleaching event (Loya et al. 2001). While coral bleaching occurred in 2001 and 2003 in the Ryukyu Islands, lasting impacts were less than those of the 1998 event (Kimrua et al. 2004).

COTS outbreaks have taken place from the southern Ryukyus to the Izu Islands since the late 1960s and continue today (Kimrua et al. 2004; Yokochi 2004). COTS are probably dispersed by the northward flow of the Kuroshio Current. COTS outbreaks cause mass predation and mortality of corals. The western coast of Okinawa was the first area to be affected by a COTS outbreak. By the end of the 1970s, all corals of Okinawa had been affected. Chronic outbreaks of COTS at Okinawa are compromising the full recovery of corals. During the 1980s, an explosive outbreak of COTS affected the entire Seksei Lagoon and spread to the surrounding area of the Yaeyama Archipelago. By the end of the 1980s, the number of live corals had significantly decreased; this was followed by a rapid decline in the number of COTS. COTS continue to proliferate and consume corals in Japan despite extermination programs that have removed over 10 million COTS. In fact, increased numbers of COTS in Seksei Lagoon recorded in 2003 suggested yet another COTS outbreak (Kimrua et al. 2004; Yokochi 2004).

Outbreaks of *Drupella* at the Izu Islands, Kyushu Island, and the west coast of Shikoku severely impacted corals starting in the late 1970s (Kimrua et al. 2004). From 1995 to 2000, extermination programs at these high-latitude locations yielded collections of up to 200,000 *Drupella* per year. In the southern Ryukyus, outbreaks of *Drupella* have caused less impact on true coral reefs than those caused by COTS (Kimrua et al. 2004).

To promote the recovery of damaged reefs of Okinawa Island, healthy corals are being transplanted to impacted reefs. In addition, aquaculture-raised reef organisms (including crustaceans, mollusks, echinoderms, and fishes) are being released in damaged reef regions. However, the recovery of reefs from bleaching and coral predation is impeded by recurrent red soil runoff and resuspension in the nearshore environment of the Ryukyu Islands and mainland Japan (Kimrua et al. 2004; Omija 2004). Farming, land development, land clearing, and heavy rainfall erodes loose red and gray soil and country rock mudstone (collectively are known as red soil). Red soil-laden terrestrial runoff causes siltation and sedimentation in the nearshore reef habitats smothering corals. Since this red soil remains in the backreef areas, it is periodically resuspended by heavy wave action during typhoons and monsoons. The chronic exposure to red soil pollution causes coral mortality. The reefs in Okinawa, Kohama, Iriomote, and Ishigaki Islands, and the Sekisei Lagoon are all affected by red soil (Kimrua et al. 2004; Omija 2004). The Okinawa Prefecture and Ichigaki City have attempted to prevent red soil pollution by the development of water quality control measures, filtering out red clay from drainage channels, repairing sedimentation ponds, controlling runoff, and stabilizing loose soil with vegetative cover.

Despite multiple efforts to reduce red soil pollution, sedimentation and siltation remain the greatest threats to coral reefs of Japan particularly those located near the mouths of rivers and nearshore fringing coral reefs (Yamazato 1997; Kimrua et al. 2004). While the low salinity of river discharge and storm runoff affect reef development (Coles and Jokiel 1992), red soil pollution potentially accentuates impacts on reefs. West and van Woesik (2001) found that fringing reefs near the mouth of the largest river on Okinawa, the Hija River (catchment of 50.2 km^2; maximum discharge: 43.04 m^3 s^{-1}; average discharge: 0.86 m^3 s^{-1}), have limited stony coral development (11 species; less than 0.2% cover per species) within a 300 m distance of the river and that the degree of reef development was correlated with varying concentrations of suspended particulate matter. A substantially more developed coral community was found 325 m from the river mouth (18 species; coral cover per species ranged from 0.4 to 8.1%) and a typical coral community was found approximately 390 m from the river mouth (13 species; coral cover per species ranged from 0.4 to 18.3%; West and van Woesik 2001).

Coral Communities of the East Japan Study Area

The East Japan study area is adjacent to three main geographical areas of outlying coral communities: the Izu Islands, the Boso Peninsula, and the Izu Peninsula (**Figure 2-10**). The coral communities of the Boso Peninsula and Izu Peninsula are high-latitude outlying coral communities; the stony corals of these communities only accrete minor amounts of calcium carbonate and do not form substantial reefs (Veron 1995, 2000a).

The Izu Islands are found along the 140° E meridian and between 35° and 33° N (**Figure 2-10 A**). Coral communities are documented on Miyakejima Island and Hachijojima Island (Igarashi 2004). Recurring natural disturbances influencing the coral communities at these islands include low winter seawater temperature (13°C) and strong seasonal wave action during monsoons and typhoons. Miyakejima Island is a volcanic island that recently erupted in 2000 causing mudflows and a 20 cm thick accumulation of ash in the reef environment. The nearby Hachijojima Island is also volcanic but it has remained inactive since 1606. Damages to corals caused by the 2000 eruption were preceded by severe impacts caused by terrestrial runoff, coastal construction, and predation by COTS and corallivorous gastropods in the 1970s and 1980s. Following the volcanic eruption of 2000, 12 coral species remained at Miyakejima Island and coral cover was 6.7%. Tabular acroporids, once relatively abundant at Miyakejima Island, were greatly affected by the mudflows and ash deposits. The coral communities of Hachijojima Island were severely affected by coastal construction from the 1960s through the 1980s and compounded the effects of naturally-occurring disturbances (Igarashi 2004).

High-latitude coral communities of the Boso Peninsula (**Figure 2-10 B**) include 32 species of stony corals (Shimoike 2004a). In Tateyama Bay there are 25 stony coral species at a water depth of 10 to 15 m. Stony corals in Tateyama Bay include *Acropora tumida*, *Favia* sp., and *Alveopora japonica* (Shimoike 2004a).

At the tip of the Izu Peninsula, there are 42 stony coral species (Ueno 2004; **Figure 2-10 C**). In Uchiura Bay, there are up to 60 stony coral species within a 5,000 m^2 area 5 to 10 m of water depth. The survival of this high-latitude coral community is governed by temperature, 12°C in February to 28°C in August. Most of this coral community was once composed of *Acropora tumida*. A prolonged exposure to cold water in 1996 and 1997 caused mass coral bleaching and mortality. As a result, live coral cover dropped from 85% to 40%. Grazing damage on corals caused by the sea urchin *Diadema setosum* in Uchiura Bay could further deplete live coral cover. Seasonal shading (December to June) caused by the large brown alga, *Colpomenia sinuosa* could also decrease coral cover (Ueno 2004).

Coral Communities of the West Japan Study Area

The West Japan study area is adjacent to the three main geographical areas of outlying and non-reefal coral communities: Kyushu Island, Osumi Islands, and the Tokara Archipelago (**Figure 2-11**). Coral communities on the west side of the Kyushu Island are mainly located around the Amakusa Islands (including Shimojima Island and Nagashima Island; Nojima 2004a; **Figure 2-11 A**); 98 stony coral species have been documented around the Amakusa Islands. The southern shores of Shimojima Island and those of neighboring small islands support relatively extensive coral communities. Dominant stony corals in this area are *Cyphastrea serailia*, *Acropora solitaryensis*, *Favia speciosa*, *Mycedium elephantotus*, *Favites abdita*, *Porites heronensis*, *Hydnophora exesa*, *Goniastrea australiensis*, and *Psammocora superficialis*. Tabular acroporids are found in water depths less than 10 m and massive corals are found from 10 to 30 m of water depth. This area also contains a rare stony coral, *Acanthastrea amakusensis*. The 1998 bleaching event caused only partial bleaching of corals in this area and all colonies recovered. Some predation on corals by COTS and corallivorous gastropods was reported for this area and an active extermination program is now controlling the occurrence of these coral predators in the Amakusa Islands. In 1991 typhoons caused damages to *A. solitaryensis* in the southern end of Shimojima Island (Nojima 2004a).

Two main land features of the southern end of Kyushu Island are the Satsuma and Osumi peninsulas. These peninsulas are separated by Kagoshima Bay (Nojima 2004b; **Figure 2-11 A**). In Kagoshima Bay,

Sakurajima Island is the most active volcano of Japan. At the tip of the Satsuma and Osumi Peninsulas there are 11 and 23 species of stony corals, respectively. Within Kagoshima Bay, 17 coral stony coral species were recorded off of Sakurajima Island. To the west of the Satsuma Peninsula are the Koshikijima and Uji Islands where high cover of branching and tabulate acroporids (*Acropora hyacinthus*, *A. solitaryensis*, and *A. gemmifera)* was documented in 1990 along the wave-exposed coastlines. Land reclamation that took place after 1990 has impacted these acroporids communities. Further, corals of the Koshikijima and Uji Islands were probably impacted by an outbreak of COTS in the 1990s. A COTS outbreak was also reported for the Sakurajima area (Nojima 2004b).

Approximately 40 stony corals occur along the northeastern coastline of Kyushu Island in the vicinity of Kamae Town (Nojima 2004c; **Figure 2-11 A**). In this area, dominant coral species along the coastline are *Pavona decussata* and *A. tumida*. On Yakata Island, dominant corals are tabular forms of *A. hyachinthus* and *Monitpora* spp. (Nojima 2004c). Further south, in the area of the Shimaurajima Island, a 1991 survey documented some 22 coral species including *A. solitaryensis*, *A. hyachinthus*, and *Turbinaria peltata* and coral cover was estimated at 13% (Nojima 2004d). At the southern end of eastern coast of Kyushu Island along the Nichinan coast and Shibushi Bay, there were 52 stony corals found in 1991. The reefscape in 1991 was dominated by tabular forms of *A. hyacinthus*, *A. solitaryensis*, and *A. gemmifera*. This area was also colonized by *T. peltata* and could be the northern limit of the stony corals, *Merulina ampliata* and *Echinopora lamellosa*. Predation by COTS has not impacted corals in this area. Yet, outbreaks of *Drupella* have impacted corals on the Nichinan coast (Nojima 2004d).

There are true coral reefs along the southern end of the West Japan study area in the Tokara Archipelago and Osumi Islands (Nakai and Nojima 2004; **Figure 2-11 B** and **C**). Tanegashima Island, within the Osumi Islands, marks the northern limit of true coral reefs (Veron 1995). While the northernmost coral reef of Japan is located at Iki Island (Yamano et al. 2001), there are no true corals between Tanegashima Island and Iki Island (Nakai and Nojima 2004). Moreover, the composition of the reefs at Iki Island is very different from that found on reefs south of Tanegashima Island. Coral reefs of the Osumi Islands are mainly found in areas protected from high energy wave exposed environments. On Tanegashima Island and on the north coast of Yakushima Island, well developed reef flats and reef slopes are located on the east side of the island.

The Tokara Archipelago is made up of 12 small islands scattered from north to south over 160 km. Coral reefs are found on Kuchinoshima, Nakanoshima, Hirashima, Kogajyajima, Kodakarajima, and Takarajima Islands (**Figure 2-11 C**). Because of recent volcanic activity, the other islands of the Tokara Archipelago are not surrounded by reefs.

In the Osumi Islands, there are 151 stony coral species at Tanegashima Island, 100 at Yakushima Island, and 68 at Kuchinoerabujima Island (Nakai and Nojima 2004; **Figure 2-11 B**). The 1998 coral bleaching affected 20 to 60% of the coral cover at Tanegashima and Yakushima Islands. There have not been any COTS outbreaks recorded to date in this area. In the Tokara Archipelago, preliminary surveys include a list of 21 dominant species at Kodakarajima and Takarajima (Nakai and Nojima 2004).

Coral Reefs of the Okinawa Study Area

The Okinawa study area surrounds Okinawa Island, the Kerama Islands, islands to the northeast of the Okinawa and Kerama Islands, and the Daito Islands. The Okinawa study area also includes four military training ranges: Ie Shima (air-to-ground range), Tori Shima (air-to-ground range), Irisuna Jima (air-to-ground and ship-to-shore range), and Okino Daito Jiwa (air-to-ground and ship-to-shore range; **Figure 2-12**). All islands found within the Okinawa study area are part of the Ryukyu Islands even though the Daito Islands are roughly 360 km to the west of Okinawa Island. Coral community mapping information is available for the Okinawa and Kerama Islands but not for the training ranges and the Daito Islands.

On Okinawa Island, there are fringing and patch reefs close to shore except on the southeastern end of the island where patch reefs are found several kilometers offshore (Sakai 2004). These offshore patch reefs form barrier-like reefs. There are 340+ stony coral species and eight non-reef building species at

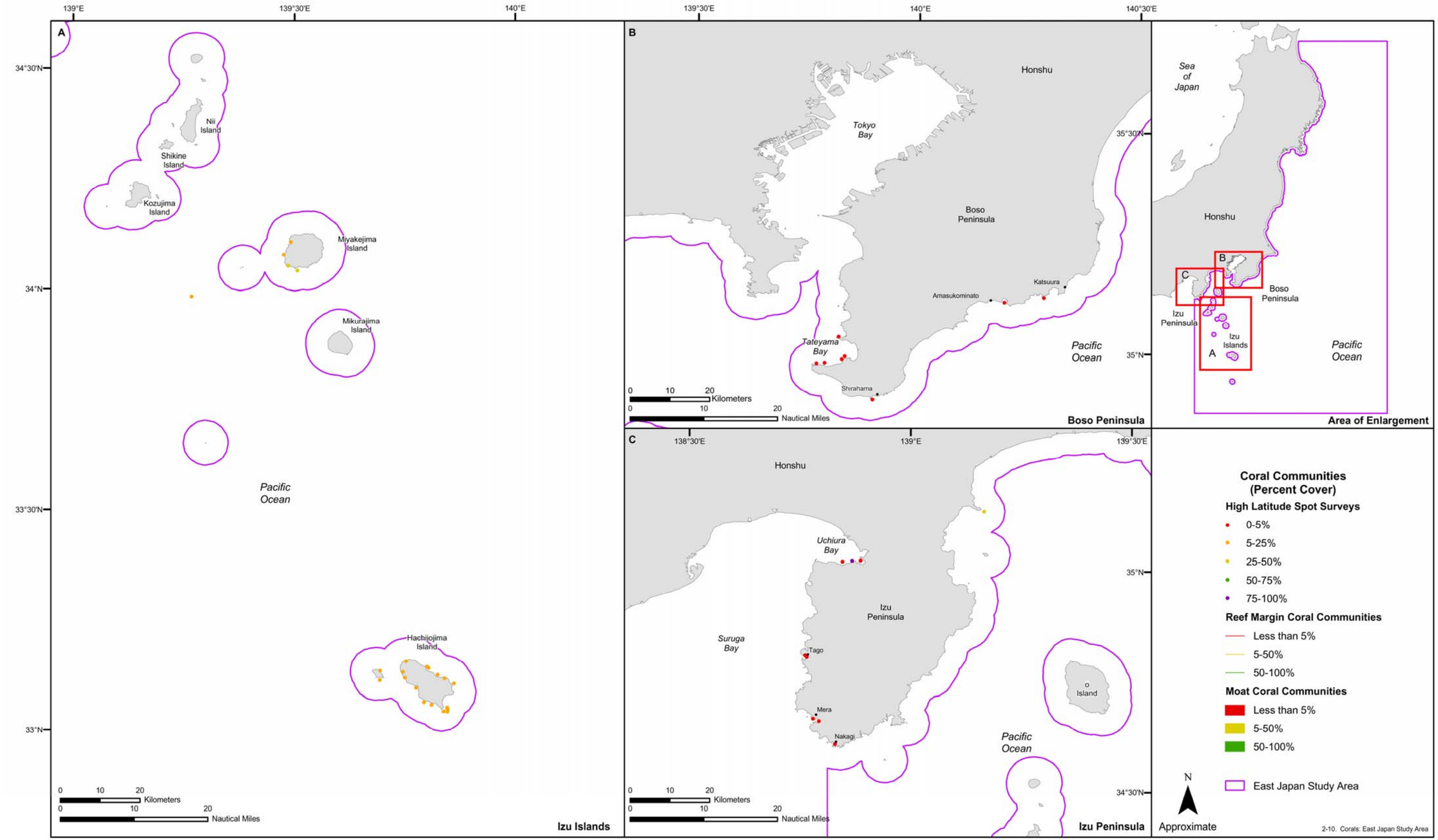

Figure 2-10. Coral reefs of the East Japan study area: (A) Bōsō Peninsula, (B) Izu Peninsula, and (C) Izu Islands. Source maps (scanned): Tsuchiya et al. (2004).

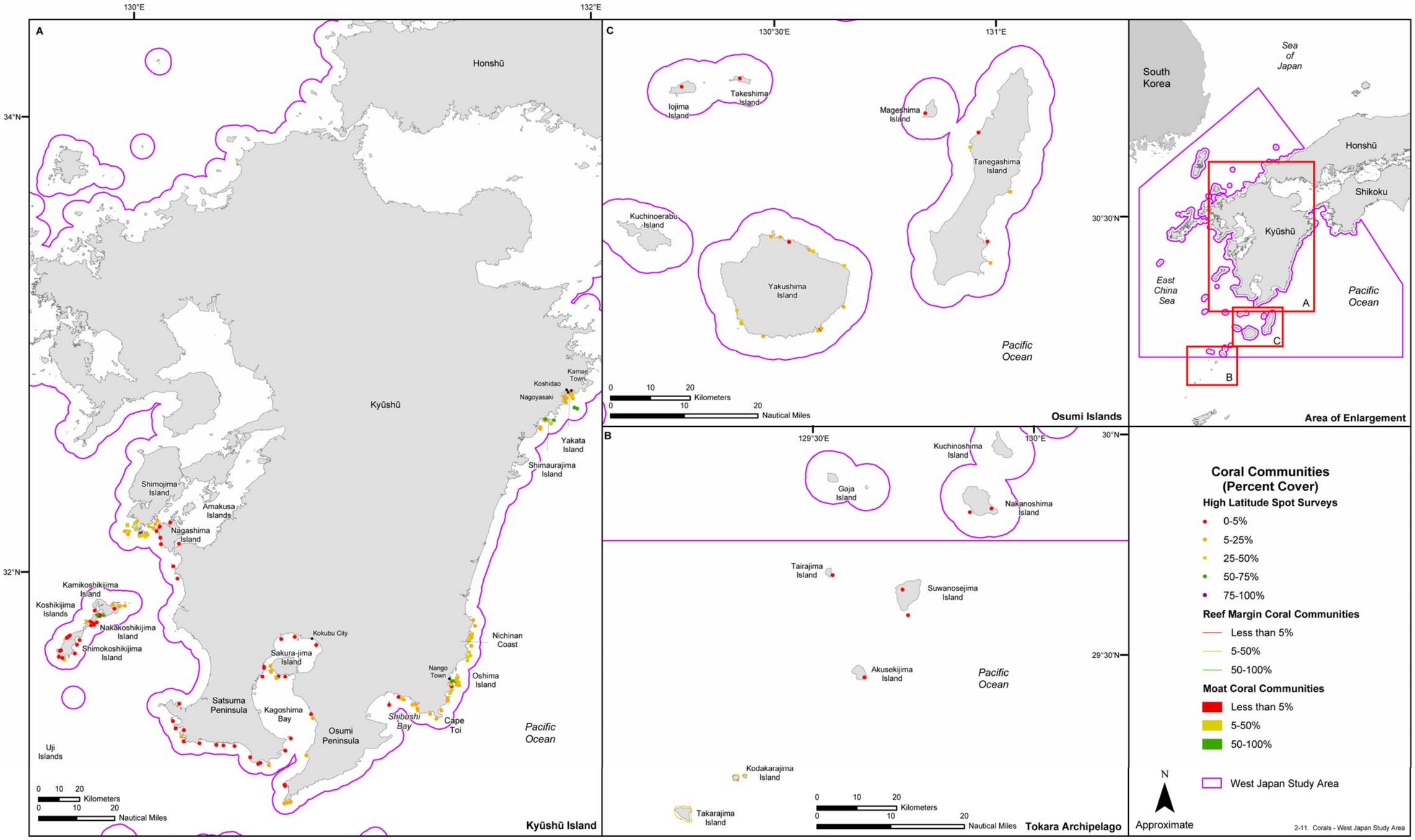

Figure 2-11. Coral reefs of the West Japan study area: (A) Sea of Japan, (B) Kyūshū, and (C) Osumi Islands and Tokara Archipelago. Source maps (scanned): Tsuchiya et al. (2004).

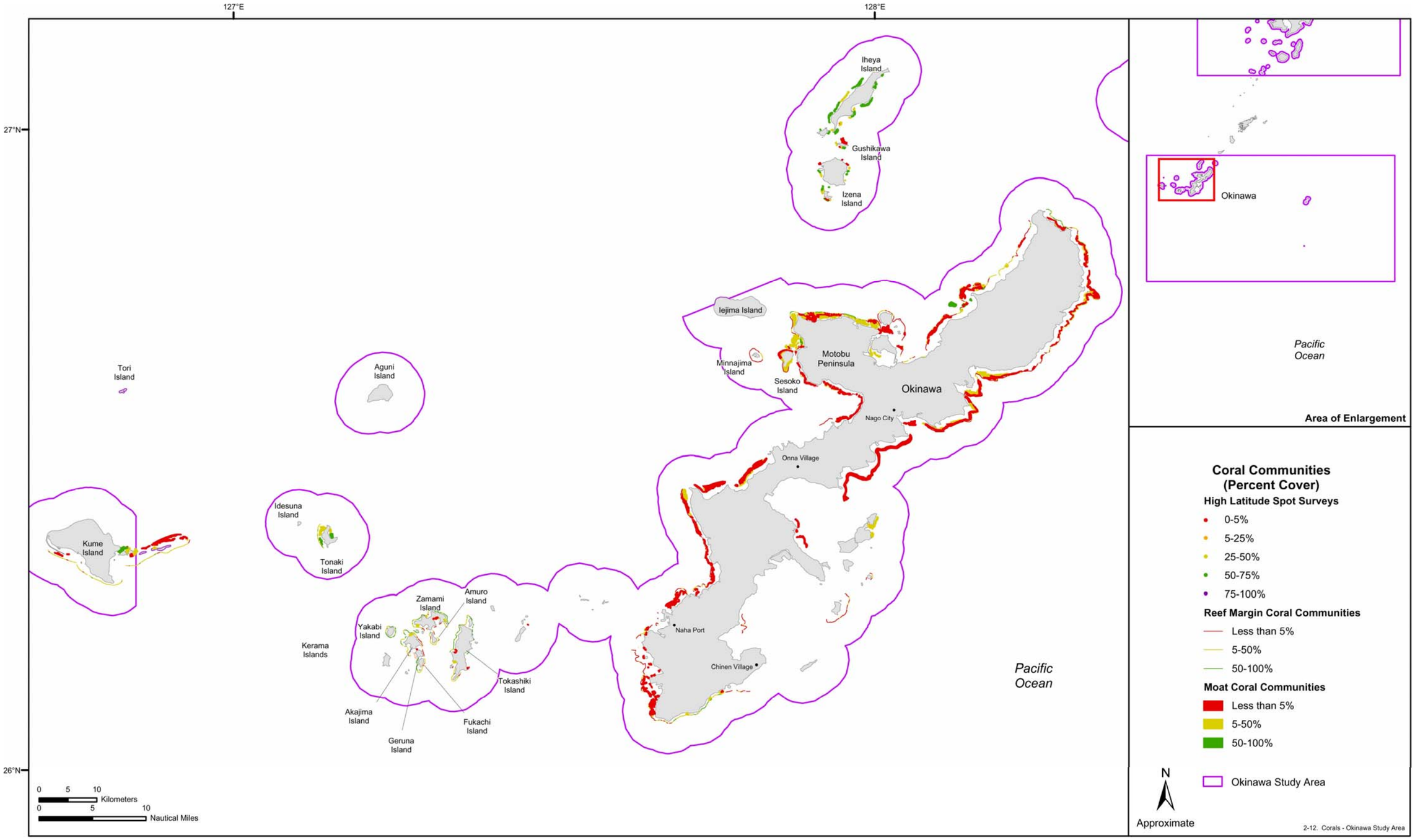

Figure 2-12. Coral reefs of the Okinawa study area: Okinawa Islands. Source maps (scanned): Tsuchiya et al. (2004).

Okinawa. As mentioned earlier, the reefs of Okinawa have been severely impacted by COTS outbreaks starting in the 1970s and by mass coral bleaching in 1998 (refer to Section 2.8.1.1). Coral cover on Okinawa reefs may have declined as much as 85% following the 1998-bleaching event (Loya et al. 2001). The current average coral cover on Okinawa is approximately less than 5% (Sakai 2004). Human-induced impacts on reefs include red soil pollution and eutrophication caused by agricultural runoff and raw sewage. (Sakai 2004).

Reefs of the Kerama Islands, 20 to 40 km west of the southern end of Okinawa Island, (**Figure 2-12**) harbor 248 species of stony corals (Iwao 2004). These reefs act as an important source of coral larvae for downstream reefs including the heavily impacted reefs of Okinawa Island. COTS outbreaks and the 1998-bleaching event have greatly affected the once abundant coral reefs at the Zamami and Akajima Islands. In 2001, average coral cover on Akajima Island ranged from 30 to 53%. Coral reefs remain in good condition on the west coast of Tokashiki Island where branching and tabular acroporids constitute more than 90% of the live coral cover. Coral development is restricted on the south and east coasts of Tokashiki Island due to strong wave action. Patch reefs made of acroporids and soft corals are found along northeastern coast of Tokashiki Island. On the northwest coast of Tokashiki Island, the 1998-bleaching event and COTS predation have greatly diminished what were once the best developed *Acropora* communities of the Kerama Islands (Iwao 2004).

Other reefs within the Okinawa study area are located off the northwestern end of Okinawa (Iheya Island, Gushikawa Island, and Izena Island) and to the northwest of the Kerama Islands (Aguni Island, Tonaki Island, and Kume Island; **Figure 2-12**). Aside from Aguni Island, reefs were surveyed at each of these islands in 1994 (Shimoike 2004b). Further reef assessments were conducted at Kume Island from 1999 to 2003 and in 2001 at Gushikawa Island (Shimoike 2004b).

In 1994 at Iheya Island, the coral cover ranged from less than 5% to more than 50% (Shimoike 2004b). Fringing reefs at Iheya Island contained substantial amounts of branching *Montipora* cover in the moat and tabular *Acropora* on the reef crest. In 2001, surveys of the northern coast of Gushikawa Island reported coral communities made of tabular and branching acroporids with 64% cover in 2 to 3 m water depth and 92% cover in 9 to 10 m water depth. On Tonaki Island, the coral cover of roughly two-thirds of the reefs surveyed ranged from 5 to 50%. Coral cover on the remaining third exceeded 50%. Branching colonies of *Porites* and *Montipora* were found in the moat. During the 1999 reef survey at Kume Island, patch reefs made of large tabular acroporids were found at the eastern end of the reef system. Reef slopes of these same reefs were in good condition. The reef slopes were primarily colonized by branching *Acropora formosa* and large colonies of *Favia*, *Pocillopora*, *Merulina ampliata*, and *Diploastrea heliopora (*Shimoike 2004b).

The Daito Islands (Kitadaito Island, Minamidaito Island, and Okidaito Island or Okino Daito Jiwa) are located 360 km west of the Ryukyu Islands and are part of the Okinawa study area. Kitadaito Island (30.6 km^2) and Minamidaito Island (12.7 km^2) are the main islands and are 7 km apart. Okidaito Island is located 150 km to the south of the main Daito Islands and is smaller than either Kitadaito or Minamidaito Island (Nonaka 2004). There are poorly developed reefs around the main islands. In 2001, average coral cover was 10%. Sixty-two species of stony corals occurred within 10 to 20 m of water depth. Dominant stony corals were of the *Porites* and *Pocillopora* genera. All species observed at the Daito Islands occur on the Okinawa and Kerama Islands. Compared with the reefs of Okinawa and Kerama Islands, the reefs of the Daito Islands harbored less acroporids and faviids and more *Astreopora* colonies. While reefs of the main Daito Islands have not been impacted by outbreaks of COTS, the 1998-bleaching event caused severe impacts. Coastal development and red soil pollution are also affecting the reefs in this area (Nonaka 2004).

<u>Nearshore Okinawa Study Area: Ie Shima range, Tori Shima range, Idesuna Jima range, Okino Daito Jiwa range</u>—While no formal surveys are available for the coral reefs surrounding the Ie Shima range, the composition and condition of reefs are probably similar to those of the nearby Okinawa Island. Recurrent COTS predation on corals since the 1970s and the 1998-bleaching event have probably altered the structure of the reefs resulting in a reef similar to what is currently found at Sesoko Island (Loya et al. 2001; Kimrua et al. 2004; refer to Section 2.8.1.1). Naturally-induced impacts have probably decreased

coral cover to less than 10% and removed branching acroporids (Loya et al. 2001). Most likely, only massive and encrusting corals occur on the reefs of Ie Shima. Physical impacts caused by air-to-ground training exercises have potentially added to the naturally-occurring impacts. Quantitative surveys of coral reefs at Ie Shima are needed to assess their current status.

Tori Shima is located 28 km north of Kume Island. No formal surveys of coral reefs have been conducted at Tori Shima. The structure of coral reefs around this island might be similar to the reefs at Kume Island. Quantitative surveys of coral reefs at Tori Shima are needed to assess their current status.

Idesuna Jima is located 4 km northeast of Tonaki Island. No formal surveys of coral reefs have been conducted at Idesuna Jima Island. Considering its proximity to Tonaki Island and not accounting for potential military training impacts on corals, coral cover on fringing reefs at possibly range from 5 to 50%. Quantitative surveys of coral reefs at Idesuna Jima are needed to assess their current status.

Okino Daito Jiwa or Okidaito Island is located 150 km south of the main Daito Islands. No formal surveys of coral reefs have been conducted at this site. Considering their southerly location and relative proximity to the southern Ryukyu Islands, reefs of Okidaito Island are possibly similar to the stony coral species at the Miyako Archipelago (Kajiwara and Matsumoto 2004). Quantitative surveys of coral reefs of Okidaito Island are needed to assess their current status.

2.7.2.1.6 Deep-Slope Terrace

A deep-slope terrace is an area with a near-vertical gradient from shore to the insular shelf or shelf break and is typically represented by a very narrow range of depths. The deep-slope terrace habitat is highly stratified as a result of depth zonation and provides high relief and extensive shelter for biota (fish, invertebrates, and macroflora) in the form of holes, crevices, and overhangs (Hixon and Beets 1993; Friedlander and Parrish 1998). Planktivorous fishes are very abundant along deep-slope terrace habitats where the larger diurnal species are found at deeper depths because their major prey is most accessible there. Transient species (i.e., piscivores or planktivores) are generally found at the shallower depths, presumably positioned to forage (Friedlander and Parish 1998).

Two important characteristics of deep-slope terrace habitats result in a region of abundant biota, biomass, and diversity. First, depth and high relief produce regions of habitat zonation as a function of depth. Second, rugosity (roughness or irregularity of a solid surface) provides important microhabitat niches for the resident biota and grazers (Friedlander and Parish 1998). Deep-slope terraces are located offshore of almost every island in the Japanese Islands; however, the distribution and location of these important habitats is poorly known.

2.7.2.1.7 Islets

In the Japanese Islands, offshore islets (small islands) are abundant; however, they are more common around the larger and older islands. Volcanic islets were initially connected to the larger, main islands before subsidence and erosion separated them; limestone islets are lithified dunes or relict reefs (Maragos 1998). Topographically, rocky beaches, sea cliffs, and some small white sand beaches characterize islets (Maragos 1998). They are typically located on sloping rocky submarine topography and have occasional caves covered with live coral and coralline algae. Generally, an islet is similar in composition/substrate to the adjacent island from which it was formed. For example, if an islet is located offshore from sandy beaches, sand substrates and beaches are more common (Maragos 1998).

Islet habitats support abundant biota that is comparable to the benthic communities that are found on fringing and barrier reefs (Maragos 1998). Human impact is generally minor, allowing islets to provide sheltered habitat for coral communities, important nesting beaches and rookeries for seabirds (Maragos 2000), and many of the beaches may be used for hauling out by sea turtles and seals (Maragos 1998).

2.7.3 Water Column

The water column makes up the largest habitat on earth but its biology is the least known and explored (Nybakken 1997). The water column can be divided into two primary areas: neritic (waters overlying continental shelf from the subtidal zone to a depth of approximately 200 m) and pelagic (open ocean; Nybakken 1997). Neritic waters can be described as the euphotic zone (light zone) and pelagic waters have a euphotic zone and an aphotic (no light) zone. Each zone is distinct in its characteristics of water movement, quantity of sunlight, temperature, pressure, availability of food, oxygen, and salinity. In the euphotic zone, sunlight reaches approximately 100 to 200 m below the water's surface and provides the energy for photosynthesis. In the aphotic zone, is a stable environment that is characterized by cold temperatures, extreme water pressure, very little sunlight, and less abundant biota. In the mesopelagic zone (the transition area between the light and dark zone) deep-living zooplankton and nekton undergo diurnal vertical migration, moving upwards into the light zone at night to feed on the abundant phytoplankton and downwards during the day to avoid predation.

2.7.3.1 Neritic Ocean

The neritic zone consists of waters overlying the continental shelf up to depths of approximately 200 m; these waters are directly associated with coasts surrounding all of the Japanese Islands. Neritic waters in the Japanese Islands receive discharges and effluents from the land, have high oxygen concentrations, and are exposed to swells, waves, and surf (Chave and Malahoff 1998; Maragos 1998). In addition, neritic waters support the majority of the oceanic photosynthetic plants including phytoplankton and floating alga (*Sargassum* and others; Maragos 1998).

2.7.3.2 Pelagic Ocean

The pelagic zone encompasses open ocean waters beyond the neritic zone (Maragos 1998). Pelagic environments in the Japanese Islands extend from the surface to water depths of more than 6,000 m, are usually pristine, are exposed to swells, currents, and winds from all directions, have deep eddies, and experience an oxygen minimum zone at 600 m depth causing a dramatic shift in deep-sea fauna (Chave and Malahoff 1998; Maragos 1998, 2000). The most important pelagic habitat in Japan is the confluence region of the Kuroshio and the Oyashio currents off the northeast of Honshu; this area is one of the most productive pelagic environments in the world (Simard 1995).

Pelagic biota lives in the water column and has little or no association with the benthos. The organisms living in pelagic communities may be drifters (plankton) or swimmers (nekton). Plankton drift with the ocean currents and can be plant-like organisms (phytoplankton) or animals (zooplankton). Phytoplankton float in the photic zone and provide food for zooplankton and some other larger marine animals. Zooplankton (70% are crustaceans) live throughout the water column; they may float about freely throughout their lives or spend only the early part of their lives as plankton. Some zooplankton become strong swimmers and join the nekton as adults; others settle to the seafloor or attach to the seafloor and become part of the benthos (DoN 2001a). Phytoplankton are the only common plants in the pelagic zone; whereas, there are many animals that associate with pelagic habitat including zooplankton, fishes, and squids. Marine mammals (e.g., endangered humpback whale), sea turtles, and seabirds may forage in pelagic habitat (Maragos 1998).

2.7.4 Deep Benthic

The deep benthic habitat and its associated boundary layer have long been perceived as a remote and exotic environment; however, it is largely coupled with the physical and biological dynamics of the upper ocean. Significant physical, chemical, and biological interactions occur between the upper ocean and the deep benthos on time scales of days to millennia (Smith 1991). Benthic communities live within, upon, or are associated with the ocean bottom and rely on the input of food or falling detritus from the surface waters. In general, benthic biomass decreases and diversity increases with increasing distance from shore. Deep benthic fauna living on or in the benthos grow more slowly, live longer, and have smaller broods than animals living in shallow waters.

The bottom substrate of the deep-sea is typically covered with silts, clays, and fine sediments; however, there is the occasional hardbottom substrate offered by seamounts and guyots. The type of bottom substrate governs the abundance and diversity of deep-sea organisms because there are distinct differences between hardbottom and softbottom communities. Abundance and diversity are generally higher on hard, irregular substrates than on smooth, hard surfaces. However, in softbottom habitats, it has recently been shown that although abundance decreases with depth, diversity increases with depth (Gage 1996). This rich species diversity can be attributed to both biological and physical mechanisms. Biological mechanisms include competition, predation, larval recruitment, and biological structuring of the substrate; physical mechanisms include nutrients, light, waves, and currents.

In the Japanese Islands, very productive deep benthic microhabitats and communities extend to depths of more than 6,000 m and include rocky outcroppings (e.g., seamounts and guyots), deep-sea corals, chemosynthetic communities, and abyssal plains (Maragos 2000). The bottom sediments covering the sea floor in much of the Japanese Islands are volcanic or marine in nature (carbonate sediments from coral reefs; Eldredge 1983). Basalt and carbonate rock substrates are common on the insular slopes; whereas, sediments (e.g., sands, gravels, and pebbles) are prevalent along the flattened surfaces of the abyssal plain. This habitat supports many fish, invertebrates, and deep-sea corals including the rare, depleted precious corals (e.g., gold and pink coral, *Corallium*); however, living plants are rare or absent on the deep sea floor because of the lack of light (Maragos 1998).

Benthic fish and crustacean communities rapidly decrease in abundance and diversity with depth. With increasing depth, light intensity declines and eventually algae and plants are unable to survive. Benthic algae and reef-building corals also decrease in abundance and size with increasing depth. Below 100 m only a few, if any, small, stony corals are found (Chave and Malahoff 1998). Thus, there is a change in community structure with depth; at greater depths animals, including non-reef-building corals, obtain their food through suspension feeding. Suspension-feeders capture food particles from the plankton or detritus suspended in the water column. This method of food capture is efficient in the deep-sea benthic environment because it takes advantage of the swift currents that commonly flow over ridges, banks, and pinnacles on the seafloor (Chave and Malahoff 1998).

2.7.4.1 Abyssal Plain

The abyssal plain extends from bordering continental rises to mid-oceanic ridges; it is a relatively flat expanse of sea floor that is 3,000 to 5,000 m below sea level. Abyssal plains are covered with fine particles that constantly rain down from the overlying water column. These particles, fine, clay-sized sediments and the remains of marine life, drift slowly downward filling in depressions on the irregular rocky ocean floor. They have accumulated to make up the 5,000 m thick sediment bed that constitutes the largest portion of the ocean floor (O'Dor 2003). Because of this thick layer of sediment, abyssal plains are among the smoothest surfaces on the planet, with less than five feet of vertical variation for every mile. The abyssal plain is regarded as the true ocean floor and is characterized by extremely cold water, no light, and extremely diverse marine inhabitants (e.g., deep sea isopods, polychaetes, worms, sponges, crustaceans, and sea stars) that are adapted to near freezing temperatures and immense pressure (Wilson 1976; Beaulieu 2001a, b; O'Dor 2003; Cunha and Wilson 2003). The deep sea is one of the largest and least explored ecosystems on Earth and is a major reservoir of biodiversity and evolutionary novelty.

Extensive areas of abyssal plains exist in the Japan and Okinawa Complexes OPAREA. These areas vary in water depth, sediment type, organic content, terrestrial influence, oceanographic conditions, and contaminant inputs (Grassel 1991). As a result, the soft substrate benthic assemblages of the region are complex and diverse. In general, organism abundance decreases and diversity increases with depth.

2.7.4.2 Deep-sea Coral Communities

Deep-sea coral communities consist of sessile stony corals (Order Scleractinia), soft corals (Sub Class Octocorallia), black corals (Order Antipatharia), and lace corals (Order Stylasterina; Freiwald et al. 2004; Hain and Corcoran 2004; Roberts and Hirshfield 2004). These corals and hydrocorals can build very

large 3D structures in deep-sea environments that are comparable in size and complexity with coral reefs that occur in shallow tropical waters. Scleractinia are the primary builders of cold-water coral reefs (Hain and Corcoran 2004). For the purposes of this MRA the deep-sea environment extends from the shelf break (150 to 200 m) to the abyssal plain (4,000+ m).

True deep-sea coral communities live in complete darkness, in temperatures as low as 4°C and in waters as deep as 6,000 m (CoRIS 2003); therefore, they are also known as "cold-water coral reefs" (Freiwald et al. 2004). Deep-sea corals lack the symbiotic zooxanthellae found in tropical reef-building corals. Thus, deep-sea corals do not benefit from a carbon supply provided by symbiotic algae but rather survive solely on suspension feeding. The biological diversity of deep-sea corals is high; from an economic perspective, this diversity creates valuable habitat for several commercially fished species (Gass 2003). However, the full ecological importance/value of deep-sea coral habitat is still unknown (Freiwald et al. 2004). Deep-sea corals are home to thousands of species including sponges, polychaetes (or bristle worms), crustaceans (crabs and lobsters), mollusks (clams, snails, octopuses), echinoderms (starfish, sea urchins, brittle stars, feather stars), bryozoans (sea moss), and fish (Freiwald et al. 2004). Cold-water coral reefs occur worldwide, including Japan (Freiwald et al. 2004; Hain and Corcoran 2004).

Much like shallow-water corals, deep-sea corals are fragile and slow growing: thus, they are vulnerable to human-induced physical impacts (Freiwald et al. 2004; Roberts and Hirshfield 2003). Deep-sea coral communities have existed for millions of years. Living communities can be 8,000 years old. The size of these communities can range from patches of small solitary colonies to massive reef structures (mounds, banks, and forests) and from several meters to tens of kilometers across and a meter to tens of meters high (Tucker and Wright 1990; Cairns 1994). The growth rate of some deep-water coral reefs (*Lophelia pertusa*) ranges from 4 to 25 millimeters per year (mm/yr) (Roberts and Hirshfield 2004). Trawls and heavy fishing gear used by commercial fishing has caused severe damages to deep-sea coral communities in many areas of the world. Deep-sea coral communities are also susceptible to physical impacts caused by fishing (e.g., bottom trawling), oil- and gas-related activities, cable laying, seabed aggregate extraction, shipping activities, the disposal of waste in deep waters, coral exploitation, other mineral exploration, and increased atmospheric CO_2 (Gass 2003; Freiwald et al. 2004; Roberts and Hirshfield 2004). It may take decades to centuries for damaged cold-water coral reefs to recover (Freiwald et al. 2004; Roberts and Hirshfield 2004).

Deep-sea coral communities are typically found from the edge of the continental shelf to the continental rise, on banks, and on seamounts (Freiwald et al. 2004). The shelf break traverses each of the Japan OPAREAs and seamounts are found in East Japan OPAREA and the Okinawa OPAREA. There are approximately 70 deep-water seamounts (that are non-active volcanoes) in the Shikoku Basin, including the Kinan Seamounts, seamounts located on the Kyūshū-Palau Ridge, those on the Amami Plateau, and those located close to the Ryukyu Trench (**Figure 2-3**). Four of the seamounts are within the East Japan OPAREA (**Figure 2-3**). Two of the seamounts are located near the Japan Trench in water depths ranging from 6,000 to 7,000 m. One seamount is found on the Isu-Ogasawara (Izu-Bonin) Trench at a depth of 7,000 m and one other seamount is located near the southeastern corner of the East Japan OPAREA in a water depth of 2,000 m. In the Okinanwa OPAREA, five seamounts are found on the Amami Plateau (5,000 m water depth) and two along the Ryukyu trench (4,000 to 5,000 m water depth; **Figure 2-3**). Hence, cold-water coral reefs potentially surround mainland Japan and the Japanese islands (**Figure 2-2**), and potentially occur on the numerous seamounts located off Japan (**Figure 2-3**). The majority of the Japanese seamounts are clustered which probably has a positive influence on the abundance, diversity, and density of deep-water corals found on the seamounts. Isolated seamounts are known to support less dense and less diverse coral populations than clustered seamounts (Grigg et al. 1987).

Based on surveys conducted in the northwest Pacific, deep-water scleractinians potentially found off Japan include *Lophelia pertusa*, *Madrepora oculata, Goniocorella dumosa* (Freiwald et al. 2004; Hain and Corcoran 2004). *L. pertusa* is a common deep-sea reef habitat builder (Freiwald et al. 2004). Individual branched colonies of *L. pertusa* can be several meters across and contiguous colonies of *L. pertusa* can form long swaths of deep-sea reef habitat. *L. pertusa* has been found in water depths ranging from 39 to 3,383 m. *M. oculata* also forms large branching colonies but they tend to be more fragile than those of *L. pertusa*. The documented depth range of *M. oculata* is 55 to 1,950 m. *G. dumosa* has been found within

the 88 to 1,488 m depth range, with concentrated populations from 300 to 400 m. These stony corals may occur both on the continental slope and seamounts (Freiwald et al. 2004).

Cold-water soft corals usually occur with the deep-water stony corals (Freiwald et al. 2004). On high latitude deep-water reefs, the abundance of cold-water soft corals is often greater than that of stony corals producing what are known as "octocoral gardens." These have been observed on Japanese seamounts (Freiwald et al. 2004). Octocoral gardens are typically dominated by gorgonians including precious corals, sea fans, and bamboo corals. Surveys conducted in water depths ranging from 120 to 300 m on the continental slope of Okinawa and Kume Islands (Okinawa OPAREA), and Miyako, Ishigaki, and Iriomote Islands (southern Ryukyu Islands, Yaeyama Archipelago) recorded abundant fan-shaped gorgonians and antipatharians on rocky slopes (Yamazato 1972). Other sessile organisms also found on hard substrates of the continental slope of the islands were sponges, lace corals, true soft corals (including *Siphonogorgia* sp.), anemones, non-reef building corals, bryozoans, bivalves, polychaetes, crustaceans, crinoids, and ophiuroids (Yamazato 1972).

Cold-water black and lace corals, which include precious corals, also form branched reef structures. Deep-water precious corals that occur in Japanese waters may include species that occur in the Hawaiian Island: black corals (*Antipathes grandis*, *A. dichotoma*); pink corals (*Corallium secundum*, *C. regale*); gold coral (*Gerardia* spp.); and bamboo corals (*Keratoisis nuda*, *Acanella* spp., *Lepidisis olapa*; Grigg 1974, 2002). Precious corals of the North and South Pacific are exploited in water depths ranging from 100 to 400 m and from 1,000 to 1,500 m (Hain and Corcoran 2004).

2.7.4.3 Deep Rocky Substrate

In the Japanese Islands, rocky areas (e.g., rocky outcroppings, rubble, talus, vertical wall, and seamounts) are interspersed with soft substrate such as sand or gravel. Characteristically, on deep hard substrate, patterns of species distribution and abundance are related to substrate relief. Abundances of most species increase with water depth due to the lack of sediments from terrestrial sources and increased nutrients of the open ocean (Thompson et al. 1993). These habitats are challenging to study because they usually lie beyond the range of SCUBA and mechanical sampling is difficult. In general, most deep hardbottom species are suspension feeders; sponges, corals, gorgonians, anemones, ophiuroids, and crinoids are all common suspension feeders found in these areas. In the Hawaiian Islands, the macrophyte and macrofauna assemblages associated with seamount habitats have been extensively studied, this information is detailed below.

2.7.4.3.1 Seamounts

Seamounts are found in all oceans but are more numerous in the Pacific Ocean, with over 2,000 having been identified (Thompson et al. 1993). Seamounts occur wherever magma has risen to the sea floor and erupted. Lava or magma that has erupted and hardened them forms new sea-floor. Seamount topography is a striking difference to the surrounding flat, sediment covered abyssal plain and the effects seamounts can impart on local ocean circulation are complex and poorly understood (Rogers 1994). Very little research has been conducted on seamounts; they are among the least understood habitats in the ocean-basins and are even more poorly understood than abyssal plains (Rogers 1994). Seamounts provide a unique habitat for both deep-sea and shallow water organisms due to the large ranges of depth, hard substrate, steep vertical gradients, cryptic topography, variable currents, clear oceanic waters, and geographic isolation that characterize seamount habitats (Rogers 1994). Thus, seamounts are capable of supporting a wide range of organisms (Wilson and Kaufman 1987). The most common invertebrates found on seamounts worldwide are cnidarians and the most common fishes are scorpaenids and morids (Wilson and Kaufman 1987). The abundant and diverse benthic fauna consists of a wide array of sponges (including large brilliant-yellow barrel sponges that have been know to support and harbor organism communities), coral (including large gorgonians and huge golden coral seafans), brittlestars, crinoids, clams, seastars, polychaete worms, crabs, tunicates, sea urchins, sea cucumbers, and octopi (Rogers 1994).

Seamounts attract significant commercial species as a result of the aggregation of exploitable populations of benthopelagic animals. A rich and diverse benthic fauna with a high degree of endemism exists on seamounts. Levels of endemism among 850 macro- and megafaunal species could be as high as 29 to 34% (Johnston and Santillo 2004). Thus, seamounts can function ecologically as island groups or chains, leading to localized species distributions with apparent speciation. Seamount-associated fish are in general very long-lived species and are thus extremely vulnerable to overexploitation. Some seamount fish and benthos are already known to have been seriously impacted by fishing activities (Johnston and Santillo 2004).

2.7.4.4 Chemosynthetic Ecosystem

In a normal marine ecosystem, the primary producers (e.g., phytoplankton and seagrasses) produce energy through photosynthesis (a photosynthetic ecosystem). In environments rich in methane and sulfides, chemosynthetic bacteria, sulfur-oxidizing bacteria, methane-oxidizing bacteria, and sulfide-reducing bacteria, create the energy that can be used by the organisms in the environment (a chemosynthetic ecosystem; JAMSTEC 1998). Chemosynthetic communities are a significant source of biological productivity on the deep-sea floor. In some locations, vast fields of hydrothermal vents can support benthic communities (Hessler and Lonsdale 1991; Hashimoto et al. 1995; Galkin 1997). In other locations, gas hydrates in the sediments support extensive chemosynthetic communities (Fisher et al. 2000; Lanoil et al. 2001; Reed et al. 2002). Bacterial communities undergo chemosynthesis to utilize chemicals released from the seafloor to create energy. Little is known regarding the significance of bacterial productivity on the ocean floor on a global scale.

Chemosynthetic habitats are formed by a variety of geological and biological processes on continental margins. The biota of geological reducing habitats (e.g., vents, hydrates, and seeps) can be compared with those of biogenic origin (due to large organic falls) to fully understand the biogeography and evolution of chemosynthetic communities (Smith et al. 2003). Natural whale falls, hydrothermal vents and seeps, and wood falls provide specific habitat duration and faunal community. Each of these chemosynthetic habitats appears to foster a characteristic fauna; sulfide-rich whale falls (50 to 80 year habitat duration) harbor a highly diverse assemblage (100 to 200 species; Smith et al. 2003). Wood falls harbor low-diversity assemblages that include wood-boring bivalves and polychaetes. At present, whale falls are known to share 11 species with hydrothermal vents and 20 species with cold seeps (Smith et al. 2003).

Chemosynthesis-based communities, despite their location in the deep sea, have high biomasses maintained by chemosynthetic bacterial production (Fujikura et al. 2002). Chemosynthetic communities occur in environments rich in methane and sulfides. There are three types of chemosynthetic communities: hydrothermal vent communities formed around hot vents, cold-seep communities formed around cold vents, and whale fall and wood fall communities formed around decaying whale carcasses and wood debris (JAMSTEC 1998). Hydrothermal vent communities are found across plate formation regions and at submarine volcanoes where volcanic activity is high. Cold-seep communities are found in subduction zones where plates collide where cold interstitial water seeps out due to compression. Cold seep and whale fall communities exist in temperatures close to that of the surrounding seawater. Chemosynthetic communities are also found around whale carcasses and grain carriers that have sunk to the deep-sea floor where the benthic fauna are sustained by the methane and sulfides produced during the decay of fat and grain (JAMSTEC 1998).

All chemosynthetic systems depend on the primary productivity of chemolithoautotrophic bacteria to survive (Nybakken 2001). Of the benthic fauna associated with chemosynthetic ecosystems, some house these symbiotic chemosynthetic bacteria inside their bodies to obtain essential nutrients (JAMSTEC 1998). In general, chemosynthetic communities around the Japanese Islands are characterized by tubeworms, giant white clams, mussels, gastropods, and sponges (Kojima 2002). The chemosynthetic communities found in the Japan and Okinawa Complexes OPAREA and vicinity are shown in **Figure 2-13**.

2.7.4.4.1 Cold Seep

Cold seep communities depend upon chemolithoautotrophic production associated with the emission of reducing chemicals from "cold" hypersaline brines or other hydrocarbon seeps such as methane hydrates (Nybakken 2001). Chemolithoautotrophic bacteria oxidize the reduced chemicals to form organic matter from carbon dioxide. In cold seeps rich in methane such as brine pools or methane hydrates, *Bathymodiolus* (mussels) are the dominant genera. *Bathymodiolus* have a methane-based symbiosis where intracellular bacteria oxidize the methane and provide energy for the mussels and the bacteria (Nybakken 2001). Chemosynthetic communities display an astonishing assemblage of megafauna forming a unique association for the deep sea (Sibuet and Olu 1998). Of the 211 species known from seeps at present, most are endemic and only 13 species are shared between vents and seeps (Sibuet and Olu 1998). Diversity at cold seeps is generally higher than at vents. This is possibly due to the fact that vent systems depend primarily on the utilization of sulfides for energy whereas cold seep systems can utilize sulfides and/or methane (Nybakken 2001). In addition, seeps are stable for a much longer period of time than vents. Also, cold seeps have a greater depth distribution than vents, displaying a decrease in species richness with depth (Nybakken 2001).

Internationally, more than 20 cold seeps have been found on the seafloor of the continental margin within the last decades (Tsunogai et al. 2002). In these continental margin cold seeps, methane gas-hydrates (clathrates) are the most likely methane source (Tsunogai et al. 2002). Hydrates are crystalline solids comprising water molecules linked by hydrogen bonds in a tight polyhedral cage structure. Methane (or other hydrocarbon) molecules are packed closely together in the hydrate lattice. They are stable at depths below 200 m and at temperatures below 10 to 15°C (Gornitz and Fung 1994). A cubic meter of hydrate yields about 160 cubic meters (m^3) of methane at standard temperature and pressure and about 0.87 m^3 of water (Masutani and Coffin 2001). Methane hydrates are found in high-pressure, moderate temperature regimes in ocean sediments and low-temperature Arctic permafrost zones. Estimates of the total volume of hydrocarbon gas locked in hydrate deposits worldwide range widely from about 2.8×10^{15} to 7.6×10^{18} m^3 (Masutani and Coffin 2001). Significant hydrate deposits have been identified worldwide in undersea basins on continental margins; sediment layers in deep ocean basins also may contain large deposits of methane hydrates but these areas have not yet been thoroughly explored. Methane hydrates may exercise a profound effect on the global climate if the carbon sequestered in these solids is released into the environment by commercial exploitation of the fuel or through destabilization and outgassing induced by ocean warming (Masutani and Coffin 2001). Methane hydrates have the potential to form on the continental margins of the Japan and Okinawa Complexes OPAREA where the water is cold and the pressure is sufficient to support hydrate formation.

In recent years, many seep communities have been reported in tectonically active as well as passive areas (Hashimoto et al. 1989). As of 2002, 24 cold seep areas have been found in areas including the eastern and western Pacific, the Gulf of Mexico, the eastern and western Atlantic, and the Mediterranean (Fujikura et al. 2002). The following details the cold seep areas in the Japan and Okinawa Complexes OPAREA and vicinity. **Table 2-3** lists the depth and biota for each cold seep community shown in **Figure 2-13**.

Sagami Bay—Cold seep communities are found at five locations in Sagami Bay: off shore Hatsushima, Okinoyama banks, Sagami knoll, Misaki knoll, and Miura knoll (JAMSTEC 1998). Geologically and seismologically, the western part of Sagami Bay is one of the most active areas around Japan (Hashimoto et al. 1989). The first chemosynthetic community from Japanese waters was discovered in 1984 in the cold seep area off Hatsushima, Sagami Bay (Kojima 2002). The giant clam (*Calyptogena soyoae*) dominates this site with a biomass of approximately 20 kilograms per square meter (kg/m^2), this biomass is about three orders of magnitude greater than that of usual nearshore benthic communities of the similar depths (Hashimoto et al. 1989; JAMSTEC 1998).

Nankai Trough—In the Nankai trough, many cold seep areas are distributed within a relatively narrow area and most likely there are many undiscovered seep sites (Kojima 2002). In all communities, *Calyptogena* is the dominant genera with at least seven confirmed species (JAMSTEC 1998).

Table 2-3. Cold seep communities in the Japan and Okinawa Complexes OPAREA and vicinity (Kojima 2002).

Region	Depth	Biota
Sagami Bay		*Calyptogena soyoae* and *C. okutanii* (vesicomyid clams), *Bathymodiolius* sp. (mussels), and *Lamellibranchia* sp. (vestimentiferans)
Sagami Bay (off Hatsushima)	830-1,230 m	
Okinoyama Bank	1,180-1,450 m	
Sagami Knoll	1,390-1,460 m	
Suruga Bay		
Suruga Bay (off Toi)	1,490-1,500 m	*C. fausta*
Nankai Trough		
Kanesu-no-Se Bank	290-330 m	*Mesolinga soliditesta* (lucinid bivalve) and three vestimentiferan species (*Lamellibranchia satsuma*, *L.* sp. L1, and *Escarpia* sp. E1
Muroto Knoll	600 m	*C. solidissima*
Ashizuri Knoll	600 m	*C. solidissima*
Daini Tenryu Knoll	590-610 m	*C. solidissima* and *L.* sp. L1
Ryuyo Submarine Canyon	1,090-1,100 m	*C. okutanii*, *C. nankaiensis*, *L.* sp. L1, and *E.* sp. E1
Omaezaki Spur	1,140-1,200 m	*B. aduloides*, *L.* sp. L1, and *E.* sp. E1
Yukie Ridge	1,940-2,180 m	*C. fausta, C. similaris, and L.* sp. L2
Tokai Thrust	2,080 m	*C. similaris*
Tenryu Submarine Canyon	3,760-3,840 m	*C. nautilei*, *C. laubieri*, and *C. kaikoi*
Daisan Tenryu Submarine Canyon	3,760 m	*C. tsubasa*
Daiichi Minami Muroto Knoll	3,620 m	*C. nautilei*
Muroto Point	3,210-3,270 m	*L.* sp. L2, *C. nautilei*, and *C. tsubasa*, and *C.* sp. (unidentified)
Zenisu Ridge	3,300 m	*C. tsubasa*, *C.* sp. (unidentified)
Japan and Kurile Trenches		
Daiichi Kashima Seamount	5,640-5,700 m	*C. phaseoliformis*
Sanriku Escarpment (upper)	5,650-6,000 m	*C. phaseoliformis*
Kurile Trench	5,100-5,800 m	*C. phaseoliformis*
Sanriku Escarpment (lower)	6,180-6,470 m	*C. phaseoliformis*, *C. fossajaponica*, *Parathyasira kairei*, and *Acharax johnsoni*
Sanriku Escarpment (on the foot)	6,600-6,800 m	*C. fossajaponica*
Japan Trench (axis)	7,330-7,430 m	*C. phaseoliformis* and *Maorithyas hadalis* (thyasirid clam)
Japan Sea		Low biodiversity
Okushiri Ridge	3,110 m	White bacterial mats, small snails, shrimps, sea cucumbers, and anemones
Ryukyu Islands		
Kuroshima Knoll	680-810 m	*C. solidissima*, *Vesicomyia kuroshimaena* (bivalves), *B.* sp., *L.* sp. L1, and *L.* sp. L5
Kikaijima Island	1,440-1,650 m	*C. similaris* and *E.* sp. E2
Hokkaido Island (Pacific)		
Hiroo Submarine Canyon	1,200 m	*C.* spp. (undescribed)
Sea of Okhotsk		
Paramushir Island	750-800 m	*C. soyoae*, *Conchocera bisecta* (thyasirid bivalve), and Ampharetidae (polychaetes)

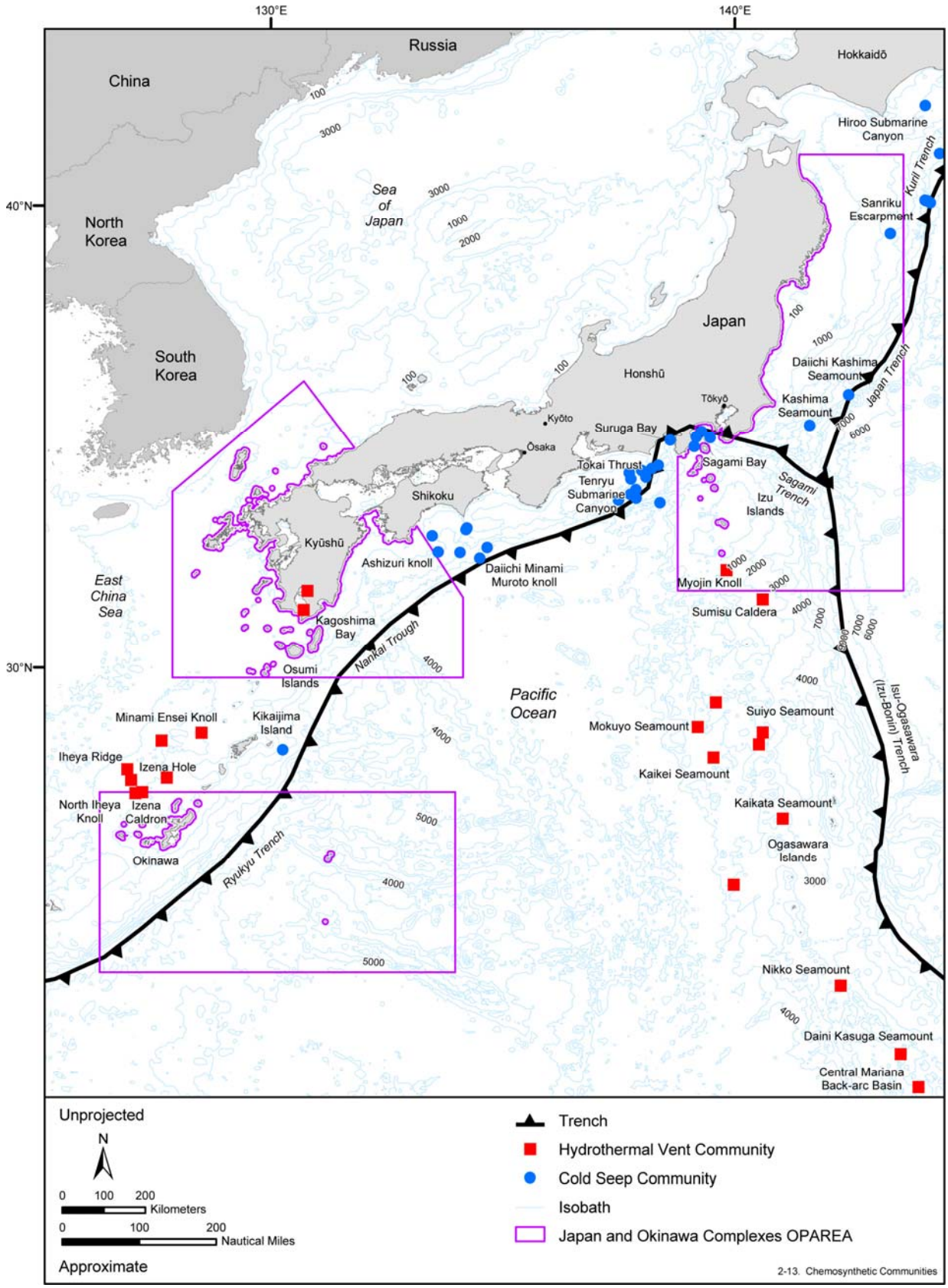

Figure 2-13. Distribution of chemosynthetic communities in the Japan and Okinawa Complexes OPAREA and vicinity including cold seeps and hydrothermal vent habitats. Source data: Kojima (2202). Source maps (scanned): Isozaki et al. (1990), JAMSTEC (1998), and Seno (1999).

Japan and Kurile Trenches—The deepest chemosynthetic communities in the world are associated with the subduction of the Pacific Plate beneath the Northern American Plate (JAMSTEC 1998; Fujikura et al. 2002; Kojima 2002). This seep area is distributed between depths from 5,225 and 7,430 m on the landward slope of the Japan Trench and the communities are dominated by *Calyptogena phaseoliformis* (Fujikura et al. 2002).

Japan Sea—These chemosynthetic communities are characterized by low biodiversity; this has been attributed to severe anoxic conditions during the middle period of the last glacial period (Kojima 2002). The cold seep community at the Okushiri Ridge consists primarily of bacterial mats and gastropods. This cold seep was probably formed in 1940 by the Shakotan earthquake (M = 7.5) (JAMSTEC 1998).

2.7.4.4.2 Hydrothermal Vents

Deep-sea hydrothermal vents occur in areas where new crust is being formed, near mid-ocean ridge systems both in fore-arc and back-arc regions (Humphris 1995). Seawater permeating through the crust and upper mantle is superheated by hot basalt and is chemically altered to form hydrothermal fluids. These less dense hydrothermal fluids rise through the network of fissures in the newly-formed seafloor (Humphris 1995; McMullin et al. 2000). Water temperature can be quite variable in vent systems and vent macrofauna are distributed with respect to water temperature (Nybakken 2001). Water that rises directly to the surface can exit at 350°C, forming “black smoker” chimneys. No animals are associated with these extreme temperatures (Nybakken 2001). The temperature of the hydrothermal fluid is 200° to 400°C in areas of focused flows and less than 200°C in areas of diffuse flow. Most vent communities survive in water that below 30°C (Nybakken 2001).

Hydrothermal vent fluids are rich in chemicals as the heated seawater reacts with the molten rock, causing metals and other minerals to dissolve into solution. The fluids are typically poor in oxygen content and contain toxic reduced chemicals including hydrogen sulfide and heavy metals (McMullin et al. 2000). As the hot hydrothermal fluids come in contact with the much cooler seawater overlying the vent, heavy metals precipitate out and accumulate, forming chimneys and mounds. In complete darkness, high ambient pressure, and extreme thermal and chemical conditions of the deep sea, metazoans (multicellular animals) are able to adapt and colonize these sites to form luxuriant chemosynthetic communities. Chemosynthetic bacteria use the reduced chemicals of the hydrothermal fluid (primarily hydrogen sulfide) as an energy source for carbon fixation and generate chemosynthetic-based primary production. Because vent water is anoxic, bacteria must be capable of utilizing oxygen from the surrounding ambient water to produce organic material. The sulfide released from the vent waters is rapidly oxidized and sulfide does not persist in the water column far from the vent site. Organisms that require both oxygen and sulfide have to live in the small area where vent water and ambient water begin to interact (Nybakken 2001).

Metazoan communities associated with these chemosynthetic environments are typically characterized by high biomass and low diversity. Metazoans can either consume chemosynthetic bacteria or form symbiotic relationships. For example, the vestimentiferan, *Riftia pachyptila*, and the giant clam, *Calyptogena magnifica*, both house symbiotic chemosynthetic bacteria in their tissues (Nybakken 2001). In both cases, metazoans use numerous morphological, physiological, and behavioral adaptations to flourish in this extreme deep-sea environment. Hydrothermal vents have a lifespan that is measured in decades. Some inactive vent systems have been observed with the remains of vent macrofauna communities; this suggests that vent organisms have life spans that are also in tens of years (Nybakken 2001).

Since 1979, more than 200 seafloor vent sites have been located (Wheat et al. 2000). These plumes are of fundamental importance to the composition of the oceans. Hot springs support a unique ecosystem of microorganisms and animals that do not need sunlight to survive: some 500 new species have been found associated with vent systems (Wheat et al. 2000). The following paragraphs detail the hydrothermal vent areas in the Japan and Okinawa Complexes OPAREA and vicinity. **Table 2-4** lists the depth and biota for each hydrothermal vent community shown in **Figure 2-13**.

Table 2-4. Hydrothermal vent communities in the Japan and Okinawa Complexes OPAREA and vicinity (Kojima 2002).

Region	Depth	Biota
Okinawa Trough		
Izena Hole	1,310-1,580 m	Galatheid crabs, lithodid crabs, shrimps, vestimentiferans, *Bathymodiolus platiformis*, and *Calyptogena* sp. (bivalves)
Minami_Ensei Knoll	640-710 m	*C. solidissima* (vesicomyid bivalve), *B. japonicus* and *B. aduloides* (mussels), and vestimentiferans (unidentified)
Iheya Ridge	1,400-1,430 m	*C. okutanii*, *Lamellibrachia* sp. L1, *Escarpia* sp. E2, and *Alaysia* sp. A2
North Iheya Knoll	1,050 m	*C. okutanii*, *C. nankaiensis*, *L.* sp. L1, *A.* sp. A2, *B. japonicus*, and *B. platifrons*
Hatoma Knoll	1,470-1,520 m	*B. platiformis*, *Shinkaia crosnieri* (galatheid crab), and *Alvinocaris longirostrus* (bresiliid shrimp)
Kagoshima Bay		
Kagoshima Bay	82 m	*L. satsuma* and a single species of *nautiliniellid* polychaete
Izu-Ogasawara-arc		
Myojin Knoll	1,290 m	*B. septemdierum*, *Austinograea yunohana* (bythograeid crab), and garatheid crabs
Sumisu Caldera	690 m	*B.* sp. tube worms (possibly vestimentiferans), and gastropods
Suiyo Seamount	1,370 m	*B. septemdierum*, *A. yunohana*, *Alvinocaris* sp., and scale worms
Mokuyo Seamount	1,260 m	*Alvinocaris* sp., *Lebbeus, B. septemdierum*, and vestimentiferans
Kaikata Seamount	430 m	*A. yunohana*, *B.* sp., and *Symphurus* sp. (tonguefish)
Nikko Seamount	430 m	Vestimentiferans (dense colonies including *L. satsuma*), a tonguefish, a bythograeid crab, *Neolepas* sp. (a primitive barnacle), *B.* sp., and *A. yunohana*
Mariana Trough		
Daini Kasuga Seamount	386 m	Three vent endemic animals: a bythograeid crab, a primitive barnacle, and a tonguefish. Also, a microscopic structure of bacteria mats.

Okinawa Trough—In the Okinawa Trough, hydrothermal vent communities can be found at Minami Ensei knoll, Iheya ridge, and at Izena caldron. At Minami Ensei knoll, there are approximately 10 chimneys with maximum temperatures exceeding 270°C. *Bathymodiolus japonicus* is dominant. White thread-type bacteria mats cover the seafloor surrounding the chimneys (JAMSTEC 1998). In a study by Hashimoto et al. (1995), at least 48 species of vent metazoans were collected and six additional species were observed at the Minami-Ensei Knoll. Of these 54 species, 18 are new species. In this study, it was noted that organisms segregate according to the hydrothermal habitat. For example, at the Minami Ensei Knoll, the hydrothermal habitat can be categorized into two types: 1) rocky or exposed field with active, superheated vents and/or low-temperature vents; and 2) sedimentary or covered field with slow, low-temperature (approximately 5 to 10°C higher than the ambient seawater) hydrothermal fluid flow from the sandy bottom (Hashimoto et al. 1995).

Kagoshima Bay—In Kagoshima Bay, gases are emitted from the seafloor with high concentrations of carbon dioxide, methane, and hydrogen sulfide. The dominant metazoan at this site is *Lamellibrachia*

satsuma with biomasses that exceed 9 kilograms per cubic meter (kg/m^3). *Lamellibrachia* are relatively insensitive to pressure and temperature and these are the shallowest communities on earth (JAMSTEC 1998).

Izu-Ogasawara Shoto region—In this region there are many submarine volcanoes and hydrothermal communities that can be found at the Suiyo seamount, Mokuyo seamount, Kaikei seamount, and the Nikko seamount. The Suiyo seamount is characterized by a field of chimneys that emit 300°C fluids surrounded by dense communities of *Bathymodiolus septemdierum* (JAMSTEC 1998).

2.7.4.4.3 Whale Falls

The chemosynthetic communities associated with whale falls are probably the least known of the chemosynthetic ecosystems. Studies of whale falls has revealed that chemolithoautotrophic bacteria reside in, on, and around whale falls (Nybakken 2001). Sulfides are produced by anaerobic bacteria that are decomposing the large lipid content inside of the whale bones. The sulfide diffuses out of the bone and provides the energy source for the chemolithoautotrophic bacteria (Nybakken 2001). Whale carcasses on the seafloor support a high abundance of organisms commonly found near seeps, vents, and other deep-sea hard substrates (Baco and Smith 2003). It has been estimated that at any given time there may be in excess of 500,000 sulfide-rich whale skeletons on the deep-sea floor (Smith and Baco 2003). Whale falls promote high species diversity by providing hard substrates for settling, organic enrichment, and free sulfides on a typically organic-poor, sediment covered sea floor (Bennett et al. 1994; Butman et al. 1995; Smith and Baco 2003); these whale falls can support productive communities of chemosynthetic organisms for decades. The falls of large whales (30 to 160t adult body weight) yield massive pulses of labile organic matter to the deep-sea floor (Smith and Baco 2003).

Whale falls are intense point sources of organic enrichment on the deep-sea floor; decay of the whale fall passes through three successional stages. At less than 1.5 months whale falls have largely intact carcasses with soft tissue; at this stage predominantly hagfish, sleeper sharks, and *lysianassic* amphipods scavenge the whale fall. Carcasses at the seafloor for 4 to 18 months still attract hagfish but are essentially stripped of soft tissue; at this stage the whale falls primarily support invertebrate opportunists on bones and in organically enriched sediments. Organic-rich bones and sediments characterize the “enrichment opportunist” stage approximately 4 to 24 months after carcass arrival on the seafloor. The bones of carcasses at the seafloor for 4.5 to >15 years are colonized by chemoautotrophic microbial mats and macrofaunal invertebrates including some taxa known from vents and seeps such as *vesicomyid* clams, *bathymodiolin* mussels, and *vestimentiferan* polychaetes (Baco and Smith 2003). During all stages, whale falls harbor a number of potentially endemic species (Dahlgren 2004).

Although whales have been much reduced throughout the world’s oceans, Smith (1992) estimates that such sulfide-rich whale falls may have an average spacing of one per 25 km in the North Pacific and may give credence to the hypothesis that such falls may be the stepping stones that permit the sulfide-based communities to disperse over vast distances between the vent systems (Nybakken 2001). Near Japan, a whale fall community was discovered in 1992 near the top of the Torishima seamount at 4,037 m during a dive by the DSV *Shinkai* 6500, Japan. This whale fall is colonized by *Munidopsis* (galatheid crabs), *Chaetopteridaes* (polychaetes), *Mytilidae* (mussels), *Buccinidae* (gastropods), echinoderms, sea anemones, and unidentifiable tube worms (Naganuma et al. 1996; JAMSTEC 1998; Kojima 2002).

2.7.5 Artificial Habitat

Artificial habitats (shipwrecks, artificial reefs, jetties, pontoons, docks, and other man-made structures) are physical alterations to the naturally-occurring marine environment. In addition to artificial structures intentionally or accidentally placed on the seafloor, FADs are suspended in the water column and anchored on the seafloor to attract fish. FADs have come to refer to a floating object physically placed in the water column solely intended to attract fish (Klima and Wickham 1971; Bohnsack et al. 1991, Blue Water 2002). Artificial structures provide a substrate upon which a marine community can develop (Fager 1971). Navigational, meteorological, and oceanographic buoys suspended in the water column potentially function like artificial habitats. Epibenthic organisms will settle on artificial substrates (including algae,

sponges, corals, barnacles, anemones, and hydroids) to eventually provide a biotope suitable for large motile invertebrates (e.g., starfish, lobster, crabs) and demersal and pelagic fishes (Fager 1971; Bohnsack et al. 1991).

2.7.5.1 Artificial Reefs

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

The material chosen for construction could influence benthic community development. Concrete has been recommended for artificial reef construction because community development is most similar to coral; it is durable in seawater and it can be shaped to specification.

In Japan, a structure was constructed in 1987 to encourage upwelling for the enhancement of the fisheries ecosystem in this area. It is a man-made structure of 10 m height and 20 m width that was set at 50 m water depth to induce upwelling at the eastern part of the Bungo Channel, the Seto Inland Sea, Japan. After the placement of this upwelling structure, the nutrients, concentration of chl *a*, and biomass of zooplankton increased (Yanagi and Nakajima 1991).

2.7.5.2 Oil and Gas Platforms

Although Japan has oil resources, specifically in the East China Sea, information concerning the placement and quantity of oil and gas platforms is limited. However, it is known that Japan contains almost no oil reserves of its own (59 million barrels of proven oil reserves; EIA 2004). Approximately 97% of Japan's natural gas is imported but it is the world's third largest oil consumer (after the U.S. and China). Japan has approximately 0.04 trillion m^3 in proven natural gas reserves; although in the seafloor surrounding the Japanese Islands there is likely much more (EIA 2004).

Oil and gas structures are comprised of a latticework superstructure of pilings, beams, and pipes; support diverse fish and invertebrate populations; and are considered *de facto* artificial reefs (Helvey 2002). Mussels (*Mytilus* spp.) dislodged during the superstructure removal form large shell mounds accentuating bottom complexity and are considered part of the platform's ecosystem. Oil and gas structures and their surrounding mussel mounds appear to function as an important nursery habitat (Love et al. 2000, 2003).

2.7.5.3 Shipwrecks

Japan played a major role in World War II (WWII); therefore the islands are littered with shipwrecks that serve as artificial reefs and dive sites. These shipwrecks provide substrate for attachment for many benthic macrofauna and macroflora; this, in turn, provides important habitat. On the other hand, the groundings of ships can also create numerous hazards for navigation or the environment including the formation of large scars through seagrass beds or coral reefs, blockage of entry into ports or harbors, and the release of engine oil and fuel into the surrounding waters (NOAA 2004). The massive numbers and location of shipwrecks in the Japan and Okinawa Complexes OPAREA and vicinity are shown in **Figure 2-14**.

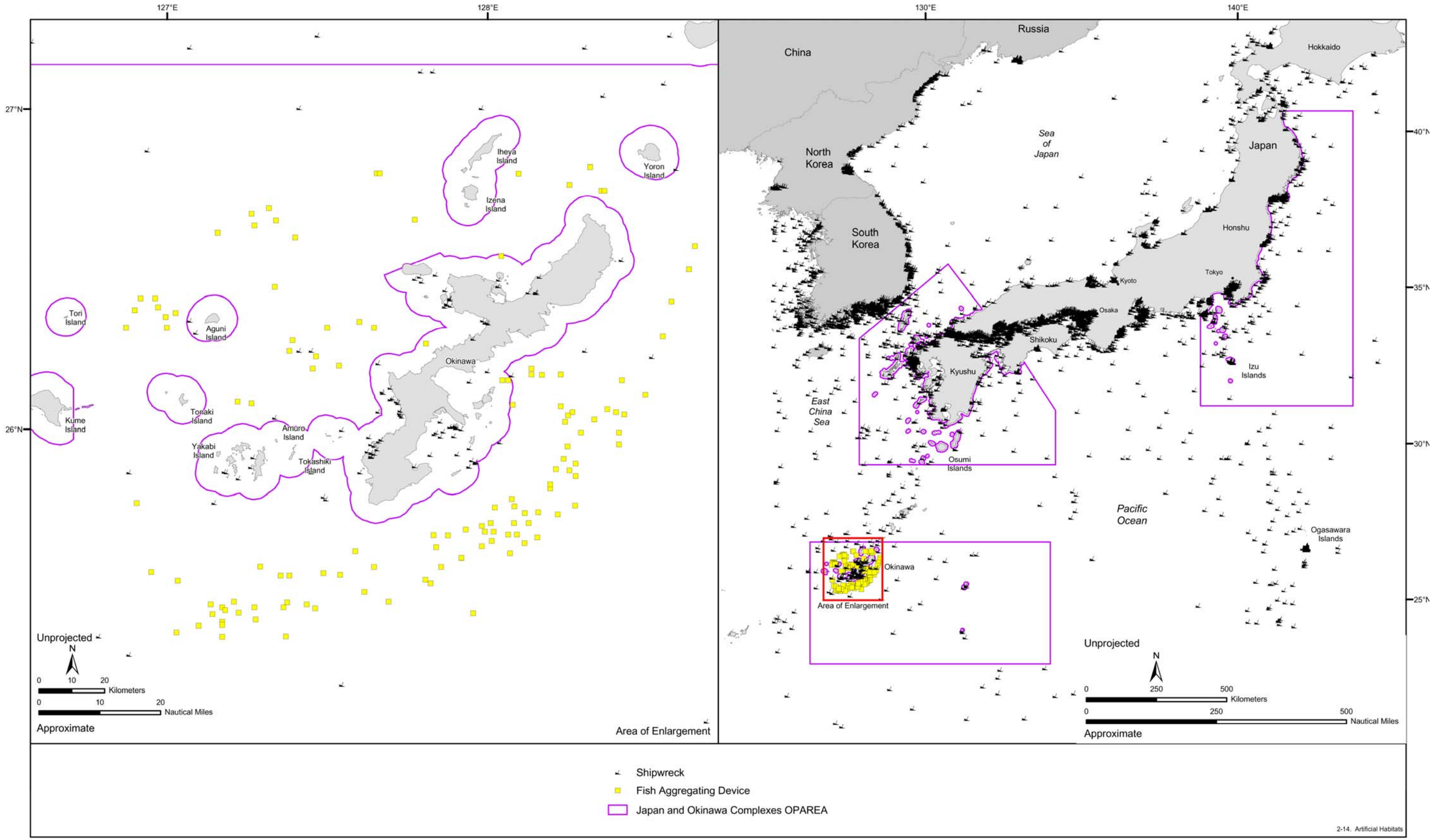

Figure 2-14. Artificial habitats of the Japan and Okinawa Complexes OPAREA including shipwrecks for the entire area and FADs for Okinawa Island only. Source data: Veridian Corporation (2001). Source map (scanned): Kakuma (1996).

2.7.5.4 Fish Aggregating Devices

It has long been known that pelagic fishes will aggregate to floating objects like logs, nets, and other debris. However, these objects drift around and may only be occasionally encountered by lucky fishermen. Researchers have found that anchoring a buoy or platform in the open ocean will also attract and hold pelagic fishes; although, whether the fish are attracted to the anchored FADs for the same reasons they associate with natural drifting objects is not yet known. Using acoustic transmitters, data loggers attached to some FAD moorings monitor the long-term movement patterns of tunas returning to the FADs (Sea Grant 2005). These studies have found that tunas tagged around seamounts behave very similarly to tunas tagged around FADs. It is thought that maybe the FAD serves the same function as a seamount, providing a point of reference for the tuna (Sea Grant 2005).

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

Surface FADs anchored using a catenary mooring method have an average life expectancy of about 3 to 4 years depending on sea and weather conditions. Subsurface FADs tend to last longer (5 to 6 years) because of decreased tugging on the mooring line and are less likely to be run over by ships. However, because they are beneath the surface, they tend to be harder for fishermen to locate (Sea Grant 2005).

In the Japan and Okinawa Complexes OPAREA and vicinity, FADs are located along virtually every coastline. FADs are also commonly placed in more offshore sites to create aggregation areas for more pelagic open ocean fishes. However, there is limited information regarding the location of FADs throughout the Japanese Islands. **Figure 2-14** shows the locations of FADs around the main island of Okinawa only. In 1995, the Okinawa Marine Zone Fisheries Regulation Committee deployed 177 FADs around Okinawa (Kakuma 1996). These FADs were placed less than a mile from each other and have supplied fisherman areas of high fish abundance and aggregation. One of the most important species in the Okinawan FAD catch is yellowfin tuna (Kakuma 1996).

2.8 LITERATURE CITED

Akimichi, T. 2004. Inappropriate activities around coral reefs. Pages 69-76 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

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

Anonymous. 1999. Animals and plants: Mangrove trees. Okinawa Times. Accessed 18 August 2005. http://www.okinawatimes.co.jp/eng/ryukyu/ryu7_12.html.

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

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

ARS (Artificial Reef Subcommittee). 1997. Guidelines for marine artificial reef materials. FWS Grant Agreement No. GS-96. Ocean Springs, Mississippi: Gulf States Marine Fisheries Commission. 118 pp.

Aruga, Y., Y. Yokohama, and M. Nakanishi. 1968. Primary productivity studies in February-March in the northwestern Pacific off Japan. Journal of the Oceanographical Society of Japan 21(6):275-280.

Atkinson, L.P., J.O. Blanton, C. McClain, T.N. Lee, M. Takahashi, T. Ishimaru, and J. Ishizaka. 1987. Observations of upwelling around the Izu Peninsula, Japan: May 1982. Journal of the Oceanographical Society of Japan 43:89-103.

Ayukai, T., and H. Hattori. 1992. Production and downward flux of zooplankton fecal pellets in the anticyclonic gyre off Shikoku, Japan. Oceanologica Acta 15(2):163-172.
Baco, A.R., and C.R. Smith. 2003. High species richness in deep-sea chemoautotrophic whale skeleton communities. Marine Ecology Progress Series 260:109-114.
Bangs, N.L., T.H. Shipley, S.P.S. Gulick, G.F. Moore, S. Kuromoto, and Y. Nakamura. 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 F.P. Chavez. 1983. Biological consequences of El Niño. Science 222:1203-1210.
Beaulieu, S.E. 2001a. Colonization of habitat islands in the deep sea: Recruitment to glass sponge stalks. Deep-Sea Research I 48:1121-1137.
Beaulieu, S.E. 2001b. Life on glass houses: Sponge talk communities in the deep sea. Marine Biology 138:803-817.
Bennett, B.A., C.R. Smith, B. Glaser, and H.L. Maybaum. 1994. Faunal community structure of a chemoautotrophic assemblage on whale bones in the deep northeast Pacific Ocean. Marine Ecology Progress Series 108:205-223.
Bertness, M.D. 1999. The ecology of Atlantic shorelines. Sunderland, Massachusetts: Sinauer Associates, Inc.
Bingham, F.M., T. Suga, and K. Hanawa. 1992. Comparison of upper ocean thermal conditions in the western North Pacific between two pentads: 1938-42 and 1978-82. Journal of Oceanography 48:405-425.
Blue Water. 2002. Fatal attraction. Accessed 30 March 2004. http://www.bluewatermag.com.au/dec02feature2.asp.
Bohnsack, J.A., D.L. Johnson, and R.F. Ambrose. 1991. Ecology of artificial reef habitats and fishes. Pages 61-107 in W. Seaman, Jr. and L.M. Sprague, eds. Artificial habitats for marine and freshwater fisheries. San Diego: Academic Press.
Boulègue, J., E.L. Benedetti, D. Dron, A. Mariotti, and R. Letolle. 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.
Brouns, J.J.W.M., and F.M.L. Heijs. 1986. Production and biomass of the seagrass *Enhalus acoroides* (L.f.) royle and its epiphytes. Aquatic Botany 25:21-45.
Butman, C.A., J.T. Carlton, and S.R. Palumbi. 1995. Whaling effects on deep-sea biodiversity. Conservation Biology 9(2):462-464.
Byrne, D.E., D.M. Davis, and L.R. Sykes. 1988. Loci and maximum size of thrust earthquakes and the mechanics of the shallow region of subduction zones. Tectonics 7(4):833-857.
Cairns, S.D. 1994. Scleractinia of the temperate North Pacific. Smithsonian Contributions to Zoology No. 557. Washington, D.C.
Cannon, G.A. 1966. Tropical waters in the western Pacific Ocean, August-September 1957. Deep-Sea Research 13:1139-1148.
Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. A volunteer's handbook for monitoring New England salt marshes. Commonwealth of Massachusetts, Office of Coastal Zone Management.
Chan, J.C.L. 1985. Tropical cyclone activity in the northwest Pacific in relation to the El Niño/Southern Oscillation phenomenon. Monthly Weather Review 113:599-606.
Chan, J.C.L. 2000. Tropical cyclone activity over the western North Pacific associated with El Niño and La Niña events. Journal of Climate 13:2960-2972.
Chang, W-b. and L-s. Fang. 2004. Temporal and spatial variations in the species composition, distribution, and abundance of copepods in Kaohsiung Harbor, Taiwan. Zoological Studies 43(2):454-463.
Chanson, H. 2002. Whirlpools. Experiencing Naruto whirlpools. IAHR/AIRH Newsletter 2 vol. 19 (Supplement to JHR 40(2)):17,28-29.
Chave, E.H. and A. Malahoff. 1998. In deeper waters: Photographic studies of Hawaiian deep-sea habitats and life-forms. Honolulu: University of Hawai'i Press.
Chen, T-C., S-P. Weng, N. Yamazaki, and S. Kiehne. 1998. Interannual variation in the tropical cyclone formation over the western North Pacific. Monthly Weather Review 126:1080-1090.

Chess, J.R. and E.S. Hobson. 1997. Benthic invertebrates of four southern California marine habitats prior to onset of ocean warming in 1976, with lists of fish predators. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFSC-243. La Jolla, California: Southwest Fisheries Science Center. 113 pp.

Chiang, K-P., F-K. Shiah, and G-C. Gong. 1997. Distribution of summer diatom assemblages in and around a local upwelling in the East China Sea northeast of Taiwan. Botanical Bulletin of Academia Sinica 38:121-128.

Chikuni, S. 1985. The fish resources of the northwest Pacific. FAO Fisheries Technical Paper (266). 190 pp.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). 2005. CITES. Accessed 20 June 2005. http://www.cites.org.

Coles, S.L., and P.L. Jokiel. 1992. Effects of low salinity on coral reefs. Pages 147-166 in D.W. Connell and D.W Hawker, eds. Pollution in tropical aquatic systems. Boca Raton, Florida: CRC Press.

Conlan, R., and R. Service. 2000. El Niño and La Niña: Tracing the dance of ocean and atmosphere. Accessed 4 August 2005. http://www7.nationalacademies.org/opus/elnino.html.

CoRIS. 2003. Deep water corals. Accessed 11 August 2005.http://www.coris.noaa.gov/about/deep/deep.html.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. Prepared for the U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Cunha, M.R. and G.D.F. Wilson. 2003. Haplomunnidae (Crustacea: Isopoda) reviewed, with a description of an intact specimen of *Thylakogaster* Wilson & Hessler, 1974. Zootaxa 326:1-16.

Curtis, G. 1998. Tsunamis. Pages 76-78 in S.P. Juvik and J.O. Juvik, eds. Atlas of Hawai'i. 3d ed. Hilo, Hawaii: University of Hawai'i Press.

Dahlgren, T.G., A.G. Glover, A. Baco, and C.R. Smith. 2004. Fauna of whale falls: Systematics and ecology of a new polychaete (Annelida: Chrysopetalidae) from the deep Pacific Ocean. Deep-Sea Research I 51:1873-1887.

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

DeFelice, R.C. and J.D. Parrish. 2001. Physical processes dominate in shaping invertebrate assemblages in reef-associated sediments of an exposed Hawaiian coast. Marine Ecology Progress Series 215:121-131.

den Hartog, C. 1970. The seagrasses of the world. Amsterdam: North-Holland Publishers.

Deysher, L.E., T.A. Dean, R.S. Grove, and A. Jahn. 2002. Design considerations for an artificial reef to grow giant kelp (*Macrocystis pyrifera*) in southern California. ICES Journal of Marine Science 59:S201-S207.

DoE (Department of Energy). 2004. Japan country analysis brief. Accessed 17 August 2005. http://www.eia.doe.gov/emeu/cabs/japan.html.

DoN (Department of the Navy). 1994. Oceanographic forecaster's handbook. U.S. Naval Oceanography Command Detachment, Misawa, Japan.

DoN (Department of the Navy). 1997a. Natural resources management plan, Naval Air Facility, Atsugi. Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii by Belt Collins Hawaii, Honolulu, Hawaii. 111 pp.

DoN (Department of the Navy). 1997b. Natural resources management plan Yokosuka naval complex. Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii by Belt Collins Hawaii, Honolulu, Hawaii. 170 pp.

DoN (Department of the Navy). 1998. Natural resources management plan, COMFLEACT Sasebo, Japan. Prepared for Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, Hawaii by Belt Collins Hawaii, Honolulu, Hawaii. 114 pp.

DoN (Department of the Navy). 2000. San Diego Bay integrated natural resources management plan, September 2000. Prepared for the U.S. Department of the Navy, Southwest Division and San Diego Unified Port District, San Diego, CA by Tierra Data Systems, Escondido, CA. 674 pp.

DoN (Department of the Navy). 2001. Integrated natural resources management plan: Pacific Missile Range Facility Hawaii. Final report. Prepared for Commander, Navy Region Hawai'i, Honolulu, Hawai'i by Belt Collins Hawaii Ltd., Honolulu, Hawai'i.

DoN (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.

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

Doty, M.S. and M. Oguri. 1956. The island mass effect. Journal du conseil 22:33-37.

Durazo, R., T.R. Baumgartner, S.J. Bograd, C.A. Collins, S. de la Campa, J. García, G. Gaxiola-Castro, A. Huyer, K.D. Hyrenbach, D. Loya, R.J. Lynn, F.B. Schwing, R.L. Smith, W.J. Sydeman, and P. Wheeler. 2001. The state of the California Current, 2000-2001: A third straight La Niña year. CalCOFI Reports 42:29-60.

EarthRef. 2005. Seamount Catalog. Accessed 15 November 2005. http://www.earthref.org.

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 Technical Memorandum NMFS. NOAA-TM-NMFS-SWFC-40. NOAA/NMFS. 181 pp.

Emery, W.J. and J.S. Dewar. 1982. Mean temperature--salinity, salinity--depth and temperature--depth curves for the North Atlantic and the North Pacific. Progress in Oceanography 11:219-305.

Evans, G.T. and J.S. Parslow. 1985. A model of annual plankton cycles. Biological Oceanography 3(3):327-347.

Fager, E.W. 1971. Pattern in the development of a marine community. Limnology and Oceanography 16(2):241-253.

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

Field, C. 1995. Journey amongst mangroves. Okinawa, Japan: ISME (International Society for Mangrove Ecosystems).

Fisher, C.R., I.R. MacDonald, R. Sassen, C.M. Young, S.A. Macko, S. Hourdez, R.S. Carney, S. Joye, and E. McMullin. 2000. Methane ice worms: *Hesiocaeca methanicola* colonizing fossil fuel reserves. Naturwissenschaften 87:184-187.

Fletcher III, C.H., E.E. Grossman, B.M. Richmond, and A.E. Gibbs. 2002. Atlas of natural hazards in the Hawaiian coastal zone. Denver, Colorado: U.S. Geological Survey.

Foster, M.S. and D.R. Schiel. 1985. The ecology of giant kelp forests in California: A community profile. Biological Report. 85(7.2). U.S. Fish and Wildlife Service. 152 pp.

Frankel, S. 2004. Students in Hawaii define anchialine ponds. MIT Online Newsletter, Vol. 18, No. 2, July 2004. Accessed 15 August 2005.

Freiwald, A., J.H. Fosså, T. Koslow, and J.M. Roberts. 2004. Cold-water coral reefs: Out of sight-no longer out of mind. Cambridge, United Kingdom: UNEP-WCMC. 84 pp.

Friedlander, A.M. and J.D. Parrish. 1998. Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. Journal of Experimental Marine Biology and Ecology 224:1-30.

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

Fujikura, K., S. Kojima, K. Tamaki, Y. Maki, J. Hunt, and T. Okutani. 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.

Fujikura, K., Y. Fujiwara, S. Kojima, and T. Okutani. 2002. Micro-scale distribution of mollusks occurring in deep-sea chemosynthesis-based communities in the Japan Trench. VENUS 60(4):225-236.

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

Fujiwara, S., T. Shibuno, K. Mito, T. Nakai, Y. Sasaki, D. Chang-Feng, and C. Gang. 2000. Status of coral reefs of east and north Asia: China, Japan and Taiwan. Pages 131-140 in C. Wilkinson, ed. Status of coral reefs of the world: 2000. Townsville, Australia: Australian Institute of Marine Science.

Fukasawa, M., H. Freeland, R. Perkin, T. Watanabe, H. Uchida, and A. Nishina. 2004. Bottom water warming in the North Pacific Ocean. Nature 427:825-827.

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

Furota T. 1981. Community structures of macro-benthic animals on tidal flats in Tokyo Bay, Japan. Estuaries 4(3):280-281.

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. and R. Marumo. 1983. The structure of the phytoplankton community in the subsurface chlorophyll maxima in the western North Pacific Ocean. Journal of Plankton Research 5(3):393-405.

Furuya, K., O. Hasegawa, T. Yoshikawa, and S. Taguchi. 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., M. Takahashi, and T. Nemoto. 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.

Gage, J.D. 1996. Why are there so many species in deep-sea sediments? Journal of Experimental Marine Biology and Ecology 200:257-286.

Galkin, S.V. 1997. Megafauna associated with hydrothermal vents in the Manus Back-Arc Basin (Bismark Sea). Marine Geology 142:197-206.

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

Gass, S.E. 2003. Conservation of deep-sea corals in Atlantic Canada. World Wildlife Fund-Canada.

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

Gornitz, V. and I. Fung. 1994. Potential distribution of methane hydrates in the world's oceans. Global Biogeochemical Cycles 8(3):335-347.

Graham, M.H. 1997. Factors determining the upper limit of giant kelp, *Macrosystis pyrifera* Agardh, along the Monterey Peninsula, central California, USA. Journal of Experimental Marine Biology and Ecology 218:127-149.

Grassle, J.F. 1991. Deep-sea benthic biodiversity. BioScience 41(7):464-469.

Green, E.P., and F.T. Short. 2003. World atlas of seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. Berkeley, California: University of California Press.

Grigg, R.W. 1974. Distribution and abundance of precious corals in Hawaii. Pages 235-240 in A.M. Cameron, B.M. Cambell, A.B. Cribb, R. Endean, J.S. Jell, O.A. Jones, P. Mather and F.H. Talbot, eds. Proceedings of the Second International Coral Reef Symposium, Brisbane, December 1974. Volume 2. Brisbane, Australia: Great Barrier Reef Committee.

Grigg, R.W. 2002. Precious corals in Hawaii: Discovery of a new bed and revised management measures for existing beds. Marine Fisheries Review 64:13-20.

Grigg, R.W., A. Malahoff, E.H. Chave, and J. Landahl. 1987. Seamount benthic ecology and potential environmental impact from manganese crust mining in Hawaii. Pages 379-390 in B.H. Keating, P. Fryer, R. Batiza and G.W. Boehlert, eds. Seamounts, islands, and atolls. Geophysical Monograph 43. Washington, D.C.: American Geophysical Union.

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

Hain, S. and E. Corcoran. 2004. The status of the cold-water coral reefs of the world. Pages 115-133 in C. Wilkinson, ed. Status of Coral Reefs of the World: 2004. Townsville, Australia: Australian Institute of Marine Science.

Hanawa, K. and H. Mitsudera. 1987. Variation of water system distribution in the Sanriku coastal area. Journal of the Oceanographical Society of Japan 42:435-446.

Hanawa, K., Y. Yoshikawa, and T. Watanabe. 1989a. Composite analyses of wintertime wind stress vector fields with respect to SST anomalies in the western North Pacific and the ENSO events--Part I. SST composite. Journal of the Meteorological Society of Japan 67(3):385-400.

Hanawa, K., Y. Yoshikawa, and T. Watanabe. 1989b. Composite analyses of wintertime wind stress vector fields with respect to SST anomalies in the western North Pacific and the ENSO events--Part II. ENSO composite. Journal of the Meteorological Society of Japan 67(5):833-845.

Hashimoto, J., S. Ohta, T. Tanaka, H. Hotta, S. Matsuzawa, and H. Sakai. 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.

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

Hare, S.H. 1996. Low frequency climate variability and salmon production. Ph.D. diss., University of Washington.

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

Harvell, C.D., K. Kim, J.M. Burkholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, E.E. Hofmann, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith, and G.R. Vasta. 1999. Emerging marine diseases-climate links and anthropogenic factors. Science 285:1505-1510.

Hashimoto, J., S. Ohta, T. Tanaka, H. Hotta, S. Matsuzawa, and H. Sakai. 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, J., S. Ohta, K. Fujikura, and T. Miura. 1995. Microdistribution pattern and biogeography of the hydrothermal vent communities of the Minami-Ensei Knoll in the Mid Okinawa Trough, Western Pacific. Deep-Sea Research I 42(4):577-598.

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.

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

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

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

Heezen, B.C. and M. Ewing. 1952. Turbidity currents and submarine slumps, and the 1929 grand banks earthquake. American Journal of Science 250:849-873.

Helvey, M. 2002. Are southern California oil and gas platforms essential fish habitat? ICES Journal of Marine Science 59:S266-S271.

Heki, K., S. Miyazaki, H. Takahashi, M. Kasahara, F. Kimata, S. Miura, N.F. Vasilenko, A. Ivashchenko, and K-D. An. 1999. The Amurian Plate motion and current plate kinematics in eastern Asia. Journal of Geophysical Research 104(B12):29147-29155.

Hessler, R.R. and P.F. Lonsdale. 1991. Biogeography of Mariana Trough hydrothermal vent communities. Deep-Sea Research 38(2):185-199.

Heuret, A. and S. Lallemand. 2005. Plate motions, slab dynamics and back-arc deformation. Physics of the Earth and Planetary Interiors 149:31-51.

Hirakawa, K., T. Goto, and M. Hirai. 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.

Hixon, M.A. and J.P. Beets. 1993. Predation, prey refuges, and the structure of coral-reef fish assemblages. Ecological Monographs 63(1):77-101.

Humphris, S.E. 1995. Hydrothermal processes at mid-ocean ridges. Reviews of Geophysics Supplement, Vol. 33. Accessed 16 August 2005. http://www.agu.org/revgeophys/humphr01/humphr01.html.

Igarashi, T. 2004. Izu Islands. Pages 237-239 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Imaoka, T. and T. Itaya. 2004. K-Ar geochronology of a middle Miocene submarine volcano-plutonic complex in southwest Japan. Geological Magazine 141(1):1-13.

Iryu, Y., T. Nakamori, S. Matsuda, and O. Abe. 1995. Distribution of marine organisms and its geological significance in the modern reef complex of the Ryukyu Islands. Sedimentary Geology 99:243-258.

Isobe, M. 1998. Toward integrated coastal zone management in Japan. Page 7 pp. in ESENA Workshop: Energy-related marine issues in the Sea of Japan. 11-12 July 1998. Tokyo, Japan.

Isozaki, Y., S. Maruyama, and F. Furuoka. 1990. Accreted oceanic materials in Japan. Tectonophysics 181:179-205.

Itakura, S., M. Yamaguchi, M. Yoshida, and Y. Fukuyo. 2002. The seasonal occurrence of *Alexandrium tamarense* (Dinophyceae) vegetative cells in Hiroshima Bay, Japan. Fisheries Science 68:77-86.

Itou, M., I. Matsumura, and S. Noriki. 2000. A large flux of particulate matter in the deep Japan Trench observed just after the 1994 Snariku-Oki earthquake. Deep-Sea Research 47:1987-1998.

Iwao, K. 2004. Kerama Islands. Pages 185-189 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Jacobs, G.A., H.E. Hurlburt, J.C. Kindle, E.J. Metzger, J.L. Mitchell, W.J. Teague, and A.J. Wallcraft. 1994. Decade-scale trans-Pacific propagation of an El Niño anomaly. Nature 370:360-363.

JAMSTEC. 1998. The discovery of a chemosynthetic ecosystem. Independent Administrative Institution, Japan Agency for Marine-Earth Science and Technology. Marine Ecosystems Research Department. http://www.jamstec.go.jp/jamstec-e/kaiiki/shinkai2/hakken.html. Accessed 28 July 2005.

Jenkins, C.J., A.J. Kettner, C. Moore, G. Sharman. 2005. *goSEABED World Seabed Data Browser*. Accessed 14 November 2005. http://instaar.colorado.edu/~jenkinsc/dbseabed/goseabed/interactive/.

Johnston, P.A. and D. Santillo. 2004. Conservation of seamount ecosystems: Application of a marine protected areas concept. Archive of Fishery and Marine Research 51(1-3):305-319.

JTB USA. 2005. Japanese custom/culture. Accessed 17 May 2005. http://www.jtbusa.com/enhome/jculture.asp.

Julian, B. 1994. Volcanic tremor: Nonlinear excitation by fluid flow. Journal of Geophysical Research 99(B6):11,859-11,877.

Julian, B. 2002. Seismological detection of slab metamorphism. Science 296:1625-1626.

Juvik, S.P., and J.O. Juvik, eds. 1998. Atlas of Hawai'i. 3d ed. Hilo, Hawaii: University of Hawai'i Press.

Kadena. 2005. Kadena air base: Okinawa, Japan. Accessed 26 April 2005. http://www.kadena.af.mil.

Kajiwara, K. and H. Matsumoto. 2004. Miyako Archipelago. Pages 204-208 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Kakuma, S. 1996. FAD fisheries of Okinawa, Japan. SPC Fish Aggregating Device Information Bulletin No. 2. pp 8-12.

Kan, H., N. Hori, Y. Nakashima, and K. Ichikawa. 1995. The evolution of narrow reef flats at high-latitude in the Ryukyu Islands. Coral Reefs 14:123-130.

Kanamatsu, T. and K. Matsuo. 2003. Rock magnetic study of sediments from the Japan Trench, ODP leg 186: Implications for deformation of sediments. Pages 1-21 in K. Suyehiro, I.S. Sacks, G.D. Acton and M. Oda, eds. Proceedings of the Ocean Drilling Program, Scientific Results, Volume 186.

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 M. Kikuchi. 1993. The 1992 Nicaragua earthquake: A slow tsunami earthquake associated with subducted sediments. Nature 361:714-716.

Kanamori M., Goshima, S., and Mukai, H. 2004. Seasonal variation in host utilization of epiphytic *Lacuna* species in mixed algal and surfgrass stands in Japan. Marine Ecology 25(1):51-69.

Kanaori, Y., S. Kawakami, and K. Yairi. 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.

Kang, I-S., C-H. Ho, and Y-K. Lim. 1999. Principal modes of climatological seasonal and intraseasonal variations of the Asian summer monsoon. Monthly Weather Review 127:322-340.

Karl, D.M. 1999. A sea of change: Biogeochemical variability in the North Pacific Subtropical Gyre. Ecosystems 2:181-214.

Karl, D.M. and R. Lukas. 1996. The Hawaii Ocean Time-series (HOT) program: Background, rationale and field implementation. Deep-Sea Research II 43(2-3):129-156.

Karl, D.M., R. Letelier, D. Hebel, L. Tupas, J.Dore, J. Christian, and C. Winn. 1995. Ecosystem changes in the North Pacific subtropical gyre attributed to the 1991-92 El Niño. Nature 373:230-234.

Kasahara, J., H. Utada, T. Sato, and H. Kinoshita. 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., H. Saito, A. Yoshimori, and S. Taguchi. 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.

Kashima, K. 2000. An attempt of diatom assemblages from brackish lagoons as an indicator for a long-term monitering (sic) of the global sea level rise. H. Mimura and H. Yokoki, eds. Proceedings of the APN/SURVAS/LOICZ Joint Conference on Coastal Impacts of Climate Change and Adaption in the Asia-Pacific Region. 14-16 November. Kobe, Japan.

Kawabe, M. 1986. Transition processes between the three typical paths of the Kuroshio. Journal of the Oceanographical Society of Japan 42:174-191.

Kayanne, H., S. Harii, Y. Ide, and F. Akimoto. 2002. Recovery of coral populations after the 1998 bleaching on Shiraho Reef, in the southern Ryukyus, NW Pacific. Marine Ecology Progress Series 239:93-103.

Kayanne, H., C. Hongo, and H. Yamano. 2004. Coral reef landforms in Japan. Pages 14-19 in in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Kennett, J.P. 1982. Marine geology. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Kimrua, T., C.F. Dai, S. Pae, H. Hui, P.O. Ang, J.G. Je, and C. Choyce L.s. 2004. Status of coral reefs in east and north Asia: China, Hong Kong, Taiwan, Korea, and Japan. Pages 277-301 in C. Wilkinson, ed. Status of coral reefs of the world: 2004. Volume 1. Townsville, Australia: Australian Institute of Marine Science.

King, M. 1993. Deepwater shrimp. Pages 513-538 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

Klima, E.F. and D.A. Wickham. 1971. Attraction of coastal pelagic fishes with artificial structures. Transactions of the American Fisheries Society 100:86-99.

Kobari, T. and T. Ikeda. 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.

Kodaira, S., N. Takahashi, A. Nakanishi, S. Miura, and Y. Kaneda. 2000. 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. 2002. Deep-sea chemoautosynthesis-based communities in the northwestern Pacific. Journal of Oceanography 58:343-363.

Kojima, S., K. Hayashi, D. Kim, A. Iijima, and T. Furota. 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., G. Mora, A. Deyhle, S. Frape, and R. Hesse. 2003. Fluid geochemistry in the Japan Trench forearc (ODP Leg 186): A synthesis. Pages 1-23 in K. Suyehiro, I.S. Sacks, G.D. Acton, M. Oda, eds. Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 186. Accessed 30 June 2005. http://www-odp.tamu.edu/publications/186_IR/186ir.htm.

Kosuga, M., H. Sato, T. Tanaka, and H.C. Sheu. 1988. Crustal movement along a collision boundary of plates (case of eastern Taiwan). Journal of Geodynamics 10:189-205.

Krishnamurti, T.N. 1985. Summer monsoon experiment--A review. Monthly Weather Review 113:1590-1626.

Kubota, I. 1987. The western Pacific and El Niño. Oceanus 30(1):75-77.

Kubotera, A. and M. Otsuka. 1970. Nature of non-volcanic microtremor observed on the Aso Caldera. Journal of Physics of the Earth 18(1):115-124.

Kuroda, M., K. Wada, and M. Kamada. 2005. Factors influencing coexistence of two brachyuran crabs, *Helice tridens* and *Parasesarma plicatum*, in an estuarine salt marsh, Japan. Journal of Crustacean Biology 25(1):146-153.

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.

Lanoil, B.D., R. Sassen, M.T. La Duc, S.T. Sweet, and K.H. Nealson. 2001. *Bacteria* and *Archaea* physically associated with Gulf of Mexico gas hydrates. Applied and Environmental Microbiology 67(11):5143-5153.

Lau, K-M., G.J. Yang, and S.H. Shen. 1988. Seasonal and intraseasonal climatology of summer monsoon rainfall over east Asia. Monthly Weather Review 116:18-37.

Le Pichon, X., T. Iiyama, J. Boulègue, J. Charvet, M. Faure, K. Kano, S. Lallemant, H. Okada, C. Rangin, A. Taira, T. Urabe, and S. Uyeda. 1987a. Nankai Trough and Zenisu Ridge: A deep-sea submersible survey. Earth and Planetary Science Letters 83:285-299.

Le Pichon, X., T. Iiyama, H. Chamley, J. Charvet, M. Faure, H. Fujimoto, T. Furuta, Y. Ida, H. Kagami, S. Lallemant, J. Leggett, A. Murata, H. Okada, C. Rangin, V. Renard, A. Taira, and H. Tokuyama. 1987b. Nankai Trough and the fossil Shikoku Ridge: Results of Box 6 Kaiko survey. Earth and Planetary Science Letters 83:186-198.

Le Pichon, X., T. Iiyama, H. Chamley, J. Charvet, M. Faure, H. Fujimoto, T. Furuta, Y. Ida, H. Kagami, S. Lallemant, J. Leggett, A. Murata, H. Okada, C. Rangin, V. Renard, A. Taira, and H. Tokuyama. 1987c. 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.

Lee, D-K., P.P. Niiler, S-R. Lee, K. Kim, and H-J. Lie. 2000. Energetics of the surface circulation of the Japan/East Sea. Journal of Geophysical Research 105(C8):19561-19573.

Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson, eds. 2001. California's living marine resources: A status report. SG 01-11. Sacramento: California Department of Fish and Game. 592 pp.

Liddell, W.D., and S.L. Ohlhorst. 1988. Comparison of Western atlatic coral reef communities. Pages 281-286 in J.H. Choat, D. Barnes, MA. Borowitzka, J.C. Coll, P.J. Davies, P. Flood, B.G. Hatcher, D. Hopley, P.A. Hutchings, D. Kinsey, G.R. Orme, M. Pichon, P.F. Sale, P. Sammarco, C.C. Wallace, C. Wilkinson, E. Wolanski, and O. Bellwood, eds. Proceedings of the Sixth International Coral Reef Symposium. Volume 3. Townsville, Australia: 6th International Coral Reef Symposium Executive Committee.

Lim, Y-K. 2004. Diagnosis of the Asian summer monsoon variability and the climate prediction of monsoon precipitation via physical decomposition. Ph.D. diss., Florida State University.

Lim, Y-K., K-Y. Kim, and H-S. Lee. 2002. Temporal and spatial evolution of the Asian summer monsoon in the seasonal cycle of synoptic fields. Journal of Climate 15:3630-3644.

Limsakul, A., T. Saino, J.I. Goes, and T. Midorikawa. 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., T. Saino, T. Midorikawa, and J.I. Goes. 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.

Littler, M.M., D.S. Littler, S.M. Blair, and J.N. Norris. 1985. Deepest known plant life discovered on an uncharted seamount. Science, New Series 227(4682):57-59.

Lonely Planet. 2003. Japan. Accessed 17 May 2005. http://www.lonelyplanet.com/destinations/north_east_asia/japan/printable.htm.

Love, M.S., D.M. Schroeder, and M.M. Nishimoto. 2003. The ecological role of oil and gas production platforms and natural outcrops on fishes in southern and central California: A synthesis of information. OCS Study MMS 2003-032. Seattle, Washington: U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division.

Love, M.S., J.E. Caselle, and L. Snook. 2000. Fish assemblages around seven oil platforms in the Santa Barbara Channel area. Fishery Bulletin 98:96-117.

Loya, Y., K. Sakai, K. Yamazato, Y. Nakano, H. Sambali, and R. van Woesik. 2001. Coral bleaching: The winners and the losers. Ecology Letters 4:122-131.

Lynn, R.J., T. Baumgartner, J. Garcia, C.A. Collins, T.L. Hayward, K.D. Hyrenbach, A.W. Mantyla, T. Murphree, A. Shankle, F.B. Schwing, K.M. Sakuma, and M.J. Tegner. 1998. The state of the California Current, 1997-1998: Transition to El Niño conditions. CalCOFI Reports 39:25-49.

Mackas, D.L. and A. Tsuda. 1999. Mesozooplankton in the eastern and western subarctic Pacific: Community structure, seasonal life histories, and interannual variability. Progress in Oceanography 43:335-363.

Mann, K.H. and J.R.N. Lazier. 1991. Dynamics of marine ecosystems: Biological-physical interactions in the oceans. Boston: Blackwell Scientific Publications.

Mantua, N. 2002. Pacific-Decadal Oscillation (PDO). Pages 592-594 in 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. Chichester, England: John Wiley & Sons, Ltd.

Mantua, N. and S.R. Hare. 2002. The Pacific Decadal Oscillation. Journal of Oceanography 58:35-44.

Maragos, J.E. 1998. Marine ecosystems. Pages 111-120 in S.P. Juvik and J.O. Juvik, eds. Atlas of Hawai'i, Third ed. Hilo, Hawaii: University of Hawaii Press.

Maragos, J.E. 2000. Hawaiian Islands (U.S.A.). Pages 791-812 in C.R.C. Sheppard, ed. Seas at the millennium: An environmental evaluation. Volume 2: Regional chapters: The Indian Ocean to the Pacific. Amsterdam: Pergamon Press.

Marris, E. 2005. Inadequate warning system left Asia at the mercy of tsunami. Nature 433:3-5.

Maragos, J.E., D.C. Potts, G. Aeby, D. Gulko, J. Kenyon, D. Siciliano, and D. VanRavenswaay. 2004. 2002-2004 rapid ecological assessment of corals (Anthozoa) on shallow reefs of the Northwestern Hawaiian Islands. Part 1: Species and distribution. Pacific Science 58(2):211-230.

Masutani, S.M. and R.B. Coffin. 2001. Fiery ice from the seas: The first workshop of the international committee on methane hydrates. Final Report. NRL Technical Report NRL/MR/6110--02-8646. Honolulu, Hawaii: National Energy Technology Laboratory, U.S. Department of Energy. 1-36.

Masuzawa, J. 1969. Suptropical mode water. Deep-Sea Research 16:463-472.

McGowan, J.A. and P.W. Walker. 1985. Dominance and diversity maintenance in an oceanic ecosystem. Ecological Monographs 55(1):103-118.

McGuire, J.C. and G.D. Acton. 2003. Composite depth scales for the Japan Trench, ODP leg 186 sites 1150 and 1151. Pages 1-23 in K. Suyehiro, I.S. Sacks, G.D. Acton and M. Oda, eds. Proceedings of the Ocean Drilling Program, Scientific Results, Volume 186.

McMullin, E.R., D.C. Bergquist, and C.R. Fisher. 2000. Metazoans in extreme environments: Adaptations of hydrothermal vent and hydrocarbons seep fauna. Gravitational and Space Biology Bulletin 13(2):13-23.

Meier, K.Z., J.P. Laurel, and J.E. Maragos. 1993. Hawaii (USA). In D.A. Scott. A directory of wetlands in Oceania. Accessed 18 August 2005. http://www.wetlands.org/inventory&/OceaniaDir/Hawaii.htm.

Metcalf, W.G. 1968. Shallow currents along the northeastern coast of South America. Journal of Marine Research 26(3):232-243.

Mendelssohn, I.A. 1979. Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. Ecology 60(3):574-584.

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., A. Sako, and M. Nakamura. 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.

Miyazawa, Y., X. Guo, and T. Yamagata. 2004. Roles of mesoscale eddies in the Kuroshio paths. Journal of Physical Oceanography 34:2203-2222.

MMS (Minerals Management Service). 2001. Delineation drilling activities in federal waters offshore Santa Barbara County, California. Draft Environmental Impact Statement. OCS EIS/EA MMS 2001-046. Camarillo, California: Pacific OCS Region. 784 pp.

Mori, J. and K. Shimazaki. 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.

Munro, J. 1993. Giant clams. Pages 431-449 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

Myers, R.F. 1999. Micronesian reef fishes: A comprehensive guide to the coral reef fishes of Micronesia. 3rd ed. Barrigada, Territory of Guam: Coral Graphics.

NACS-J (Nature Conservation Society of Japan). 2002. Okinawa Jungusa watch No.1 (First report of seagrass watch survey in Okinawa). Accessed 15 November 2005. http://www.nacsj.or.jp/old_database/henoko/okinawa_jungusawatch2.pdf.

NACS-J (Nature Conservation Society of Japan). 2003. Diverse nature–An outline of Japan's natural ecosystems. Accessed 18 August 2005. http://www.nacsj.or.jp/english/e-diverse.html.

Naganuma, T., H. Wada, and K. Fujioka. 1996. Biological community and sediment fatty acids associated with the deep-sea whale skeleton at the Torishima seamount. Journal of Oceanography 52:1-15.

Nakai, T. and S. Nojima. 2004. Osumi Islands and Tokara Archipelago. Pages 166-169 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nakamura, H., G. Lin, and T. Yamagata. 1997. Decadal climate variability in the North Pacific during the recent decades. Bulletin of the American Meteorological Society 78(10):2215-2225.

Nakamura, Y. and M. Sano. 2004. Comparison between community structures of fishes in *Enhalus acoroides*- and *Thalassia hemprichii*- dominated seagrass beds on fringing coral reefs in the Ryukyu Islands, Japan. Ichthyological Research. 51:38-45.

Nakano, Y. 2004. Global environmental change and coral bleaching. Pages 42-48 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nakata, H., S. Kimura, Y. Okazaki, and A. Kasai. 2000. Implications of meso-scale eddies caused by frontal disturbances of the Kuroshio current for anchovy recruitment. ICES Journal of Marine Science 57:143-152.

Nakata, K. and K. Hidaka. 2003. Decadal-scale variability in the Kuroshio marine ecosystem in winter. Fisheries Oceanography 12(4/5):234-244.

NASA (National Aeronautics and Space Administration). 1998. Goddard Earth Sciences Data and Information Services Center, Distributed Active Archive Center. Accessed 30 June 2005. ftp://daac.gsfc.nasa.gov/data/czcs/level_3/monthly_data/subsets/Chlor/.

NASA (National Aeronautics and Space Administration). 2000. AVHRR oceans pathfinder global equalangle best weekly SST averages (NOAA/NASA). Goddard Earth Sciences Data and Information Services Center, Distributed Active Archive Center. Accessed 4 May 2004. ftp://disc1.gsfc.nasa.gov/data/avhrr/tile_8km/.

Nash, W. 1993. Trochus. Pages 451-495 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

NCCOS/NOAA (National Centers for Coastal Ocean Science/National Oceanic and Atmospheric Administration). 2005. Shallow-water benthic habitats of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. NOAA Technical Memorandum NOS NCCOS CCMA 8. (On-Line). Prepared by the Biogeography team, Silver Spring, Maryland. 48 pp.

NERC (Natural Environment Research Council). 2000. The tsunami risks project. Accessed 8 August 2005. http://www.nerc-bas.ac.uk/tsunami-risks/.

Niitsuma, N. 2004. Japan trench and tectonics of the Japanese Island arcs. Island Arc 13:306-317.

Nishihira, M. 2004. Hermatypic corals of Japan. Pages 10-13 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nishimura, Y., N. Miyaji, and M. Suzuki. 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.

Nixon, S.W. 1982. The ecology of New England high salt marshes: A community profile. FWS/OBS-81/55. Washington, D.C.: U.S. Fish and Wildlife Service, Office of Biological Services. Prepared for National Coastal Ecosystems Team 70 pp.

NOAA (National Oceanic and Atmospheric Administration). 2004. Derelict Vessels in Saipan, Commonwealth of the Northern Marianas Islands (CNMI). NOAA Coral Reef News 1(4):3.

NOAA (National Oceanic and Atmospheric Administration). 2005a. What is La Niña? Accessed 11 January 2005. http://www.pmel.noaa.gov/tao/elnino/la-nina-story.html.

NOAA (National Oceanic and Atmospheric Administration). 2005b. What is an El Niño? Accessed 11 January 2005. http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html.

Nohara, S., T. Yabe, and K. Kaneko. 2004. The succession of salt marsh vegetation in the largest delta in Tokyo Bay, Japan. Abstracts: Seventh INTECOL International Wetlands Conference. 27 July 2004. Utrecht University, The Netherlands.

Nojima, S. 2004a. Kumamoto Prefecture. Pages 272-274 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nojima, S. 2004b. Kagoshima Prefecture. Pages 279-281 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nojima, S. 2004c. Oita Prefecture. Pages 275-276 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nojima, S. 2004d. Miyazaki Prefecture. Pages 277-278 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nonaka, M. 2004. Daito Islands. Pages 199-201 in M. Tsuchiya, K. Nadaoka, H. Kayanne and H. Yamano, eds. Coral reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Nybakken, J.W. 1997. Marine Biology: An ecological approach. 4th ed. Menlo Park, California: Addison Wesley Educational Publishers, Inc.

Nybakken, J.W. 2001. Marine Biology: An ecological approach. Fifth ed. Menlo Park, California: Addison Wesley Educational Publishers, Inc.

OCDA (Oahu Civil Defense Agency). 2003. Multi-hazard pre-disaster mitigation for the city and county of Honolulu. Prepared for OCDA, Honolulu, Hawaii by Martin & Chock, Inc., Honolulu, Hawaii. 783 pp.

Odate, T. and K. Furuya. 1998. Well-developed subsurface chlorophyll maximum near Komahashi No. 2 seamount in the summer of 1991. Deep-Sea Research I 45:1595-1607.

Odate, T. and Y. Maita. 1989. Regional variation in the size composition of phytoplankton communities in the western North Pacific Ocean, spring 1985. Biological Oceanography 6:65-77.

O'Dor, R.K. 2003. The unknown ocean: The baseline report of the census of marine life research program. Washington, D.C.: Consortium for Oceanographic Research and Education. 28 pp.

Oguma, S., T. Suzuki, and Y. Nagata. 2002. Seasonal variations in the sea off Sanriku coast, Japan. Journal of Oceanography 58:825-835.

Oka, E. and T. Suga. 2003. Formation region of North Pacific subtropical mode water in the late winter of 2003. Geophysical Research Letters 30(23):2205, doi:2210,1029/2003GL018581.

Okada, H. 1980. Sedimentary environments on and around island arcs: An example of the Japan trench area. Precambrian Research 12:115-139.

Omija, T. 2004. Terrestrial inflow of soils and nutrients. Pages 64-68 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Ondrusek, M.E., R.R. Bidigare, S.T. Sweet, D.A. Defreitas, and J.M. Brooks. 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., R.R. Bidigare, K. Waters, and D.M. Karl. 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 K. Ohtani. 1997. Volume transport of the Tsushima warm current, west of Tsugaru Strait bifurcation area. Journal of Oceanography 53:27-34.

Open University. 1995. Ocean circulation. Oxford, Great Britain: Pergamon Press.

Park, J-O., H. Tokuyama, M. Shinohara, K. Suyehiro, and A. Taira. 1998. Seismic record of tectonic evolution and backarc rifting in the southern Ryukyu island arc system. Tectonophysics 294:21-42.

Patrick, R. 1994. Southeastern estuaries. Pages 399-458 in R. Patrick, ed. Rivers of the United States. Volume 1: Estuaries. New York: John Wiley & Sons.

Philander, S.G.H. 1983. El Niño Southern Oscillation phenomena. Nature 302:295-301.

Phillips, R.C. and E.G. Menez. 1988. Seagrasses. Smithsonian contributions to the Marine Sciences 34:1-104.

Piatt, J.F., and P.J. Gould. 1994. Postbreeding dispersal and drift-net mortality of endangered Japanese murrelets. Auk 111(4):953-961.

PICES (North Pacific Marine Science Organization). 2004. Marine ecosystems of the North Pacific. PICES Special Publication 1. North Pacific Marine Science Organization.

Pickard, G.L., and W.J. Emery. 1982. Descriptive physical oceanography: An introduction. Fourth ed. Oxford, Great Britain: Pergamon Press.

Pitcher, C.R. 1993. Spiny lobster. Pages 539-607 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

Polet, J. and H. Kanamori. 2000. Shallow subduction zone earthquakes and their tsunamigenic potential. Geophysical Journal International 142:684-702.

Prior, D.B., B.D. Bornhold, J. W.J. Wiseman, and D.R. Lowe. 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. Pages 1413-1425 in J.H. Steele, K.K. Turekian and S.A. Thorpe, eds. Encyclopedia of ocean sciences. San Diego, California: 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 K.A. Kelly. 1993. Upper-ocean heat balance in the Kuroshio extension region. Journal of Physical Oceanography 23:2027-2041.

Qiu, B. and R. Lukas. 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 W. Miao. 2000. Kuroshio path variations south of Japan: Bimodality as a self-sustained internal oscillation. Journal of Physical Oceanography 30:2124-2137.

Qu, T., H. Mitsudera, and B. Qiu. 2001. A climatological view of the Kuroshio/Oyashio system east of Japan. Journal of Physical Oceanography 31:2575-2589.

Qu, T., H. Mitsudera, and T. Yamagata. 1999. A climatology of the circulation and water mass distribution near the Philippine coast. Journal of Physical Oceanography 29:1488-1505.

RAE/ERF (Restore America's Estuaries/Estuarine Research Foundation). 1999. Principles of estuarine habitat restoration: Working together to restore America's estuaries. Report on the RAE-ERF partnership - year one - September 1999. Arlington, VA/Port Republic, MD: RAE/ERF. 24 pp.

Reed, D.W., Y. Fujita, M.E. Delwiche, D.B. Blackwelder, P.P. Sheridan, T. Uchida, and F.S. Colwell. 2002. Microbial communities from methane hydrate-bearing deep marine sediments in a forearc basin. Applied and Environmental Microbiology 68(8):3759-3770.

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.

Rienecker, M.M. and L.L. Ehret. 1988. Wind stress curl variability over the North Pacific from the comprehensive ocean-atmosphere data set. Journal of Geophysical Research 93(C5):5069-5077.

Roberts, S. and M. Hirshfield. 2004. Deep-sea corals: Out of sight, but no longer out of mind. Frontiers in Ecology and the Environment. 2(3):123-130.

Rodriguez, A.R. 2003. Consumption of drift kelp by intertidal populations of the sea urchin *Tetrapygus niger* on the central Chilean coast: Possible consequences at different ecological levels. Marine Ecology Progress Series 251:141-151.

Rodriguez, S., A.R.T. Santiago, and G. Shenker. 2001. A public-access GIS-based model of potential species habitat distribution for the Santa Barbara Channel and the Channel Islands National Marine Sanctuary. Masters, Donald Bren School of Environmental Science and Management.

Rogers, A.D. 1994. The biology of seamounts. Pages 305-364 in J.H. Blaxter and A.J. Southward, eds. Advances in Marine Biology. Volume 30. San Diego: Academic Press.

Ronghui, H. and S. Fengying. 1992. Impacts of the tropical western Pacific on the east Asian summer monsoon. Journal of the Meteorological Society of Japan 70(1):243-256.

Rountree, R.A. 1990. Community structure of fishes attracted to shallow water fish aggregation devices off South Carolina, U.S.A. Environmental Biology of Fishes 29:241-262.

Rydelek, P.A. and I.S. Sacks. 1990. Asthenospheric viscosity and stress diffusion: A mechanism to explain correlated earthquakes and surface deformations in NE Japan. Geophysical Journal International 100:39-58.

Sakai, K. 2004. Okinawa Island. Pages 182-184 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Samples, K.C., and J.R. Hollyer. 1989. Economic considerations in configuring fish aggregation device networks. Bulletin of Marine Science 44(2):863-872.

Sandwell, D.T., W.H.F. Smith, S.M. Smith, and C. Small. 2004. Global topography: Measured and estimated seafloor topography. Accessed 21 February 2005. http://topex.ucsd.edu/marine_topo/mar_topo.html.

Saunders, M.A., R.E. Chandler, C.J. Merchant, and P.F. Roberts. 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.

Schwing, F.B., S.J. Bograd, C.A. Collins, G. Gaxiola-Castro, J. García, R. Goericke, J. Goméz-Valdéz, A. Huyer, K.D. Hyrenbach, P.M. Korso, B.E. Lavaniegos, R.J. Lynn, A.W. Mantyla, M.D. Ohman, W.T. Peterson, R.L. Smith, W.J. Sydeman. E. Venrick, and P.A. Wheeler. 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., C.S. Moore, S.R. Ralston, and K.M. Sakuma. 2000. Record coastal upwelling in the California Current in 1999. CalCOFI Reports 41:148-160.

Scott, D.A. 1993. A directory of wetlands in Oceania. Accessed 13 June 2005. http://www.wetlands.org/inventory&/OceaniaDir/Contents.htm.

Sea Grant. 2005. Hawaii Institute of Marine Biology (HIMB), SOEST, University of Hawaii. State of Hawaii Fish Aggregation Device Program. Accessed 14 June 2005. http://www.hawaii.edu/HIMB/FADS/.

Seaman, W., Jr. and A.C. Jensen. 2000. Purposes and practices of artificial reef evaluation. Pages 1-19 in W. Seaman, Jr., ed. Artificial reef evaluation with application to natural marine habitats. New York: CRC Press.

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.

Seno, T. and T. Sakurai. 1996. Can the Okhotsk plate be discriminated from the North American plate? Journal of Geophysical Research 101(B5):11305-11315.

Seno, T., and T. Yamasaki. 2003. Low-frequency tremors, intraslab and interplate earthquakes in Southwest Japan--from a veiwpoint of slab dehydration. Geophysical Research Letters 30(22):2171,doi:10.1029/2003BL018349.

Seno, T., S. Stein, and A.E. Gripp. 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.

Shimoike, K. 2004a. Boso Peninsula. Pages 232-233 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Shimoike, K. 2004b. Iheya, Izena, Aguni, Tonaki, and Kume Islands. Pages 190-193 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Shimozuru, D., K. Kamo, and W.T. Kinoshita. 1966. Volcanic tremor of Kilauea Volcano, Hawaii, during July-December, 1963. Bulletin of the Earthquake Research Institute 44:1093-1133.

Shiomoto, A., S. Hashimoto, and T. Murakami. 1998. Primary productivity and solar radiation off Sanriku in May 1997. Journal of Oceanography 54:539-544.

Shiomoto, A., K. Sasaki, T. Shimoda, and S. Matsumura. 1994. Primary productivity in the offshore Oyashio in the spring and summer 1990. Journal of Oceanography 50:209-222.

Short, F.T., D.M. Burdick, C.A. Short, R.C. Davis, and P.A. Morgan. 2000. Developing success criteria for restored eelgrass, salt marsh and mud flat habitats. Ecological Engineering 15:239-252.

Sibuet, M. and K. Olu. 1998. Biogeography, biodiversity and fluid dependence of deep-sea cold-seep communities at active and passive margins. Deep-Sea Research II. 45:517-567.

Simard, F. 1995. Marine Region 16: Northwest Pacific. In: A global representative system of marine protected areas. Vol. 4: South Pacific, northeast Pacific, northwest Pacific, southeast Pacific, and Australia/New Zealand. Accessed 17 August 2005. http://www.deh.gov.au/coasts/mpa/nrsmpa/global/volume4/chapter16.html.

Simpson, J.H., P.B. Tett, M.L. Argote-Espinoza, A. Edwards, K.J. Jones, and G. Savidge. 1982. Mixing and phytoplankton growth around an island in a stratified sea. Continental Shelf Research 1(1):15-31.

Sims, N.A. 1993. Pearl oysters. Pages 409-430 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

Smith, C.R. 1991. The bottom of the sea. Science 251(4993):576-577.

Smith, C.R. 1992. Whale falls: Chemosynthesis on the deep seafloor. Oceanus (Fall):74-78.

Smith, C.R. and A.R. Baco. 2003. Ecology of whale falls at the deep-sea floor. Oceanography and Marine Biology: An Annual Review 41:311-354.

Smith, C.R., A.R. Baco, A. Hannides, and D. Ruplinger. 2003. Chemosynthetic habitats on the California slope: Whale-, wood- and kelp-falls compared to vents and seeps. Page 1 in Biogeography and Biodiversity of Chemosynthetic Ecosystems: Planning for the Future, UNESS Workshop, Southampton, 16-18 June 2003.

Sohma, A., Y. Sekiguchi, K. Nakata. 2004. Modeling and evaluating the ecosystem of sea-grass beds, shallow waters without sea-grass, and an oxygen-depleted offshore area. Journal of Marine Systems. 45:105-142.

South, G.R. 1993. Seaweeds. Pages 683-710 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

Spalding, M.D., F. Blasco, and C.D. Field, eds. 1997. World Mangrove Atlas.178 pp. Okinawa, Japan: The International Society for Mangrove Ecosystems.

Steneck, R.S., M.H. Graham, B.J. Bourque, D. Corbett, J.M. Erlandson, J.A. Estes, and M.J. Tegner. 2002. Kelp forest ecosystems: Biodiversity, stability, resilience, and future. Environmental Conservation 29(4):436-459.

Stott, L., K. Cannariato, R. Thunell, G.H. Haug, A. Koutavas, and S. Lund. 2004. Decline of surface temperature and salinity in the western tropical Pacific Ocean in the Holocene epoch. Nature 43:56-59.

Strayer, D. 1988. On the limits of secondary production. Limnology and Oceanography 33(5):1217-1220.

Suga, T. and K. Hanawa. 1990. The mixed-layer climatology in the northwestern part of the North Pacific subtropical gyre and the formation area of subtropical mode water. Journal of Marine Research 48:543-566.

Suga, T. and K. Hanawa. 1995. The subtropical mode water circulation in the North Pacific. Journal of Physical Oceanography 25:958-970.

Suga, T., A. Kato, and K. Hanawa. 2000. North Pacific tropical water: Its climatology and temporal changes associated with the climate regime shift in the 1970s. Progress in Oceanography 47:223-256.

Sugimoto, T., S. Kimura, and K. Tadokoro. 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., K. Tadokoro, and Y. Furushima. 1995. Climate and weather effects on the chlorophyll concentration in the northwestern North Pacific. Pages 575-592 in H. Sakai and Y. Nozaki, eds. Biogeochemical Processes and Ocean Flux in the Western Pacific. Tokyo, Japan: Terra Scientific Publishing Company (TERRAPUB).

Suzuki, T. and M. Matsuyama. 2000. Numerical experiments on stratified wind-induced circulation in Tokyo Bay, Japan. Estuarine, Coastal and Shelf Science 50:17-25.

Takada, Y. 1999. Influence of shade and number of boulder layers on mobile organisms on a warm temperate boulder shore. Marine Ecology Progress Series. 189:171-179.

Takahashi, M. and M.J. Kishi. 1984. Phytoplankton growth response to wind induced regional upwelling occurring around the Izu Islands off Japan. Journal of the Oceanographical Society of Japan 40:221-229.

Takahashi, M., I. Koike, T. Ishimaru, T. Saino, K. Furuya, Y. Fujita, A. Hattori, and S. Ichimura. 1980. Upwelling plumes in Sagami Bay and adjacent water around the Izu Islands, Japan. Journal of the Oceanographical Society of Japan 36:209-216.

Takahashi, D., Y. Nishida, K. Uehara, and H. Miyake. 2004. Dynamics and water mass structure of a summertime anticyclonic eddy in Funka Bay, Hokkaido, Japan. Estuarine, Coastal and Shelf Science 61:185-195.

Talley, L.D. and Yun, J-Y. 2001. The role of cabbeling and double diffusion in setting the density of the North Pacific intermediate water salinity minimum. Journal of Physical Oceanography 31:1538-1549.

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., T. Kani, H. Ishizuka, S. Maruyama, and Y. Nishimura. 2000. Activitation of Pacific mantle plumes during the Carboniferous: Evidence from accretionary complexes in southwest Japan. Geology 28(7):580-582.

Teague W.J., G.A. Jacobs, H.T. Perkins, J.W. Book, K-I. Chang, and M-S. Suk. 2002. Low-frequency current observations in the Korea/Tsushima Strait. Journal of Physical Oceanography 32(6): 1621–1641.

Teague, W.J., H.T. Perkins, G.A. Jacobs, and J.W. Book. 2001. Tide observations in the Korea-Tsushima Strait. Continental Shelf Research 21:545-561.

TEMIS (Tropospheric Emission Monitoring Internet Service). 2005. Volcanic SO2 Service -- volcano information. Accessed 14 November 2005. http://www.temis.nl/aviation/volcanoes/index.php?Region=23.

Thayer, G.W., K.A. Bjorndal, J.C. Ogden, S.L. Williams, and J.C. Zieman. 1984. Role of larger herbivores in seagrass communities. Estuaries 7(4A):351-376.

Thompson, B., J. Dixon, S. Schroeter, and D.J. Reish. 1993. Benthic invertebrates. Pages 369-458 in M.D. Dailey, D.J. Reish and J.W. Anderson, eds. Ecology of the Southern California Bight. Berkeley: University of California Press.

Thunell, R., E. Tappa, R. Varela, M. Llano, Y. Astor, F. Muller-Karger, and R. Bohrer. 1999. Increased marine sediment suspension and fluxes following an earthquake. Nature 398:233-236.

Thurman, H.V. 1997. Introductory oceanography. 8th ed. Upper Saddle River, New Jersey: Prentice Hall.

Tiner, R.W. 1993. Field guide to coastal wetland plants of the southeastern United States. Amherst: The University of Massachusetts Press.

Tiner, R.W., Jr. 1984. Wetlands of the United States: Current status and recent trends. Newton Corner, Massachusetts: U.S. Fish and Wildlife Service. 59 pp.

Toba, Y. and H. Murakami. 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 S.J. Godfrey. 2001. Regional oceanography: An introduction. Online by M. Tomczak and J.S. Godfrey.

Toole, J.M., R.C. Millard, Z. Wang, and S. Pu. 1990. Observations of the Pacific North Equatorial Current bifurcation at the Philippine coast. Journal of Physical Oceanography 20:307-318.

Trenberth, K.E. 1997. The definition of El Niño. Bulletin of the American Meteorological Society 78(12):2771-2777.

Trenberth, K.E., W.G. Large, and J.G. Olson. 1990. The mean annual cycle in global ocean wind stress. Journal of Physical Oceanography 20:1742-1760.

Tsuchiya, M., K. Nadaoka, H. Kayanne, and H. Yamano, eds. 2004. Coral reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Tsuda, T. and H. Sugisaki. 1994. In situ grazing rate of the copepod population in the western subarctic North Pacific during spring. Marine Biology 120:203-210.

Tsuda, A., H. Saito, and H. Kasai. 1999. Life histories of *Neocalanus flemingeri* and *Neocalanus plumchrus* (Calanoida: Copipoda) in the western subarctic Pacific. Marine Biology 135:533-544.

Tsuda, A., H. Saito, and H. Kasai. 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.

Tsunogai, U., N. Yoshida, and T. Gamo. 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.

Tsunogai, U., N. Yoshida, J. Ishibashi, and T. Gamo. 2000. Carbon isotopic distribution of methane in deep-sea hydrothermal plume, Myojin Knoll Calera, Izu-Bonin arc: Implications for microbial methane oxidation in the oceans and applications to heat flux estimation. Geochimica et Cosmochimica Acta 64(14):2439-2452.

Tucker, M.E., and V.P. Wright. 1990. Carbonate depositional systems: Marine-shallow water and lacustrine carbonates. Pages 190-227 in Carbonate sedimentology. Cambridge, Massachusetts: Blackwell Scientific Publications.

Uehara, H., T. Suga, K. Hanawa, and N. Shikama. 2003. A role of eddies in formation and transport of North Pacific subtropical mode water. Geophysical Research Letters 30(13):1705, doi:1710,1029/2003GL017542.

Ueno, S. 2004. Izu Peninsula. Pages 234-236 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

UN (United Nations). 2001. UN Atlas of the Oceans. Uses:Human Settlements on the Coast: Destruction of Habitats: Types of Habitats. Accessed 18 August 2005. http://www.oceansatlas.org/servlet/CDSServlet?status=ND0yNTQ4JjY9ZW4mMzM9KiYzNz1rb3M~.

Ursin, M.J. 1972. Life in and around the salt marsh. New York: Thomas Y. Crowell Company.

USGS (U.S. Geological Survey). 2004. Tsunami Statistics. Accessed 8 June 2005. http://earthquake.usgs.gov/eqinthenews/2004/usslav/tsustats.pdf

Uye, S-I., N. Nagano, and H. Tamaki. 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. 2d ed. New York: Springer-Verlag.

Venrick, E.L. 1990. Phytoplankton in an oligotrophic ocean: Species structure and interannual variability. Ecology 41(4):1547-1563.

Veron, J.E.N. 1995. Corals in space and time: The biogeography and evolution of the Scleractinia. Ithaca, New York: Cornell University Press.

Veron, J. 2000. Corals of the world. (Volumes 1, 2 and 3). Townsville, Australia: Australian Institute of Marine Science.

von Huene, R., M. Langseth, N. Nasu, and H. Okada. 1982. A summary of Cenozoic tectonic history along the IPOD Japan Trench transect. Geological Society of America Bulletin 93:829-846.

Wang, B. and J.C.L. Chan. 2002. How strong ENSO events affect tropical storm activity over the western North Pacific. Journal of Climate 15:1643-1658.

Wang, B., R. Wu, and X. Fu. 2000. Pacific-East Asian teleconnection: How does ENSO affect east Asian climate? Journal of Climate 13:1517-1536.

Wazniak, C., P. Tango, and W. Butler. 2004. Abundance and frequency of occurrence of brown tide, *Aereococcus anophagefferens*, in the Maryland Coastal Bays. Pages 7-1-7-10 in Maryland Department of Natural Resources. Maryland's coastal bays: Ecosystem Health Assessment. DNR-12-1202-0009. 389pp.

Web Japan. 2005. Japan fact sheet: Geography and climate. Accessed 3 August 2005. http://web-japan.org/.

West, K. and R. van Woesik. 2001. Spatial and temporal variance of river discharge on Okinawa (Japan): Inferring the temporal impact on adjacent coral reefs. Marine Pollution Bulletin 42(10):864-872.

Wheat, C.G., H.W. Jannasch, J.N. Plant, C.L. Moyer, F.J. Sansone, and G.M. McMurtry. 2000. Continuous sampling of hydrothermal fluids from Loihi Seamount after the 1996 event. Journal of Geophysical Research 105(B8):19353-19367.

White, W.B. and Y. He. 1986. Interannual variability in the heat content of the Kuroshio extension associated with the 1982 ENSO event. Journal of Physical Oceanography 16:309-321.

Wiegert, R.G., R. Pomeroy, and W.J. Wiebe. 1981. Ecology of salt marshes: An introduction. Pages 3-20 in L.R. Pomeroy and R.G. Wiegert, eds. The ecology of a salt marsh. New York: Springer-Verlag.

Wilson, G.D. 1976. The systematics and evolution of *Haplomunna* and its relatives (Isopoda, Haplomunnidae, new family). Journal of Natural History 10:569-580.

Wilson, R.R.J. and R.S. Kaufmann. 1987. Seamount biota and biogeography. Pages 355-377 in B.H. Keating, P. Fryer, R. Batiza and G.W. Boehlert, eds. Seamounts, islands, and atolls. Washington, D.C.: American Geophysical Union.

Wong, A.P.S., N.L. Bindoff, and J.A. Church. 1999. Large-scale freshening of intermediate waters in the Pacific and Indian Oceans. Nature 400:440-443.

Wu, M.C., W.L. Chang, and W.M. Leung. 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., L. Magaard, and J. Hager. 1976. Eddy energy in the oceans. Journal of Geophysical Research 81(15):2641-2646.

Yamagata, T., Y. Shibao, and S. Umatani. 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.

Yamaguchi, M. 1993. Green snail. Pages 497-511 in A. Wright and L. Hill, eds. Nearshore marine resources of the South Pacific. Honiara, Solomon Islands; Suva, Fiji; and Canada: Forum Fisheries Agency; Institute of Pacific Studies; and International Centre for Ocean Development.

Yamamoto, M., H. Makino, T. Kagawa, and O. Tominaga. 2004. Occurrence and distribution of larval and juvenile Japanese flounder *Paralichthys olivaceus* at sandy beaches in eastern Hiuchi-Nada, central Seto Inland Sea, Japan. Fisheries Science 70:1089-1097.

Yamano, H., K. Hori, M. Yamauchi, O. Yamagawa, and A. Ohmura. 2001. Highest-latitude coral reef at Iki Island, Japan. Coral Reefs 20:9-12.

Yamashiro, H. 2004. Coral diseases. Pages 56-59 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Yamazato, K. 1972. Bathymetric distribution of corals in the Ryukyu Islands. Pages 121-133 in C. Mukundan and C.S.G. Pillai, eds. Proceedings of the First International Symposium on Corals and Coral Reefs. Mandapan Camp, India: Marine Biological Association of India.

Yamazato, K. 1997. Recent status of coral reefs in Okinawa, Japan. Pages 103-110 in R.W. Grigg and C. Birkeland, eds. Status of coral reefs in the Pacific. Sea Grant College Program, School of Ocean and Earth Science and Technology, University of Hawaii.

Yanagi, T. and M. Nakajima. 1991. Change of oceanic condition by the man-made structure for upwelling. Marine Pollution Bulletin 23:131-135.

Yasuda, T. and K. Hanawa. 1999. Composite analysis of North Pacific subtropical mode water properties with respect to the strength of the wintertime east Asian monsoon. Journal of Oceanography 55:531-541.

Yokochi, H. 2004. Predation damage to corals. Pages 49-55 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Yokoyama, H. and Y. Ishihi. 2003. Feeding of the bivalve *Theora lubrica* on benthic microalgae: Isotopic evidence. Marine Ecology Progress Series 255:303-309.

Yoo, J-T., H. Nakata, and T. Sugimoto. 2004. Effect of horizontal advection induced by intrusion of the Kuroshio water on plankton biomass in the spring fishing period of shirasu on the Pacific coast of Japan. Fisheries Science 70:937-944.

Yoshimori, A., J. Ishizaka, T. Kono, H. Kasai, H. Saito, M.J. Dishi, and S. Taguchi. 1995. Modeling of spring bloom in the western subarctic Pacific (off Japan) with observed vertical density structure. Journal of Oceanography 51:471-488.

Zedler, J.B. 1982. The ecology of southern California coastal salt marshes: A community profile. FWS-OBS-81/54. Washington, D.C.: U.S. Fish and Wildlife Service, Biological Services Program. 110 pp.

3.0 SPECIES OF CONCERN

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

Marine mammals, which include cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, fur seals, and sea lions), and sirenians (manatees and dugongs), make up the largest number of federally protected species in the Japan and Okinawa Complexes OPAREA. Section 3.1 of this chapter provides information on the 48 marine mammal species with potential occurrence in the Japan and Okinawa Complexes OPAREA. All marine mammals potentially occurring in the OPAREA are protected by the MMPA; seven cetacean, one pinniped, and one sirenian species are additionally listed as threatened or endangered under the ESA. An overview of marine mammals, as well as a brief introduction to acoustics and hearing, which is useful in consideration of any potential anthropogenic impacts to these animals, is included. A detailed narrative has been prepared for each marine mammal species, consisting of a species' description, status, habitat preferences, distribution (including a focus on the Japan and Okinawa Complexes OPAREA), behavior and life history, and an account of its vocalizations and hearing capabilities (when available). Maps depicting the predicted areas of occurrence for each marine mammal species in the OPAREA are found in **Appendix A** (**Figures A-1** through **A-42**).

Five sea turtle species are known or have the potential to occur in the Japan and Okinawa Complexes OPAREA and all are either threatened or endangered under the ESA. Section 3.2 of this chapter consists of an overview on sea turtle biology and life history and provides basic information on the hearing capabilities of these animals. Each of the sea turtle species is then described in detail by its physical description, status, habitat preferences, distribution (including a focus on the Japan and Okinawa Complexes OPAREA), and behavior and life history. Maps depicting the predicted areas of occurrence for each sea turtle species in the OPAREA are found in **Appendix B** (**Figures B-1** through **B-6**).

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

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3.1 MARINE MAMMALS

3.1.1 Introduction

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

The vast majority of the 48 marine mammal species with confirmed or possible occurrence in the Japan and Okinawa Complexes OPAREA are cetaceans (whales and dolphins). Cetaceans are divided into two major suborders: Mysticeti and Odontoceti (baleen and toothed whales, respectively). Toothed whales use teeth to capture prey, while baleen whales use baleen plates to filter their food from the water. Beyond contrasts in feeding methods, there are also life history and social organization differences between baleen and toothed whales (Tyack 1986).

Pinnipeds are divided into three families: Phocidae (the “true” or earless seals); Otariidae (sea lions and fur seals); and Odobenidae (walruses). Relative to otariids, phocids are more streamlined and better adapted to an aquatic lifestyle. Some of the more obvious distinctions of phocids are that they lack external ears; are unable to rotate the pelvis to position the hind limbs under the body, leading to relatively poor terrestrial locomotion; use of pelvic flippers for underwater propulsion; and have small pectoral appendages (which are used for steering) (Riedman 1990). Beyond the physical differences, there are also life history differences (e.g., Riedman 1990). Interesting to note is that in most pinniped species whose reproductive physiologies have been studied, once the egg has been fertilized, development proceeds for only 7 to 10 days and then stops for several weeks or months. The pause in embryonic development that occurs between the time of fertilization and the time at which the blatocyst attaches to the uterine wall is generally called “delayed implantation”. This allows for synchronization of reproductive activity by seal species, and also likely provides the seal pups with the greatest opportunity for abundant prey.

Four living sirenian species are classified into two families: Trichechidae, with three species of manatees, and Dugongidae, the dugong. Of the sirenians, only the dugong occurs in the Japan and Okinawa Complexes OPAREA, specifically, in the Okinawa study area. Sirenians are the only completely aquatic mammals that are herbivores.

3.1.1.1 Adaptations to the Marine Environment—Sound Production and Reception

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

Pinnipeds are faced with two different environments (terrestrial and aquatic), and as a result, they have compromised full underwater or full terrestrial adaptation to allow for functional vision and hearing in both media (Wartzok and Ketten 1999). The vibrissae (whiskers) of pinnipeds are extensively developed and provide the animal with information about contour and texture (Wartzok and Ketten 1999). A recent study has demonstrated that the whiskers of harbor seals are highly sensitive to water movements, and may be an important mechanism for seals hunting in the dark (or in murky waters) to detect water movements generated by fish (Dehnhardt et al. 2001; Vester et al. 2001).

Sirenians do have acute underwater vision (Wartzok and Ketten 1999). Tactile sensation appears to be quite important as evidenced by sensory hairs over the entire surface of the body, being denser on the muzzle (Wartzok and Ketten 1999). The bristle-like hairs on the face are used in a grasping manner during feeding and manipulation of objects (Marshall et al. 2003).

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

Sounds produced by pinnipeds include airborne and underwater vocalizations (Thomson and Richardson 1995). Calls include grunts, barks, and growls, in addition to the more conventional whistles, clicks, and pulses. The majority of pinniped sounds are in the sonic range (20 Hz to 20 kHz) (Ketten 1998; Wartzok and Ketten 1999). In general, phocids are far more vocal underwater than are otariids. Phocid calls are commonly between 100 Hz and 15 kHz, with peak spectra less than 5 kHz, but can range as high as 40 kHz (Ketten 1998; Wartzok and Ketten 1999). There is no evidence that pinnipeds echolocate (Schusterman et al. 2000).

Underwater sounds produced by sirenians are often described as squeals, whistles, and chirps. These vocalizations range in frequency from about 0.6 to 16 Hz (Thomson and Richardson 1995). Sirenian hearing has not been reported in any great detail, compared to pinnipeds and cetaceans, but these animals likely hear infrasonic to ultrasonic frequencies (Ketten 1998).

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

In comparison with toothed whales, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, and poorer sensitivity at the best frequency (Richardson et al. 1995). However, some pinnipeds (especially phocids) may have better sensitivity at low frequencies (<1 kHz) than do toothed whales (Richardson et al. 1995). The pinniped ear appears to have been constrained during its evolution by the necessity of functioning in two acoustically dissimilar media (air and water). The patterns of air and water hearing sensitivity appear to correspond to the patterns of life history of the pinniped species (Kastak and Schusterman 1998). Comparisons of the hearing characteristics of otariids and phocids suggest two types of pinniped ears, with phocids being better adapted for underwater hearing (Richardson et al. 1995; Kastak and Schusterman 1998; Ketten 1998; Wartzok and Ketten 1999). In phocids tested, peak sensitivities ranged between 10 and 30 kHz, with a functional high-frequency limit of about 60 kHz (Richardson et al. 1995; Ketten 1998; Wartzok and Ketten 1999).

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

3.1.1.2 Marine Mammal Distribution—Habitat and Environmental Associations

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

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

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

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

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

Long-ranging movements are quite common in pinnipeds; hooded seals and northern elephant seals are both good examples, since they make extensive movements. Pinniped movements depend on the abundance of prey, its energy content, and the seasonality of prey distribution (Forcada 2002). Additionally, the pinniped reproductive cycle mandates that individuals return to land or ice to pup (give

birth), nurse, and rear their offspring and molt. Pinnipeds will also haul out for resting, thermoregulation, and to escape predators. As with migrating cetaceans, there are variations in the timing of these movements and in the patterns between age classes (Forcada 2002).

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

Pinniped movements, as noted earlier, are a reflection of both foraging ecology and the need to return to land for the purpose of breeding and molting. Like cetaceans, pinnipeds are often associated with either transient (oceanographic features such as frontal systems) or non-transient, physical features that serve to concentrate prey. Individual seal foraging behavior is probably related to oceanographic features in the water column, such as thermal discontinuities that act to concentrate prey species (Field et al. 2001). McConnell and Fedak (1996) hypothesized that seals out in the open ocean may be influenced by mesoscale frontal systems with locally enhanced prey abundance. Thompson et al. (1991) observed that the spatial and temporal occurrence of feeding harbor seals was in response to fish distribution which also shifts spatially and temporally, with concentrations over trenches and holes more than 10 m deep during daylight hours.

All pinniped species leave the water periodically to haul out on land or ice to molt, sleep, mate, pup, or avoid marine predators (Riedman 1990). Seasonal changes in oceanographic conditions and ice cover condition the distribution of pinnipeds in the pack ice (Forcada 2002). Haul out by ice-associating pinnipeds seems to be affected by both weather and time of day during breeding and molting periods (Moulton et al. 2000). The incidence, biological significance, and controlling factors for haul out at other times of the year, when weather is coldest, are essentially unknown (Moulton et al. 2000). For harbor seals, tidal stage has a significant effect on haulout behavior (Schneider and Payne 1983). Human disturbance can affect haulout behavior by causing seals to return to the water, thereby reducing the amount of time mothers spend nursing pups (Moulton et al. 2000; Schneider and Payne 1983).

Climatic fluctuations have produced a growing concern about the effects of climate change on marine mammal populations (MacGarvin and Simmonds 1996; IWC 1997; Evans 2002; Würsig et al. 2002). Large-scale climatic events and long-term temperature change may affect the distribution and abundance of marine mammal species, either impacting them directly or indirectly through alterations of habitat characteristics and distribution or prey availability (Kenney et al. 1996; IWC 1997; Harwood 2001; Greene and Pershing 2004). The impacts on pinnipeds and other marine mammals during the 1982/1983 El Niño event differed from region to region, but generally included a diminished food supply for the species. For example, sea lions in the southern California region were less successful in obtaining sufficient food of good quality, even on more extensive foraging trips (Feldkamp et al. 1991). The loss of food induced by warm waters resulted in nutritionally stressed adult females with pups and lower milk production, leading to a higher mortality rate among sea lion pups and juveniles and lower pup growth rates. This pattern was again evident in the 1997/1998 El Niño event (Hayward 2000). Similar patterns indicative of reduced foraging success and increased nutritional stress are also evident in elephant seals in central California during cyclic warming periods (Le Boeuf and Crocker 2005). Decreased squid abundance during El Niño events has been attributed to shifts in marine mammal distribution and abundance. For example, short-finned pilot whales virtually disappearing from the Santa Catalina Island area and being replaced by Risso's dolphins (Shane 1994, 1995). In Monterey Bay, following the onset of El Niño 1997/1998, both the diversity and abundance of toothed whales in Monterey Bay increased (Benson et al. 2002). The increase in diversity was caused by an influx of warm-water species coupled with the persistence of temperate species typically found off central California (Benson et al. 2002).

In the Pacific Ocean, climate variability has been linked to the PDO and the ENSO. The PDO is a long-term climatic pattern capable of altering SST, winds, and SLP over the Pacific Basin (Mantua 2002; Mantua and Hare 2002) and has been linked to cycles in fishery production (e.g., Hare 1996). Warm phases of the PDO coincide with cool and dry conditions along including Japan (Mantua and Hare 2002; Gordon and Giulivi 2004). In addition, SST in the North Pacific Ocean declines and tends to be below average until a climatic shift to the cool phase of the PDO (Nakamura et al. 1997). During a positive PDO (warm phase) a large pool of cold water is centered northwest of Hawaii and extends to Japan (Hare 1998). SSH increases along the Pacific coast of Japan during negative (cool phases) of the PDO and appears to be related to changes in flow of the Kuroshio, which weakens during a negative PDO. The decrease in flow from the Kuroshio enhances the Tsushima Current, which can affect the SSH in the Japan Sea (Gordon and Giulivi 2004). The ENSO is the result of interannual swings in SLPs in the tropical Pacific between the eastern and western hemispheres. The atmosphere-ocean system over Japan fluctuates with periods of 2 to 6 years in response to ENSO events (Nakamura et al. 1997; Conlan and Service 2000). ENSO events typically last 6 to 18 months, and can initiate large shifts in the global atmospheric circulation. Response of the region tends to be delayed in the year with maximum development of El Niño conditions occurring from September through February, resulting in a warmer and wetter than normal climate during an El Niño winter and the ensuing spring. For further information regarding the PDO and the ENSO, refer to Chapter 2.

3.1.2 Marine Mammals of Japan and Okinawa Complexes OPAREA

The vast majority (39) of the marine mammal species with confirmed or possible occurrence in the Japan and Okinawa Complexes OPAREA are cetaceans (whales, dolphins, and porpoises) (**Table 3-1**). The Okinawa study area has the northernmost population of the endangered dugong; there has been much public interest recently regarding this particular population. Eight pinniped species are documented for the area. 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 to be extinct (Nishiwaki and Nagasaki 1960; Nishiwaki 1973; 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).

Table 3-1. Marine mammal species of the Japan and Okinawa Complexes OPAREA. Taxonomy follows IWC (2004) for cetaceans and Rice (1998) for pinnipeds and sirenians. [Regular = A species that occurs as a regular or normal part of the fauna of the OPAREA, regardless of how abundant or common it is; Rare = A species that only occurs in the OPAREA sporadically; Extralimital = A species that does not normally occur in the OPAREA, but for which there are one or more records that are considered beyond the normal range of the species; *****includes more than one species, but nomenclature is still unsettled.[1]Endangered except for the population in the eastern North Pacific Ocean]. Status is based on the ESA listing.

	Scientific Name	Status	Occurence
Order Cetacea			
Suborder Mysticeti (baleen whales)			
Family Balaenidae (right whales)			
North Pacific right whale	*Eubalaena japonica*	Endangered	Rare
Bowhead whale	*Balaena mysticetus*	Endangered	Extralimital
Family Balaenopteridae (rorquals)			
Humpback whale	*Megaptera novaeangliae*	Endangered	Regular
Minke whale	*Balaenoptera acutorostrata*		Regular
Sei whale	*Balaenoptera borealis*	Endangered	Regular
Fin whale	*Balaenoptera physalus*	Endangered	Regular
Blue whale	*Balaenoptera musculus*	Endangered	Regular
Bryde's whale	*Balaenoptera edeni/brydei**		Regular
Family Eschrichtiidae (gray whale)			
Gray whale	*Eschrichtius robustus*	Endangered[1]	Rare

Table 3-1. Marine mammal species of the Japan and Okinawa Complexes OPAREA. Taxonomy follows IWC (2004) for cetaceans and Rice (1998) for pinnipeds and sirenians. (continued) [Regular = A species that occurs as a regular or normal part of the fauna of the OPAREA, regardless of how abundant or common it is; Rare = A species that only occurs in the OPAREA sporadically; Extralimital = A species that does not normally occur in the OPAREA, but for which there are one or more records that are considered beyond the normal range of the species; *****includes more than one species, but nomenclature is still unsettled.[1]Endangered except for the population in the eastern North Pacific Ocean].

	Scientific Name	Status	Occurence
Order Cetacea (continued)			
Suborder Odontoceti (toothed whales)			
Family Physeteridae (sperm whale)			
Sperm whale	*Physeter macrocephalus*	Endangered	Regular
Family Kogiidae (pygmy sperm whales)			
Pygmy sperm whale	*Kogia breviceps*		Regular
Dwarf sperm whale	*Kogia sima*		Regular
Family Ziphiidae (beaked whales)			
Cuvier's beaked whale	*Ziphius cavirostris*		Regular
Blainville's beaked whale	*Mesoplodon densirostris*		Regular
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*		Regular
Hubbs' beaked whale	*Mesoplodon carlhubbsi*		Rare
Stejneger's beaked whale	*Mesoplodon stejnegeri*		Regular
Longman's beaked whale	*Indopacetus pacificus*		Rare
Baird's beaked whale	*Berardius bairdii*		Regular
Family Delphinidae (dolphins)			
Rough-toothed dolphin	*Steno bredanensis*		Regular
Common bottlenose dolphin	*Tursiops truncatus*		Regular
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*		Regular
Pantropical spotted dolphin	*Stenella attenuata*		Regular
Spinner dolphin	*Stenella longirostris*		Regular
Striped dolphin	*Stenella coeruleoalba*		Regular
Short-beaked common dolphin	*Delphinus delphis*		Regular
Long-beaked common dolphin	*Delphinus capensis*		Regular
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*		Regular
Northern right whale dolphin	*Lissodelphis borealis*		Regular
Risso's dolphin	*Grampus griseus*		Regular
Melon-headed whale	*Peponocephala electra*		Regular
Fraser's dolphin	*Lagenodelphis hosei*		Regular
Pygmy killer whale	*Feresa attenuata*		Regular
False killer whale	*Pseudorca crassidens*		Regular
Killer whale	*Orcinus orca*		Regular
Short-finned pilot whale	*Globicephala macrorhynchus*		Regular
Family Phocoenidae (porpoises)			
Harbor porpoise	*Phocoena phocoena*		Rare
Dall's porpoise	*Phocoenoides dalli*		Regular
Finless porpoise	*Neophocoena phocaenoides*		Regular
Order Carnivora			
Suborder Pinnipedia (seals, sea lions, walruses)			
Family Phocidae (true seals)			
Spotted seal	*Phoca largha*		Rare
Harbor seal	*Phoca vitulina*		Extralimital
Ringed seal	*Phoca hispida*		Extralimital
Ribbon seal	*Phoca fasciata*		Extralimital
Northern elephant seal	*Mirounga angustirostris*		Extralimital
Bearded seal	*Erignathus barbatus*		Extralimital
Family Otariidae (sea lions and fur seals)			
Steller sea lion	*Eumetopias jubatus*	Threatened	Rare
Northern fur seal	*Callorhinus ursinus*		Regular
Order Sirenia			
Family Dugongidae (dugongs)			
Dugong	*Dugong dugon*	Endangered	Regular

Japan is a whaling nation, with a very long history of hunting marine mammals, in particular, cetaceans. In addition to pelagic whaling for great whales using factory ships, Japan also conducts “small-type” coastal whaling operations (Nishiwaki 1973; Miyazaki 1983). This hunting method is used mostly for the smaller species of whales, like the minke, Baird’s beaked, short-finned pilot, and killer whales. In addition, there are numerous local fisheries in Japan targeting 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 (e.g., Ohsumi 1972; Kishiro and Kasuya 1993). These latter fisheries take place mostly within Japan’s national waters. Locations in the Japan and Okinawa Complexes OPAREA and vicinity where community-based coastal whaling takes place are Hakodate (northwest of the East Japan study area), Ayukawa (part of Oshika-cho) and Wada in the East Japan study area and Taiji in the West Japan study area; Baird’s beaked whales, short-finned pilot whales, and Risso’s dolphins are the primary targets (JSWA 2002).

Most of what is known about the biology of cetaceans in Japan comes from or is associated with the whaling and dolphin-hunting industries (e.g., Omura and Ohsumi 1974). Japan’s scientific whaling 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 (Government of Japan 2002; Clapham et al. 2003). For this reason, there is much known about distribution, population biology, and life history of some Japanese cetacean stocks. However, little ecological work has been conducted until very recently.

The Japan and Okinawa Complexes OPAREA lies within an oceanic region of transition. Marine mammals with cool and warm water preferences are found in this area (**Table 3-1**). The southern extents of the OPAREA generally have 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 hotspots in production may attract all components of the food chain. However, the more northern areas of the OPAREA 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 et al. 1968; Kasai et al. 1997; Taniguchi 1999; **Figure 2-8**). Okinawa has a subtropical climate, experiencing SST in excess of 20°C year-round (**Figure 2-5**), some marine mammal species that have a preference for warmer waters would be expected to occur here. In addition, strong interactions between the local oceanography and topography exist in the study area. Deep trenches along the eastern shore of Japan and the numerous seamounts in the region may concentrate prey. Furthermore, the continental shelf is narrow, resulting in deep bodies of water occurring close to shore (e.g., the Tsushima Strait west of Kyūshū).

3.1.2.1 Marine Mammal Occurrences

The occurrence patterns for marine mammals in the Japan and Okinawa Complexes OPAREA and vicinity are presented for the winter-spring (December through May) and summer-fall (June through November) in the maps in **Appendix A**. For some of the species, occurrence patterns in the OPAREA apply year round. The process used to create the map figures is described in Section 1.4.2.4. On the map figures, various types of shading and terminology designate the occurrence of marine mammals in the Japan and Okinawa Complexes OPAREA. "Expected occurrence" (area shaded in purple) is defined as the area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and documented occurrence records. "Concentrated occurrence" (area shaded in light green) is the subarea of a species’ expected occurrence where there is the highest likelihood of encountering that species; the designation is based primarily on areas of concentrated sightings and preferred habitat. "Low/unknown occurrence" (light blue area) is where the likelihood of encountering a species is rare or not known. "Occurrence not expected" (white, unmarked area) is the area within the protected species data extent where a species encounter is not expected to occur.

Published documentation of whaling catches, sighting surveys, strandings, photo-identification projects, whalewatching, tagging, and fishery bycatch were considered in determination of the occurrence patterns. In 1949, Japanese agencies involved in the management of whaling began a research program of whale marking (or tagging) in the North Pacific Ocean (Omura and Kawakami 1956; Ohsumi and Masaki 1975).

Many thousands of whales from several different species were marked. Marks were shot into whales' bodies from a shotgun and were recovered when the whales were killed and cut-up or flensed. The data on the marks were then used to obtain information on the movements of the animals (Omura and Kawakami 1956). Until 1972, the number of whales marked in low-latitude areas was very small (Ohsumi and Masaki 1975). Additional records, particularly for the Ryuku Islands (includes Amami Islands and Okinawa), not only come from whaling records but also surveys associated with live captures for aquarium display (e.g., Uchida 1982, 1985; Miyazaki and Nakayama 1989). Lastly, information collected during marine mammal monitoring efforts associated with Littoral Warfare Advanced Development testing in these waters was considered (ONR 2001, 2004); 2001 testing occurred within the East Japan study area and just west of the Okinawa study area, while 2004 testing took place just west of the Okinawa study area.

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

3.1.2.2 Threatened and Endangered Marine Mammals of Japan and Okinawa Complexes OPAREA

There are ten marine mammal species that are listed as endangered under the ESA with confirmed or possible occurrence in the OPAREA: North Pacific right whale, bowhead whale, humpback whale, sei whale, fin whale, blue whale, gray whale, sperm whale, Steller sea lion, and the dugong. All these cetacean species are expected to occur here, with the exception of the bowhead whale. The dugong has a regular occurrence at Okinawa, while the Steller sea lion might make infrequent appearances.

> Information Specific to the Japan and Okinawa Complexes OPAREA—During the winter-spring period, threatened and endangered marine mammals are expected to occur from the shore to seaward of the OPAREA boundaries (**Figure A-1**). This takes into consideration both the expected sperm whale occurrence seaward of the shelf break as well as expected North Pacific right whale and gray whale occurrences between the shore and the shelf break. There is an area of concentrated occurrence around Okinawa and the Ogasawara Islands from the shore to 100 NM (185 km) offshore of these islands, which is based on the concentrated occurrence patterns of the dugong around Okinawa and the humpback whale that occurs on its breeding grounds during this time of year, in particular, around Okinawa and the Ogasawara Islands. There is also a low or unknown occurrence for this group of marine mammals within the bays and the Inland Sea based on possible gray whale in these areas. During the summer-fall period, the areas of expected and low or unknown occurrence are assumed to be the same as during winter-spring. The difference is in the areas of concentrated occurrence. In addition to the area off the east coast of Okinawa (based on the dugong), there is an area of concentrated occurrence that extends south of 30°N in the East China Sea during this time of year due to evidence for a major whaling ground there (Mizroch et al. 2005).

- North Pacific Right Whale (*Eubalaena japonica*)

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

  Right whales have a robust body shape; overall body color is black, although many individuals also have irregular white patches on their undersides (Reeves and Kenney 2003). There is no dorsal fin on the broad back. The largest recorded North Pacific right whales were an 18.3 m female and a 16.4 m male (Omura et al. 1969); North Pacific right whales are larger than their North Atlantic counterparts (Reeves and Kenney 2003). The head is nearly one-third of the total body length. The

jawline is arched and the upper jaw is very narrow in dorsal view. The head is covered with irregular whitish patches called "callosities," which have whale lice attached.

Status—The North Pacific right whale is perhaps the world's most endangered large whale species (Perry et al. 1999; IWC 2001). North Pacific right whales are classified as endangered both under the ESA and on the IUCN Red List (Reeves et al. 2003). There are insufficient genetic or resighting data to address whether the traditional separation into eastern and western stocks is valid (Brownell et al. 2001); however, Clapham et al. (2004) noted that north-south migratory movements support the hypothesis of two largely discrete populations of right whales in the eastern and western North Pacific. No reliable population estimate presently exists for this species; in the western North Pacific, the population may number at least in the low hundreds (Brownell et al. 2001; Clapham et al. 2004; MMC 2005), while the population in the eastern North Pacific is considered to be very small, perhaps only in the tens of animals (NMFS 2002; Clapham et al. 2004). Designated critical habitat was recently proposed for the North Pacific right whale; it includes an area in the western Gulf of Alaska and in the southeastern Bering Sea (NMFS 2005). None of these areas are within the OPAREA.

Habitat Preferences—Feeding habitat for right whales is defined by the presence of sufficiently high densities of prey, especially calanoid copepods (Reeves and Kenney 2003). Development of those patches is essentially a function of oceanic conditions, such as SST, stratification, bottom topography, and currents, which concentrate zooplankton, and concentration is probably enhanced by the behavior of the organisms themselves (Beardsley et al. 1996; Tynan et al. 2001). The shift in Bering Sea right whale occurrences from deep waters in the mid-twentieth century to the mid-shelf region in the late 1900s was attributed to changes in the availability of optimal zooplankton patches, possibility relating to climatic forcing (variability in oceanic conditions caused by changes in atmospheric patterns) (Tynan et al. 2001). Sightings in the Bering Sea are clustered in relatively shallow water (waters with a bottom depth of 50 to 80 m) (Tynan et al. 2001). However, North Pacific right whales have been sighted in waters with bottom depths deeper than 2,000 m (Shelden et al. 2005). The International Whaling Commission (IWC) (2001) noted a surprising absence of evidence for coastal calving grounds, since right whales in the North Atlantic and in the Southern Hemisphere have calving grounds located in shallow bays, lagoons, or in waters over the continental shelf.

Distribution—Right whales occur in subpolar to temperate waters. The North Pacific right whale historically occurred across the Pacific Ocean north of 35°N, with concentrations in the Gulf of Alaska, eastern Aleutian Islands, south-central Bering Sea, Sea of Okhotsk, and the Sea of Japan (Omura et al. 1969; Scarff 1986, 1991; Clapham et al. 2004). Presently, sightings are extremely rare, occurring primarily in the Okhotsk Sea and the eastern Bering Sea (Brownell et al. 2001; Shelden et al. 2005). Prior to 1996, right whale sightings were very rare in the eastern North Pacific (Scarff 1986; Brownell et al. 2001). Recent summer sightings of right whales in the eastern Bering Sea represent the first reliable consistent observations in this area since the 1960s (Tynan et al. 2001; LeDuc 2001). Right whales were probably never common along the west coast of North America (Scarff 1986; Brownell et al. 2001).

Historical whaling records provide virtually the only information on North Pacific right whale distribution. During the summer, whales were found in the Gulf of Alaska, along both coasts of the Kamchatka Peninsula, the southeastern Bering Sea, and in the Okhotsk Sea (Omura 1986; Clapham et al. 2004; Shelden et al. 2005). 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. 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 (Tynan et al. 2001; Shelden et al. 2005). Scarff (1986) hypothesized that those right whales that summer in the eastern North Pacific mate, calve, and overwinter in the mid-Pacific or in the western North Pacific.

Current distribution patterns and migration routes of these whales are not known (Scarff 1986; NMFS 2002). The extent to which right whales in the eastern North Pacific engage in north-south migrations

is unknown (Scarff 1986). There is very little information on the winter distribution of right whales in the eastern North Pacific. The location of calving grounds for the eastern population is unknown (Scarff 1986; NMFS 2002; Clapham et al. 2004). There are no records of newborn or very young calves in the eastern North Pacific, which appears to reflect a true absence of coastal calving grounds, at least within historic times (Scarff 1986). Neither the west coast of North America nor the Hawaiian Islands constituted a major calving ground for right whales within the last 200 years (Scarff 1986). No coastal calving grounds for right whales have been found in the western North Pacific either (Scarff 1986). Mid-ocean whaling records of right whales in the winter suggest that right whales may have wintered and calved far offshore in the Pacific (Scarff 1986, 1991; Clapham et al. 2004). Such pelagic calving would appear to be inconsistent with the records of nearshore calving grounds in other locales for the other right whale species.

Feeding grounds for North Pacific right whales are also poorly known. Based on historical whaling records and some recent sightings, the principal feeding grounds were most likely in the Sea of Okhotsk, central and eastern Bering Sea, and southeast of Kodiak Island in the Gulf of Alaska. All of these feeding areas are much further offshore than the well-studied North Atlantic habitats. The eastern Bering Sea is used for foraging (NMFS 2002). Right whales have been observed each summer since 1996 in the eastern Bering Sea in roughly the same location (Goddard and Rugh 1998; Moore et al. 2000; Tynan et al. 2001; Shelden et al. 2005).

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence patterns in **Figure A-2** are based primarily on Clapham et al. (2004), who reviewed and plotted all available records. 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 takes into account that most of the available records are within a few hundred miles of the coast. The predicted occurrence for the study area reflects the possibility that right whales might be encountered close to shore, as well as in much deeper waters. There is an area of low or unknown occurrence seaward of this area. During the summer-fall period, the area of expected occurrence is north of 35°N off the Pacific coast of Japan, which is based on both the presumed northward migration and available occurrence records. There is a low or unknown occurrence everywhere else (except bays) to account for unknown migration patterns, and the highly endangered status of the species.

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

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

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

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

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

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

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

- Bowhead whale (*Balaena mysticetus*)

Description—The bowhead whale is rotund in shape and lacks a dorsal fin. To insulate themselves from the icy water, bowheads are wrapped in blubber that is 5.5 to 28 cm thick (Rugh and Shelden 2002). Bowhead whales weigh as much as 75 to 100 tons (Rugh and Shelden 2002). Males attain lengths of about 14 to 17 m and females are 16 to 18 m, perhaps as much as 20 m (Rugh and Shelden 2002). At birth, the calf measures 4 m in length. The broad triangular tail fluke is 2 to 6 m across; there are white patterns around and on the tail. This species is predominantly black, with a prominent white chin patch. The head is triangular in profile and about one-third the length of the body; baleen may be as long as 4 m (Rugh and Shelden 2002). The massive head of the bowhead

whale can reportedly break through ice up to 1.8 m in thickness (Würsig and Clark 1993). The bowed appearance of the mouth gives them their name.

Status—The bowhead whale is listed as endangered under the ESA and, therefore, is also designated as depleted under the MMPA. This species is designated as lower risk (conservation dependent) on the IUCN Red List (Reeves et al. 2003). For management purposes, five stocks of bowhead whales are recognized by the IWC: two in the North Pacific basin and three in the North Atlantic basin (Rugh et al. 2003). Bowheads in the North Pacific include the Bering Sea and Okhotsk Sea stocks; only the Okhotsk Sea stock might have stragglers into the Japan and Okinawa Complexes OPAREA. The Okhotsk Sea stock is estimated to be about 100 to 200 individuals (MMC 2005). The Okhotsk Sea stock is designated as endangered by the IUCN Red List (Reeves et al. 2003). There is no designated critical habitat for any of the bowhead whale stocks.

Habitat Preferences—The bowhead whale is associated with relatively heavy ice cover and shallow continental shelf waters for most of the year (Moore and Reeves 1993). This species is always found near the ice edge, migrating north and south as the ice retreats or expands (Moore and Reeves 1993; Rugh et al. 2003). The inter- and intra-annual variation in distribution, relative abundance, and movements, particularly during summer and early fall, is likely related to the dynamic nature of oceanic fronts and eddies that serve to concentrate zooplankton (Moore and Reeves 1993).

Distribution—The bowhead whale is found in seasonally ice-covered arctic and subarctic waters of the Bering, Chukchi, and Beaufort Seas from approximately 54 to 75°N in the North Pacific and 60 to 85°N in the North Atlantic (Moore and Reeves 1993). Bowhead whales migrate seasonally within these waters, between summer feeding areas and wintering areas; this is the only baleen whale species that spends its entire life near sea ice and does not migrate to temperate or tropical waters to calve.

The southernmost record for a living bowhead whale was an individual in Ōsaka Bay, Honshū, Japan in June 1969 (Nishiwaki and Kasuya 1970). As noted by Moore and Reeves (1993), this individual may have been a stray from the Okhotsk Sea stock which summers along the western and perhaps northern portion of the Okhotsk Sea, notably around the Shantar Islands (Moore and Reeves 1993; Reeves et al. 2002). The wintering ground for this stock is largely unknown, but it is likely that most remain in the Okhotsk Sea year-round (Moore and Reeves 1993; Reeves et al. 2002).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The bowhead whale is extralimital to this OPAREA; no occurrence map is provided for this species. This species is represented by only one record in the OPAREA. During June 1969, an individual wandered into Ōsaka Bay, Honshū, was live captured by fishermen and then died (Nishiwaki and Kasuya 1970). While this location is not in any of the study areas, this individual would have had to pass through either the East Japan or West Japan study areas to get to Ōsaka Bay.

Behavior and Life History—Bowhead whales are usually seen in groups of three or fewer; larger aggregations form during the fall migration and on the feeding grounds, or when whales are forced by ice into a restricted area. Mating groups of multiple males and one adult female are observed (Würsig and Clark 1993). The bowhead whale's life history is not well-known. Mating behavior has been observed year-round although conception is thought to occur during late winter or early spring. Gestation is approximately 13 to 14 months (Koski et al. 1993). Females give birth every three to four years between April and June (Koski et al. 1993). Growth is slow compared to other baleen whale species, and sexual maturity for females is at roughly 15 years of age (Rugh and Shelden 2002). Little has been published on male reproductive biology (e.g., O'Hara et al. 2002). Bowhead whales are known to feed during spring, summer, and fall (Würsig and Clark 1993). While winter feeding has not been observed, analysis of stable isotopes in baleen plates suggests that significant winter feeding occurs (Würsig and Clark 1993). Feeding is conducted throughout the water column, from the surface all the way to the ocean bottom, although these whales are skim feeders, typically feeding near the surface (Würsig and Clark 1993). The primary prey is copepods and krill, with a wide variety of other invertebrates also taken (Lowry 1993; Lowry et al. 2004). Bowheads usually feed alone,

though occasionally are sighted together in groups feeding in an echelon formation, similar to a line of migrating geese. Dive durations as long as 40 min are documented (Leatherwood and Reeves 1983). Bowhead whales are able to travel long distances under ice (Reeves et al. 2002).

Acoustics and Hearing—Bowhead whales produce very loud and very low-frequency sounds. Vocalizations are categorized as seven types of simple, low frequency FM calls and complex calls. Within the first group are call types labeled up, down, constant, and inflected: these are often referred to as moans (Würsig and Clark 1993). The moans typically have a frequency range of 50 to 400 Hz (Clark and Johnson 1984; Würsig and Clark 1993). The source levels of simple moans range from about 128 to 178 dB re 1 µpa-m (Clark et al. 1986; Cummings and Holliday 1987). The complex calls have been labeled as high, pulsed tonal, and pulsive, or as growl and trumpet calls (Würsig and Clark 1993). Pulsive sounds have a frequency range of 25 to 3,500 Hz and source levels as high as 185 to 189 re 1 µpa-m (Thomson and Richardson 1995). Additionally, during spring migration through ice leads around northern Alaska, bowhead whales "sing" (Ljungblad et al. 1982; Cummings and Holliday 1987; Würsig and Clark 1993). The song notes are different from the before-mentioned calls; they are long patterned combinations of sounds. Typical song duration is about 1 min although they may last from several minutes to hours (Thomson and Richardson 1995). The dominant frequencies of the song are <4,000 Hz with a source level of 158 to 189 re 1 µpa-m (Thomson and Richardson 1995). There is no information about the age or sex class(es) of the singing bowheads, or about the function of their songs (Würsig and Clark 1993).

While no audiometric data on hearing ability for this species are available, cochlear morphology supports that the auditory response capabilities of the bowhead whale range from high infrasonic or low sonic to high sonic or low ultransonic frequencies (Norris and Leatherwood 1981). Observed reactions to airguin pulses and underwater playbacks of recorded man-made sounds show that bowhead whales hear sounds with dominant components in the 50 to 500 Hz range (Thomson and Richardson 1995). Bowhead whales may use the reverberations of their calls off the undersides of an ice floe to help them judge its dimensions, and to assist in navigation (Clark and Ellison 2004).

- Humpback Whale (*Megaptera novaeangliae*)

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

Status—Humpback whales are classified as endangered under the ESA and are designated as vulnerable by the IUCN Red List (Reeves et al. 2003). There is no designated critical habitat for this species in the North Pacific. As an endangered species under the ESA, the humpback whale is designated as depleted under the MMPA and, as a result, is classified as a strategic stock (Angliss et al. 2005).

Recent information from photo-identification studies and genetic work suggests that there are probably three stocks or populations in the North Pacific: Eastern, Central, and Western North Pacific stocks (Baker et al. 1998; Calambokidis et al. 2001; Carretta et al. 2005). Calambokidis et al. (2001) further suggested that up to six subpopulations of humpback whales in the North Pacific Ocean might be recognized. Site fidelity to feeding areas is very high, but there is at least occasional interchange among different breeding areas (Salden et al. 1999; Calambokidis et al. 2001). Most individuals that breed in Hawai'i travel to waters of Alaska to feed (Calambokidis et al. 2001). The Hawaiian breeding group shares some genetic inter-relatedness with the group that breeds off the coast of Mexico (Baker et al. 1998) and even off Japan (Salden et al. 1999; Darling and Mori 1993), but it is rare enough that these are still considered to be separate management stocks.

Humpback whales in Japanese waters are considered to be from the Western North Pacific stock (Angliss and Outlaw 2005). The Western North Pacific stock of humpback whales is clearly the smallest of the various North Pacific stocks. Using mark-recapture analysis of photo-identification data, Calambokidis et al. (1997) derived an estimate of 400 whales for the Western North Pacific stock in 1993, although this estimate is probably biased downwards. The minimum population estimate for the Western North Pacific stock of humpback whales is considered to be 367 individuals (Angliss and Outlaw 2005).

Habitat Preferences—Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (Miyashita et al. 1996; Mori et al. 1998; Clapham and Mead 1999). Shallow banks or ledges with high sea-floor relief characterize feeding grounds (Payne et al. 1990; Hamazaki 2002). The habitat requirements of wintering humpbacks appear to be determined by the conditions necessary for calving. Breeding grounds are in tropical or subtropical waters, generally with shelter created by islands or reefs. Optimal calving conditions are warm water (24° to 28°C) and relatively shallow, low-relief ocean bottom in protected areas (behind reefs), apparently to take advantage of calm seas, to minimize the possibility of predation by sharks, or to avoid harassment by males (Smultea 1994; Craig and Herman 2000; Clapham 2000). Females with calves occur in significantly shallower waters than other groups of whales, and breeding adults use deeper, more offshore waters (Smultea 1994; Ersts and Rosenbaum 2003).

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

North Pacific humpback whales are distributed primarily in four more-or-less distinct wintering areas: the Ryukyu and Ogasawara (Bonin) Islands (south of Japan), Hawai'i, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). In the western North Pacific, whales use the waters around the Ogasawara and Ryukyu Islands as a major breeding ground in winter and spring (December through May) (Mori et al. 1998). The peak abundance of humpback whales occurs in February (Mori et al. 1998). Individuals have also been sighted in the breeding areas during the summer months (Uchida 1985). There is known to be some interchange of whales among different wintering grounds, and matches between Hawai'i and Japan, and Hawai'i and Mexico have been found (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2000, 2001; **Figure 3-1**). However, it appears that the overlap is relatively small between the Western North Pacific humpback whale population and Central and Eastern North Pacific populations (Darling and Mori 1993; Calambokidis et al. 2001).

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

In addition to Japanese waters, humpbacks have been documented in recent years off Taiwan and the Philippines (Yamaguchi et al. 2002) although it is not known if whales are breeding in these latter areas or simply using them as stopover points. The waters of the Ogasawara and the Ryukyu Islands off Japan are considered to be one of the main wintering grounds for humpback whales of the western North Pacific population (Mori et al. 1998). Individuals from the Ogasawara Islands have also been sighted in Okinawa, indicating that both regions are used by the same population during breeding seasons (Darling and Mori 1993; Uchida 1997). Mori et al. (1998) suggested that calving

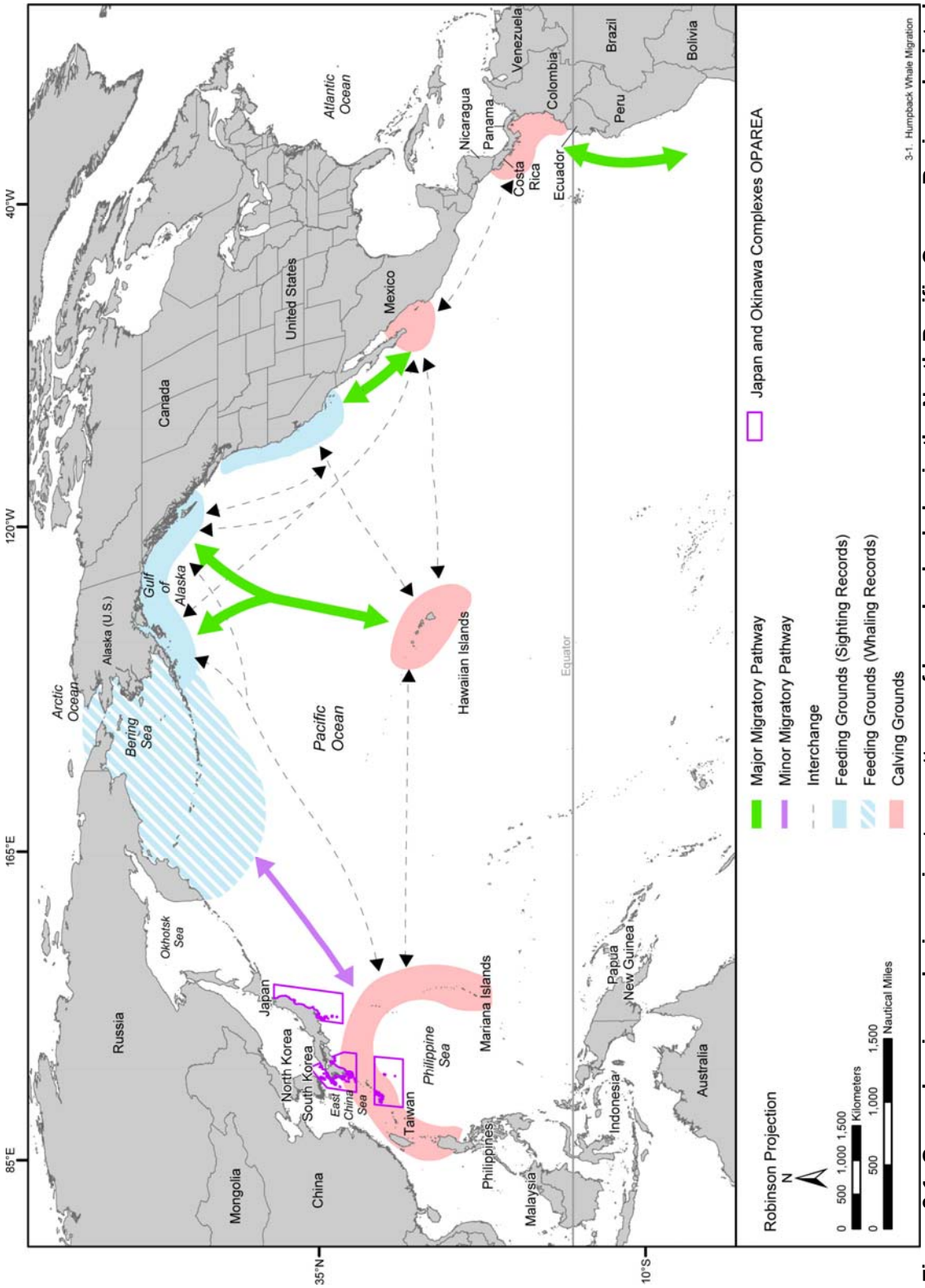

Figure 3-1. General major and minor migratory patterns of humpback whales in the North Pacific Ocean. Regions depicted with solid shading are defined by current observations of seasonal return by naturally marked individuals. Regions depicted with striped shading are defined by historical patterns of distribution during periods of commercial whaling. Source information: Baker et al. (1990) and Jefferson personal communication.

might actually take place in waters with slightly higher temperatures than the waters of the Ogasawara Islands, for example, in the lower latitudes along the Ogasawara Islands rim, possibly extending from the Kazan Retto to the Northern Mariana Islands. The historical winter range in the western North Pacific included the waters around Taiwan, Hainan Island, and the Mariana and Marshall islands (Darling and Mori 1993). Darling and Mori (1993) suggested that the recent humpback whale sightings off Saipan might indicate that the range of the population is currently expanding, or alternatively, these could just be a few wayward individuals. In addition, humpback whales have recently been observed in the Babuyan Islands off the northern Philippines, raising the question as to whether this also may have been part of their traditional wintering range (Yamaguchi et al. 2002).

During summer months, North Pacific humpback whales feed in a nearly continuous band from southern California to the Aleutian Islands, Kamchatka Peninsula, and the Bering and Chukchi seas (Calambokidis et al. 2001; **Figure 3-1**). There is much interchange of whales among different feeding grounds although some site fidelity is the rule. Whales migrate between the Mexican breeding ground and feeding grounds along the west coast of the continental U.S. using a corridor along the coast of Baja California (**Figure 3-1**). The primary feeding range of the Western North Pacific humpback stock is not known. Mark recoveries from whaling operations suggest connections with summering areas in the Okhotsk and Bering Seas, off Kamchatka, and the Aleutian Islands (Nishiwaki 1966; Ohsumi and Masaki 1975). There are recent photo-identification matches to the Gulf of Alaska, southeast Alaska, and the Pacific Northwest (Calambokidis et al. 2001). However, there are also indications of genetic associations of Ogasawara humpbacks with the North American coastline (Baker et al. 1998), and some Western North Pacific humpbacks apparently feed off British Columbia (Darling et al. 1996; Calambokidis et al. 1997). Recent photo-identification research also supports the possibility of humpback whales using Russia as a major summer feeding ground (Yamaguchi and Burdin 2003). The paucity of photo-identification data for the Aleutian Islands, Bering and Okhotsk seas, and Kamchatcka waters may be somewhat masking the true identity of the primary feeding grounds, but this remains to be tested. Also, it seems reasonable to assume that the aggregation of humpbacks that feeds around Kodiak Island (Waite et al. 1999) may largely represent individuals from the Western North Pacific stock.

The humpback whale has one of the longest migrations known for any mammal; individuals can travel nearly 8,000 km from feeding to breeding areas (Clapham and Mead 1999). The exact migration corridor of whales moving between the Hawaiian breeding ground and the Alaskan feeding ground is not known, although it is clear that whales migrate through deep, oceanic waters. Similarly, the specific migration route of whales between Japanese breeding grounds and the apparent Aleutian Island/Bering Sea/Gulf of Alaska feeding grounds is not clear. Some evidence suggests that humpback whales may migrate north through the Sea of Japan and past Hokkaidō and the Kuril Islands in the Okhotsk Sea (Omura and Ohsumi 1964; Nishiwaki 1966; Yamada et al. 1998). It is possible that humpback whales in Japan may migrate more than 4,000 km to feeding grounds along the Pacific rim from northern Japan to Alaska (Darling and Mori 1993; Darling et al. 1996). Humpback whales identified in the Ogasawara Islands have also been sighted in the British Columbia feeding grounds (Darling et al. 1996; Calambokidis et al. 2001). Migratory transits between Hawai'i and southeastern Alaska have been documented to take as little as 36 to 39 days (Gabriele et al. 1996; Calambokidis et al. 2001). Based on Japanese whaling records, the migratory sequence of arrival on the Ryukyu Islands grounds is that immature whales arrive first, following by adult males and non-pregnant females, while late pregnant females and those with newborn calves arrive last (Nishiwaki 1966).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Humpback whales use Japanese waters as a major breeding ground during the winter-spring period (December through May with peak abundance in February). 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). Miyazaki and Nakayama (1989) noted catches off the Amami Islands during the whaling season of December to April. Some humpback whales are also taken in the coastal waters as bycatch (Brownell personal communication). During the winter-spring period, an area of

expected occurrence extends south of 30°N and connects the Ogasawara and Ryukyu Islands to account for animals moving between these breeding areas and other breeding grounds in the Marianas, Phillippines, and Taiwan (**Figure A-3**). There is an area of concentrated occurrence that extends from the shoreline out to around 100 NM (185 km) offshore of the Ogasawara and Ryukyu Islands (**Figure A-3** and **A-4**). This takes into consideration sighting records and the preferred breeding habitat in shallow, coastal waters. There is a low or unknown occurrence seaward of the shelf break around the Ogasawara and Ryuku Islands and throughout the rest of the Japan and Okinawa Complexes OPAREA to account for migrating individuals. During the summer-fall period, there is a low or unknown occurrence seaward of the shelf break, north of 35°N, to account for early and late season migrants (**Figure A-3**). Most of the population is expected to occur on feeding grounds north of the OPAREA during this time of year.

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

Humpback whales feed on a wide variety of invertebrates and small schooling fishes. The most common invertebrate prey are euphausiids (krill); the most common fish prey are herring, mackerel, sand lance, sardines, anchovies, and capelin (Nishiwaki 1959; Clapham and Mead 1999). These whales are lunge feeders, taking in huge batches of prey items as they lunge laterally, diagonally, or vertically through patches of prey (Clapham 2002). Feeding behavior is highly diverse, and humpbacks employ unusual behaviors, such as bubble netting, to corral prey (Jurasz and Jurasz 1979; Weinrich et al. 1992). This is the only species of baleen whale that shows some evidence of cooperation when feeding in large groups (D'Vincent et al. 1985). Humpback whales are not typically thought to feed on the wintering grounds; however, Salden (1989) observed apparent feeding by a juvenile humpback whale off Hawai'i.

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

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

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

The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males (Helweg et al. 1992). Singing is most common on breeding grounds during the winter and spring months, but is occasionally heard outside breeding

areas and out of season (Matilla et al. 1987; Clark and Clapham 2004). Humpback song is an incredibly elaborate series of patterned vocalizations, which are hierarchical in nature (Payne and McVay 1971; Guan et al. 1999). There is geographical variation in humpback whale song, with different populations singing different songs, and all members of a population using the same basic song. The song evolves over the course of a breeding season but remains nearly unchanged from the end of one season to the start of the next (Payne et al. 1983).

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

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

- Sei Whale (*Balaenoptera borealis*)

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

Status—Sei whales are listed as endangered under the ESA; they are also designated as endangered by the IUCN Red List (Reeves et al. 2003). The IWC designates the entire North Pacific Ocean as one sei whale stock unit (Donovan 1991), although some evidence exists for multiple stocks (NMFS 1998a; Carretta et al. 2005). There are no abundance estimates available for this species in this area.

The taxonomy of the baleen whale group formerly known as sei and Bryde’s whales is currently confused and highly controversial (see Reeves et al. 2004 for a recent review, also see the Bryde’s whale species account below for further explanation). It clearly consists of three or more species, but the final determination will have to await additional studies.

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

Distribution—Sei whales have a worldwide distribution, but are found primarily in cold temperate to subpolar latitudes, rather than in the tropics or near the poles (Horwood 1987). Sei whales are also

known for occasional irruptive occurrences in areas followed by disappearances for sometimes decades (Horwood 1987; Schilling et al. 1992; Clapham et al. 1997).

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence patterns for the sei whale in this OPAREA were determined by examining Horwood (1987) and Springer et al. (1999), both of which compiled and reviewed Japanese occurrence records (primarily whaling catches) for the species. The exact limits of this species' occurrence in the OPAREA are unknown because of many previous misidentifications with Bryde's whales (Jefferson personal communication). Systematic surveys could address this particular question in the future. The sei whale is an oceanic species. During the winter-spring, the area of expected occurrence extends south to about 32°N on the Pacific coast of Japan due to cooler water temperatures. 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). There is a low or unknown occurrence for this species elsewhere in the OPAREA, seaward of the shelf break. During the summer-fall, sei whales are expected to occur seaward of the shelf break north of the Chiba prefecture on Honshū (**Figure A-5**). There is a low or unknown occurrence for this species elsewhere in the OPAREA, seaward of the shelf break. This takes into account the 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 (NMFS 1998a).

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

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

- Fin Whale (*Balaenoptera physalus*)

Description—The fin whale is the second-largest whale species, with adults reaching 24 m in length and females growing somewhat larger than males (Jefferson et al. 1993). Fin whales have a very sleek body, with a pale, V-shaped chevron on the back, just behind the head. The dorsal fin is prominent, but with a shallow leading edge and is set back two-thirds of the body length from the head (Jefferson et al. 1993). The head color is asymmetrical, with a lower jaw that is white on the

right and black or dark gray on the left. Fin and sei whales are very similar in appearance, which has resulted in confusion about the distribution of both species (NMFS 1998a).

Status—Fin whales are classified as endangered under the ESA and are designated as endangered by the IUCN Red List (Reeves et al. 2003). There is no designated critical habitat for this species in the North Pacific. The IWC recognizes two management stocks in the North Pacific: a single widespread stock in the North Pacific and a smaller stock in the East China Sea (Donovan 1991). There are some very old and outdated estimates of abundance 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 1966).

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

Distribution—Fin whales are broadly distributed throughout the world's oceans, usually in temperate to polar latitudes, and less commonly in the tropics (Reeves et al. 2002). Fin whales are distributed across the North Pacific during the summer (May through October) from the southern Chukchi Sea (69°N) south to the Subarctic Boundary (approximately 42°N) and to 30°N in the California Current (Mizroch et al. 2005). They have been observed during the summer in the central Bering Sea (Moore et al. 2000). During the winter (November through April), fin whales are sparsely distributed from 60°N south to the northern edge of the tropics, near which it is assumed that mating and calving take place (Mizroch et al. 2005). However, some fin whales have been sighted as far north as 60°N all winter (Mizroch et al. 2005). 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). There is also some evidence of a resident population of fin whales in the Gulf of California, Mexico (Tershy et al. 1993). Such cases indicate that not all members of the species necessarily make the long, north/south migrations that are typical of the species.

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence patterns portrayed in **Figure A-6** are based mostly on Nishiwaki (1966, 1967) and Mizroch et al. (2005). During winter-spring, the expected occurrence of the fin whale is from the middle of Honshū south (beyond the shelf break) to account for the presumed breeding area occupancy, which is supported by Mizroch et al. (2005). The area of expected occurrence extends into the Sea of Japan, as there is evidence of a resident stock there (Mizroch et al. 2005). There is a low or unknown occurrence for the fin whale to the north, beyond the shelf break. This also accounts for a possible resident stock off the northeast coast of Honshū (Mizroch et al. 2005). During summer-fall, expected occurrence is north of 35°N (beyond the shelf) to account for most of the population being on northern feeding grounds (Mizroch et al. 2005). Occurrence is also expected occurrence in the Sea of Japan, due to evidence of a resident stock there. There is a concentrated occurrence in the East China Sea, south of 30°N, due to evidence for a major whaling ground there (Mizroch et al. 2005). The area of low or unknown occurrence in the southern area (off the shelf) accounts for other possible non-migrators and potential residents.

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

Female fin whales in the North Pacific mature at 8 to 12 years of age (Boyd et al. 1999). Peak calving is in October through January (Hain et al. 1992) after a gestation period of approximately 11 months. Weaning may occur at 6 months (Boyd et al. 1999). The calving interval for fin whales ranges between 2 to 3 years (Agler et al. 1993).

Fin whale dives are typically 5 to 15 min, separated by sequences of 4 to 5 blows at 10 to 20 s intervals (CETAP 1982; Stone et al. 1992; Lafortuna et al. 2003). Kopelman and Sadove (1995) found significant differences in blow intervals, dive times, and blows per hour between surface-feeding and non-surface-feeding fin whales. Croll et al. (2001) determined that fin whales dived to 97.9 (±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. Fin whale dives exceeding 150 m and coinciding with the diel migration of krill were reported by Panigada et al. (1999).

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

- Blue Whale (*Balaenoptera musculus*)

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

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

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

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

The range of the blue whale is known to encompass much of the North Pacific Ocean, from Kamchatka (Russia) to southern Japan in the west, and from the Gulf of Alaska south to at least

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—Very little information is available for this species. Miyazaki and Nakayama (1989) reported that a blue whale stranded in the Amami Islands during 1913. There are no recent records of blue whales in Japanese waters; the blue whale population that historically occurred in Japanese coastal waters is likely extinct (Brownell personal communication). The occurrence patterns portrayed in **Figure A-7** are based mostly on Nishiwaki (1967), with some assumptions regarding seasonal migrations and possible residency from information available from the eastern North Pacific. During winter-spring, there is an expected occurrence for the blue whale in the southern part of this area, beyond the shelf break, based on the assumption that animals would mostly be on the breeding grounds. There is a low or unknown occurrence in the Sea of Japan, East China Sea, and the northeast part of the OPAREA. During summer-fall, there is a low or unknown occurrence for the blue whale throughout the entire area seaward of the shelf break (except in the East China Sea and Sea of Japan), due to unknown feeding areas which are presumably north of this area. The area of low or unknown occurrence accounts for possible non-migrators and potential resident animals in the more southern portions of the range (as is known in the eastern North Pacific).

Behavior and Life History—Blue whales are found singlely or in groups of 2 or 3 (Yochem and Leatherwood 1985). As noted by Wade and Friedrichsen (1979), apparently solitary whales are likely part of a large dispersed group. Blue whales, like other rorquals, feed by "gulping" (Pivorunas 1979) almost exclusively on krill (Nemoto and Kawamura 1977). Female blue whales reach sexual maturity at 5 to 15 years of age (Yochem and Leatherwood 1985). There is usually a 2 year interval between calves. Calving occurs primarily during the winter (Yochem and Leatherwood 1985).

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

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

- Gray Whale (*Eschrichtius robustus*)

Description—Gray whales are easily identified by their mottled grayish-brown color and the white to orangish patches of whale lice and barnacles attached to their bodies, particularly their heads and tails (Jefferson et al. 1993). Instead of a dorsal fin, there is a dorsal hump followed by a series of 6 to 12 smaller knobs or bumps along the dorsal ridge of the tail stock (Jefferson et al. 1993). The flippers are paddle-shaped with pointed tips. The upper jaw is moderately arched, and the head appears triangular and narrow when viewed from the top (Jefferson et al. 1993). Adults are 11 to 15 m in length and weigh up to 35 metric tons (mt) (Jefferson et al. 1993); females are slightly larger than males (Leatherwood et al. 1988).

Status—There are two extant populations of gray whales, the eastern (California-Chukchi) and the western (Korean-Okhotsk) Pacific populations (LeDuc et al. 2002). The eastern population has recovered from overexploitation in the late 1800s and early 1900s and was removed from listing under the ESA in 1994. The western Pacific population, which may number only around 100 individuals, is designated as endangered under the ESA and critically endangered by the IUCN Red List and shows no apparent signs of recovery (Brownell et al. 1999; Reeves et al. 2003).

Habitat Preferences—Gray whales primarily occur in shallow waters over the continental shelf (Jones and Swartz 2002). When migrating, they periodically travel near the surface over deep water due to changes in bottom contour, such as nearshore submarine canyons (Moore and Ljungblad 1984; Crane and Lashkari 1996). The feeding grounds in the eastern North Pacific are generally less than 68 m deep (Nerini 1984; Jones and Swartz 2002). Western Pacific gray whales primarily feed in waters less than 20 m deep and within 5 km of the shore (Weller et al. 2002a). Breeding grounds in the western North Pacific are unknown but may be in coastal waters of the South China Sea (Jones and Swartz 2002). The breeding grounds in the eastern North Pacific 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 2002). These warm-water, protected lagoons are more conducive to the rearing of calves and mating and offer protection from predation by killer whales and large sharks (Swartz 1986). 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 2002).

Distribution—Gray whales are found only in the North Pacific. 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 2002). The eastern North Pacific population is found from the upper Gulf of California (Tershy and Breese 1991), south to the tip of Baja California and up the Pacific coast of North America to the Chukchi and Beaufort Seas (Jefferson et al. 1993).

The western North Pacific population is distributed off the coast of Russia, Japan, North Korea, South Korea, and China (Weller et al. 2002b). 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. 1999; Weller et al. 2002a). 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 2002; Kato and Kasuya 2002). During the north-south migration, western gray whales remain in shallow, nearshore waters, except when passing through the La Perouse and Tartarskiy 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. 2002b).

Prior to the turn of the 20th century, two groups of gray whales may have migrated to Japanese waters (Omura 1984). 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; Omura 1984). 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; Omura 1984). Omura (1974) 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 due to the increase in industrial development and boat traffic in this area. Despite Omura's (1974) claim, researchers have since argued that it is unlikely that the Seto Inland Sea was ever a calving or mating area for western North Pacific gray whales (Weller et al. 2002b).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The highly endangered status of this species necessitates an extremely conservative determination of its occurrence in the Japan and Okinawa Complexes OPAREA (Jefferson personal communication). Recent sightings and strandings of gray whales south of the Okhotsk Sea are rare (Brownell and Kasuya 1999). However, several records of gray whales off Hokkaidō suggest that few gray whales migrate through this area (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).

  Occurrence patterns are based largely on whaling and sighting records (Omura 1974, 1988; Kato and Kasuya 2002). Due to the lack of specific information on migration patterns for this very small population and to account for the probability that the monthly spreads of both seasons span both northward and southward migrations, occurrence is assumed to be similar year-round. Occurrence is expected in a narrow band extending 50 NM (93 km) off the coast (not including bays), all along the east coast of Japan, and extending to around the Ryukyu Islands (**Figure A-8**). It also extends into the East China Sea and Sea of Japan (Tsushima Strait) based on possible movement patterns towards winter breeding grounds off the coast of Korea in the South China Sea. There is a low or unknown occurrence in the bays and inland seas, as well as offshore another 50 NM (93 km), to account for offshore migrants and strays into inshore waters (**Figure A-8**).

Behavior and Life History—On the feeding grounds, gray whales are often solitary but may be in close proximity to each other at food-rich areas (Leatherwood et al. 1988; Weller et al. 2002a). During migration, gray whales are predominantly solitary; groups of more than 6 are rare (Rice and Wolman 1971; Leatherwood et al. 1988). In the eastern North Pacific, the sequence of southward migration begins with females in late pregnancy, followed by females that have recently ovulated, adult males, immature females, and then immature males (Rice et al. 1984). In the breeding lagoons, female-calf pairs and groups of consorting adults and juveniles are most common (Swartz 1986). Female-calf pairs are concentrated in the inner lagoons and primarily rest, nurse, and move about with the changing tides (Swartz 1986). Courting whales congregate near the lagoon inlets and are mostly engaged in social activities related to courtship and mating (Swartz 1986). Northward migration begins with newly pregnant females, followed by anestrous females, adult males, and immature males and females. Females with calves are the last to leave the lagoons (Rice et al. 1984).

Males and females both attain sexual maturity at about 8 years (Rice et al. 1984). The gestation period is around 13.5 months (Rice et al. 1984). The calving season in the eastern North Pacific is from January through March; weaning occurs within 9 months (Rice and Wolman 1971).

Gray whales are predominantly bottom feeders (Weller et al. 2002a). They filter amphipods and other crustaceans by engulfing sediments from the sea floor and straining the prey out with their baleen plates (Nerini 1984). The whales carry most of the sediment with them when they surface to breathe, creating mud plumes in their wake (Rugh and Fraker 1981). Gray whales occasionally engulf fishes and skim the surface for prey (Sund 1975; Wellington and Anderson 1978). Although fasting is the rule, opportunistic feeding may occur in or near the calving lagoons (Norris et al. 1977) or in the

shallow coastal waters along the migration path in the eastern North Pacific (Braham 1984; Sund 1975).

When foraging, gray whales typically dive to 50 to 60 m for 5 to 8 min. In the breeding lagoons of the eastern North Pacific, dives are usually less than 6 min (Jones and Swartz 2002), although dives as long as 26 min have been recorded (Harvey and Mate 1984). 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 2002).

Migrating gray whales off California sometimes exhibit a unique "snorkeling" behavior in which they surface cautiously, exposing only the area around the blow hole, exhale quietly without a visible blow, and sink silently beneath the surface (Jones and Swartz 2002).

Acoustics and Hearing—Au et al. (2000) reviewed the characteristics of gray whale vocalizations. Gray whales produce broadband signals ranging from 100 Hz to 4 kHz (and up to 12 kHz) (Dahlheim et al. 1984; Jones and Swartz 2002). The most common sounds on the breeding and feeding grounds are knocks (Jones and Swartz 2002), which are broadband pulses from about 100 Hz to 2 kHz and 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 et al. 1968). During migration, individuals most often produce low-frequency moans (Crane and Lashkari 1996).

The structure of the gray whale ear is evolved for low-frequency hearing (Ketten 1992). The ability of gray whales to hear frequencies below 2 kHz has been demonstrated in playback studies (Cummings and Thompson 1971; 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 (e.g., Moore and Clarke 2002).

- Sperm Whale (*Physeter macrocephalus*)

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

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

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

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—Globally, sperm whales are typically distributed in waters over the shelf break and continental slope. They regularly occur throughout the entire Japan and Okinawa Complexes OPAREA. Sperm whales are expected to occur seaward of the shelf break in the Japan and Okinawa Complexes OPAREA including in the south Sea of Japan and East China Sea (**Figure A-9**). In some locales, sperm whales also may be found in waters less than 100 m deep (Scott and Sadove 1997; Croll et al. 1999); sperm whales have frequently been sighted near coastal areas in Japan (Yoshioka et al. 1999). To account for the possibility of encountering this species in shallow waters, there is a low or unknown sperm whale occurrence from the shoreline to the shelf break along the east coast of Japan and around the Ryuku and Ogasawara Islands (**Figure A-9**). 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, particulary off the coast of Cape Muroto, an area known for sperm whale watching (Hoyt 1993). Whaling grounds are located off the coast of Hokkaidō, Sanriku, Boso, and the Ogasawara Islands (Kasuya and Miyashita 1988). Miyazaki and Nakayama (1989) noted whaling catches off the Amami Islands during the whaling season of December to April. There is some north-south movement along the east coast of Japan; female groups are known to move north in the summer (to breed north of the Kuroshio/Oyashio front off 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, 1999a; Mori et al. 1999). Occurrence patterns are assumed to be similar throughout the year.

Behavior and Life History—Female sperm whales live a highly social life, while large male sperm whales typically occur alone or in pairs, at times joining groups of adult females for breeding (Whitehead 2003). Female and immature sperm whales form groups that move together in a coordinated fashion over periods of days (Whitehead 2003). Mean group size is approximately 20 to 30 individuals, although there is much variation (Whitehead 2003). For a review of sperm whale social

organization, see Whitehead and Weilgart (2000) and Whitehead (2003). Mating behavior is observed from winter through summer and calving during spring through fall. Gestation is 14 to 15 months, lactation is approximately 2 years, and the typical inter-birth interval is 4 to 7 years. Sperm whales prey on large mesopelagic squid and other cephalopods, as well as demersal fishes and occasionally benthic invertebrates (Rice 1989; Clarke 1996; Springer et al. 1999).

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

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

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

- Steller Sea Lion (*Eumetopias jubatus*)

Description—The Steller sea lion, or northern sea lion, is the largest eared seal species. The average male is 2.8 m long and weighs 566 kg. Females are quite a bit smaller with an average length and weight of 2.3 m and 263 kg, respectively (Loughlin 2002). They are quite robust, with a thick snout. Adult coloration is pale yellow to light tan on the dorsal side with dark, reddish brown shading on the flippers and underside of the body (Jefferson et al. 1993).

Status—The Steller sea lion is designated as endangered on the IUCN Red List (IUCN 2004). There are two distinct populations of Steller sea lions based on genetics and population trends (Loughlin 1997; Angliss and Outlaw 2005). The western U.S. stock includes animals at and west of Cape Suckling, Alaska (144°W), while the eastern U.S. stock includes all the animals east of Cape Suckling (NMFS 1997; Angliss and Outlaw 2005). Steller sea lions in Russia are currently considered part of the western U.S. stock; however, genetic evidence suggests that this may be a third stock (Angliss and Outlaw 2005). Individuals that make their way into Japanese waters are from this western stock. The western stock of Steller sea lions is listed as endangered under the ESA, and is therefore a

strategic stock for NMFS (Angliss and Outlaw 2005). Conflict with commercial fisheries is the main reason for the decline of Steller sea lions in Japan (Wada 1988).

Designated critical habitat for both the western and eastern U.S. stocks includes a 37 km buffer around all major haulouts and rookeries; associated terrestrial, air, and aquatic zones; and three large offshore foraging areas in Alaska (NMFS 1997; **Figure 3-2**).

Habitat Preferences—Foraging habitat is primarily shallow, nearshore and continental shelf waters; some Steller sea lions even feed in freshwater rivers (Reeves et al. 1992; Robson 2002). Steller sea lions are also known to feed in deep waters past the shelf break (Jefferson personal communication). Steller sea lions in the Bering Sea regularly haul out on pack ice near the ice front during winter. Pack ice offers close proximity to prey and protection from terrestrial predators (Riedman 1990). Other haulout and rookery sites are located on isolated islands and rocky shorelines throughout their range (NRC 2003).

Distribution—The range of the Steller sea lion extends throughout most of the North Pacific from southern California through the Aleutian and Pribilof Islands to the Kuril Islands and Okhotsk Sea, to Japan (Kenyon and Rice 1961). Major haulout sites and rookeries are centered in the Aleutian Islands and at islands and mainland sites in the Gulf of Alaska (Loughlin et al. 1984; **Figure 3-2**). In Asia, Steller sea lions breed on the Kuril Islands, along the Kamchatkan Coast, and on islands in the Okhotsk Sea (Loughlin et al. 1984). There are no Steller sea lion rookeries in Japan, but Steller sea lions haul out along the coast of Hokkaidō during October through May. These individuals are from the Kuril Islands and small islands around Sakhalin (Ishinazaka and Endo 1999; Wada 1998; Watanabe et al. 2003). Steller sea lions from the Kuril Islands have been sighted as far south as Yokohama, Japan, and in the Yellow Sea in China (Loughlin 2002).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Steller sea lions are only found on Hokkaidō (Nishiwaki and Nagasaki 1960; Wada 1988). They are expected to be rare in the Japan and Okinawa Complexes OPAREA. Although they commonly occur from Hokkaidō to the north, there are extralimital records south to Jiangsu Province, China (Zhou 1991). Based on their tendency to disperse widely and the extralimital records, there is a low or unknown occurrence of Steller sea lions from the coast to about 100 to 150 NM (185 to 278 km) offshore of the OPAREA and north of 35°N (Loughlin 2002; **Figure A-10**). Occurrence patterns are similar throughout the year.

Behavior and Life History—Steller sea lions are gregarious animals. They do not migrate but often disperse widely during the nonbreeding season (Loughlin 2002). At sea, groups usually consist of females and subadult males; adult males are usually solitary while at sea (Loughlin 2002). On land, Steller sea lions form large rookeries during late spring when adult males arrive and establish territories (Pitcher and Calkins 1981). Large males aggressively defend prime territories while nonbreeding males remain at peripheral sites or haulouts (Pitcher and Calkins 1981). Females arrive soon after the males and give birth to a single pup within a few days (Pitcher and Calkins 1981). Most births occur from mid-May through mid-July, and mating takes place about 10 days postpartum (Pitcher and Calkins 1981). Due to delayed implantation, fetal development does not begin until late September or October (Pitcher and Calkins 1981). Most pups are weaned within a year (Pitcher and Calkins 1981). Females reach sexual maturity between 4 to 5 years of age; most males become sexually mature by the age of 8 (Pitcher and Calkins 1981).

Steller sea lions are opportunistic predators, feeding primarily on fishes and cephalopods. The diet varies geographically and seasonally (Merrick et al. 1997). In Hokkaidō, Steller sea lions mainly feed on walleye pollock, Pacific cod (*Gadus macrocephalus*), saffron cod (*Eleginus gracilis*), cephalopods, and flatfishes (Goto and Shimazaki 1998).

Diving and foraging activity varies by sex, age, and season. During the breeding season, females with pups feed mostly at night, while territorial males eat little or no food (Loughlin 2002). In the winter,

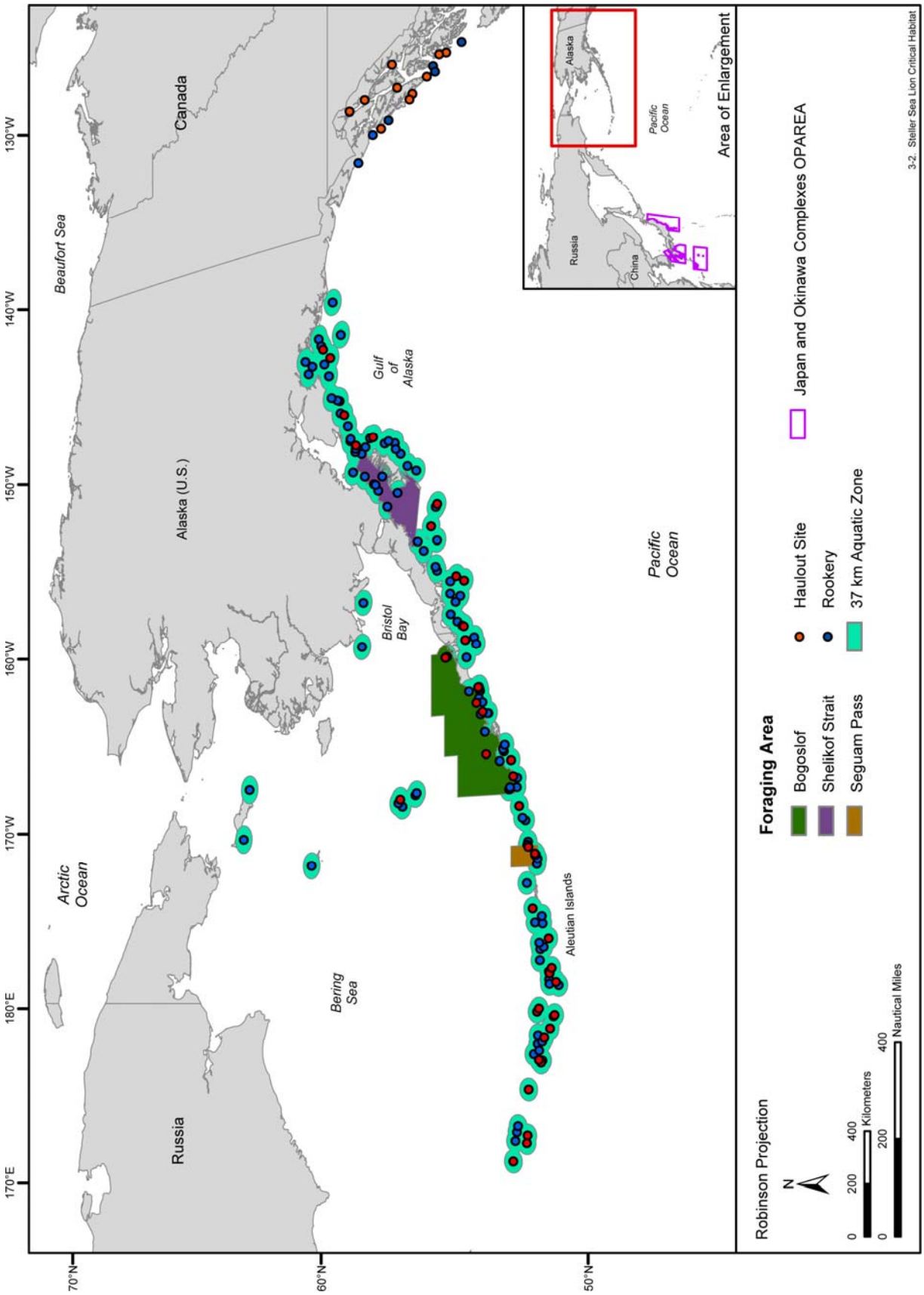

Figure 3-2. Steller sea lion rookeries designated as critical habitat. Source data: NMFS (1993).

females make long trips of around 130 km and dive deep to locate prey (Merrick and Loughlin 1997; Loughlin 2002). In the summer trip length is about 17 km and dives are shallower (Loughlin 2002). Females usually go to sea to feed and return to nurse their pups in 24 to 48 hr cycles (NRC 2003). Steller sea lions tend to make shallow dives less than 250 m. Adult females are known to dive 100 to 250 m in summer, but maximum depth in the winter may be greater than 250 m (Loughlin 2002). Juvenile Steller sea lions make shallow (70 to 140 m) and short (1 to 2 min) dives and do not travel as far as adults due to developmental constraints (Merrick and Loughlin 1997; Rehberg et al. 2001).

Acoustics and Hearing—In-air territorial male Steller sea lion sounds are usually low frequency roars, while females vocalize less and at a higher frequency (Schusterman et al. 1970; Loughlin et al. 1987). Campbell et al. (2002) determined that females have distinctive acoustic signatures. These calls range in frequency from 30 to 3,000 Hz, with peak frequencies from 150 to 1000 Hz; typical duration is 1,000 to 1,500 ms (Campbell et al. 2002). Pups produce bleating sounds. Underwater sounds are like the in-air signals (Loughlin et al. 1987). There is no published information on the hearing range of the Steller sea lion.

- Dugong (*Dugong dugon*)

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

Status—The dugong is listed as endangered under the ESA throughout its entire range (USFWS 2003) and is designated as endangered by the IUCN Red List (Marsh et al. 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 dugong at Okinawa is designated as a protected animal ("tennen-kinenbutsu," literally meaning natural monument) under Japanese law; it is considered an important component of the culture and history of native Okinawans (see Chapter 1 for more information). There are no abundance estimates (Kasuya 1999b; MMC 2005), but recent surveys have sighted fewer than dozen animals (MMC 2005). Genetic analyses demonstrate that the Okinawan and Phillipine populations share the same mtDNA structure (Yoshida and Trono 2004).

Habitat Preferences—The dugong generally frequents coastal waters, but unlike manatees, it strictly occurs in marine waters. This species tends to concentrate in wide, shallow protected bays; wide, shallow, mangrove channels; and in the lees of large inshore islands (Marsh et al. 2002). These areas are coincident with sizeable seagrass beds (Marsh et al. 2002). Shallow waters, such as tidal sandbanks and estuaries, have also been reported sites for calving (USFWS 2003). Dugongs in Australia are also regularly observed in deeper water further 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* that occurs in western Australia waters (Anderson 1994; Marsh et al. 2003). Dugong feeding trails have been observed at depths of up to 33 m off northeastern Queensland, Australia (Marsh et al. 2002).

Dugongs are able to undertake long-distance movements. Whiting (1999) reported dugongs, including calves, at Ashmore Reef on the Sahul Banks at the edge of the Australian continental shelf. Although Ashmore Reef is only 140 km from the Indonesian island of Roti; the Timor Trough, which is 2,000 m in depth, separates these locations (Marsh et al. 2002). The capacity of dugongs to cross deep ocean trenches (up to 4 km in depth) is also supported by recent reports of dugongs at Aldabra Atoll, which is located 425 km from Madagascar; dugongs had not previously been observed at this atoll (Marsh et al. 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 the availability of prey plants in one area (Gales et al. 2004).

Distribution—The dugong's historic distribution is believed to have been broadly coincident with the tropical Indopacific distribution of its food plants, the seagrasses of the families Potamogetonaceae and Hydrocharitaceae (Husar 1978). Currently, the dugong has a large range that spans at least 37 countries and territories and includes tropical and subtropical coastal and inland waters from east Africa to Vanuatu, between about 26° and 27° north and south of the equator (Nishiwaki et al. 1979; Marsh et al. 2002). The Okinawa islands are thought to be the northernmost limit of the dugong's range. This distribution is disjunct, reflecting habitat availability and human activities. Over most of its range, the dugong is known only from incidental sightings, accidental drownings, and the anecdotal reports of fishermen (Marsh et al. 2002).

- Information Specific to the Japan and Okinawa Study Area—In Japanese waters, the dugong is only known from Okinawa Island (Kasuya 1999b, 2001). There is an expected occurrence for the dugong from the shore to the shelf break around all of Okinawa (**Figure A-11**) which takes into account sighting, stranding, and fishery bycatch records reported by Dugong Network Okinawa (DNO 2001). There is a concentrated occurrence off the east coast of Okinawa, from the shore out to the shelf break which takes into account the high density of sightings there (DNO 2001; Yoshida and Trono 2004), along with information suggesting that the density is high on the east coast and sightings extend offshore to waters with a bottom depth of at least 90 m (Kasuya personal communication). 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 the primary location for this population (Kasuya and Brownell 2001). 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 1999b). Kasuya (1999b) noted that there are 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. There is a low or unknown occurrence extending 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 takes into account 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); the 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 patterns are anticipated to be similar throughout the year. It should be noted that it has been speculated that during the daytime, dugongs are found outside the reef and during the nighttime, come into inshore feeding areas.

  In September 2002, an adult dugong was found dead on the Ushibuka coast of Kyūshū (approximately 750 km north of Okinawa; Yamamuro et al. 2004). This individual is considered to be extralimital (Jefferson personal communication), since Yamamuro et al. (2004) noted that it appeared the animal had been feeding further south than the area where it stranded and it is well-established that the northern range for the species is Okinawa.

  There have been few aerial surveys at Okinawa for the dugong. During 1998, 10 dugongs were recorded off the east coast of middle and northern Okinawa Island, where previous sightings and mortalities were concentrated (Kasuya 1999b; 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 (MMC 2005). Subsurface feeding trails were confirmed in shallow sea grass beds at about the same time (MMC 2005). The Ministry of Environment carried out a 3 year survey from 2001 through 2003 for dugongs at Okinawa (Yoshida and Trono 2004).

Behavior and Life History—Most dugongs are sighted alone or in groups of 2 animals (Marsh 2002; Davis 2004). Large aggregations of up to several hundred animals are regularly seen at some locations, feeding on seagrass meadows (Marsh 2002; Lanyon 2003). Dugongs are slow-growing mammals, with females only reaching sexual maturity after 6 to 17 years and producing a single calf every 2.5 to 5 years (Marsh et al. 2002). The estimated gestation period is about 13 months; calves are nursed for at least 13 months (Marsh 1995). Dugongs start eating seagrasses soon after birth

(Marsh et al. 2002). Dugongs are benthic feeding specialists; depending on the species of seagrass being consumed, dugongs target either the leaves alone or uproot the entire plant and consume the leaves, roots, and rhizomes, leaving distinct feeding scars (Preen 1995a; Marshall et al. 2003). Seagrasses of the genera *Halophila* and *Halodule* are preferred (Aketa 2002; Marsh 2002). Marine algae are also eaten (Marsh 2002; Yamamuro et al. 2004). In northern Australia, Whiting (2002) documented long-term feeding by dugongs on algal-covered rocky reefs in the intertidal zone. It is not known whether algae form a minor part of their diet or if dugongs only feed on algae when seagrasses are scarce (Whiting 2002). Dugongs are known to occasionally supplement their herbivorous diet with macro-invertebrates (Preen 1995b; Aketa 2002). The highly specialized dietary requirements of the dugong suggest that only certain seagrass meadows may be suitable as dugong habitat (Preen 1995a). At Okinawa, no depth preference in feeding has been identified (Kasuya 1999b); feeding in the seagrasses is thought to take place at night (Kasuya personal communication). Stomach content analyses of dugongs from Okinawa reveal 7 species of seagrasses, as well as annelids, ascidians, and algae (Aketa 2002; Yamamuro et al. 2004).

Maximum recorded dive depth for a tagged dugong is 20.5 m, although as noted earlier, maximum dive depths of up to 33 m are inferred from feeding scars in seagrass meadows (Chilvers et al. 2004). Maximum dive time at depths greater than 1.5 m is 12.3 min (Chilvers et al. 2004). Typical mean dive duration for depths less than 3 m from the water's surface is 2.7 (±S.D. 0.17) min (Chilvers et al. 2004).

Acoustics and Hearing—Dugongs produce complex sounds such as chirp-squeaks, barks, and trills (Anderson and Barclay 1995). Chirp-squeaks are in the 3 to 18 kHz range and last approximately 60 ms (Anderson and Barclay 1995). 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 as ranging from 3 to 6 kHz. No hearing data are available for this species (Ketten 1998).

3.1.2.3 Non-Threatened and Non-Endangered Marine Mammal Species of the Japan and Okinawa Complexes OPAREA

There are 37 non-endangered/non-threatened marine mammal species: two baleen whale species, 28 toothed whale species, and seven pinniped species.

- Minke Whale (*Balaenoptera acutorostrata*)

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

Status—The IWC recognizes 3 stocks of minke whales in the North Pacific: one in the Sea of Japan/East China Sea, one in the rest of the western Pacific west of 180ºN, and one in the remainder of the Pacific (Donovan 1991). Smith (2003) suggested that there are only 3 breeding groups 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. Lavery et al. (2003), however, suggested that there are probably multiple stocks within what is now considered the J-stock, and that current levels of bycatch could lead to depletion or even extinction of those stocks.

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

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

Distribution—Minke whales are distributed in polar, temperate, and tropical waters of all oceans (Jefferson et al. 1993); they are less common in the tropics than in cooler waters. Minke whales are present in the North Pacific from near the equator to the Arctic (Horwood 1990). The summer range extends to the Chukchi Sea (Perrin and Brownell 2002). In the winter, minke whales are found south to within 2° of the equator (Perrin and Brownell 2002). The distribution of minke whale vocalizations (specifically, "boings") suggests that the winter breeding grounds are the offshore tropical waters of the North Pacific Ocean (Rankin and Barlow 2005). There is no obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations in the western North Pacific, as there is in the North Atlantic (Horwood 1990); however, there are some monthly changes in densities in both high and low latitudes (Okamura et al. 2001). In the northern part of their range, minke whales are believed to be migratory, 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 et al. 1999).

- Information Specific to the Japan and Okinawa Complexes OPAREA—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 (**Figure A-12**). This expected close to shore year-round pattern is based on whaling and survey data (e.g., Horwood 1990; Miyashita and Hatanaka 1997; Okamura et al. 2001). Also, minke whales are regularly seen within a kilometer or two of shore around the San Juan Islands of Washington State (Dorsey 1983). Whaling catches off the Korean coastline are also reported (Dalebout et al. 2002). There is some evidence for residency of populations in the warmer waters of southern Japan (Wada 1993). There is a low or unknown occurrence offshore of the area of expected occurrence, since there are less data for offshore waters (primarily since coastal whaling vessels were not as far offshore). There is also a low or unknown occurrence between the shore and the shelf break to account for individuals moving into more shallow waters. Occurrence patterns for both seasons are anticipated to be similar for the OPAREA, although seasonal shifts in minke whale high density areas have been noted for waters off Japan (Okamura et al. 2001). With data, it is likely that the occurrence polygons would need to be refined.

  There is no obvious migration like in the North Atlantic (Horwood 1990). There is an overall impression of the movement of minke whales from south of Japan to the north and back or of a movement in and out of the marginal seas (Horwood 1990; Miyashita and Hatanaka 1997). Okamura et al. (2001) further suggested that there is a northward seasonal migration for minke whales off Japan. Females migrate into the coastal regions earlier than do the males (Horwood 1990).

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

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

Recorded vocalizations from minke whales have dominant frequencies of 60 to greater than 12,000 Hz, depending on vocalization type (Thomson and Richardson 1995). Recorded source levels, depending on vocalization type, range from 151 to 175 dB re 1 µPa-m (Ketten 1998). Gedamke et al. (2001) recorded a complex and stereotyped sound sequence ("star-wars vocalization") in the Southern Hemisphere that spanned a frequency range of 50 Hz to 9.4 kHz. Broadband source levels between 150 and 165 dB re 1 µPa-m were calculated. "Boings" recorded in the North Pacific have many striking similarities to the star-wars vocalization, in both structure and acoustic behavior. "Boings", recently confirmed to be produced by minke whales and suggested to be a breeding call, consist of a brief pulse at 1.3 kHz, followed by an amplitude-modulated call with greatest energy at 1.4 kHz, with slight frequency modulation over a duration of 2.5 s (Rankin and Barlow 2005). While no data on hearing abilities for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

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

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

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

Status—The IWC recognizes three management stocks of Bryde's whales in the North Pacific: western North Pacific, eastern North Pacific, and East China Sea (Donovan 1991). The Bryde's whale is designated as data deficient on the IUCN Red List (Reeves et al. 2003). The North Pacific Bryde's whale population was estimated at 17,840 in 1977 (Tillman 1978).

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence information for the Bryde's whale (**Figure A-13**) is a composite of information for various sources (e.g., Ohsumi 1978; Kato et al. 1996; Kishiro 1996; Miyashita et al. 1996). The Bryde's whale is expected everywhere in the OPAREA, with the exception of enclosed bays (**Figure A-13**). There is a concentrated occurrence at the southwest end of Kyūshū; occurrence is predictable and whalewatching is targeted at this species (**Figure A-13**; Kato and Miyashita 2004). Occurrence is anticipated to be similar year-round. With the inclusion of actual data, it is likely that additional areas of concentrated occurrence will be added and seasonal shifts in densities considered (Jefferson personal communication). For example, 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). Whale marking has shown the movement of a Bryde's whale from the Ogasawara Islands to Sanriku (Omura 1977). Miyazaki and Nakayama (1989) noted whaling watches off the Amami Islands during the whaling season of December to April.

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

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

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

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

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

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

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

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

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

More reliable is a conclusion that the pygmy sperm whale is more temperate, and the dwarf sperm whale more tropical, since it is based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993; Plön 2004). There, the pygmy sperm whale was not seen in truly tropical waters south of the southern tip of Baja California, but the dwarf sperm whale was common in those waters. This idea is also supported by the distribution of strandings in South American waters (Muñoz-Hincapié et al. 1998). Also, in the western tropical Indian Ocean, the dwarf sperm whale was much more common than the pygmy sperm whale, which is consistent with this hypothesis (Ballance and Pitman 1998).

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

Distribution—Both *Kogia* species have a worldwide distribution in tropical and temperate waters (Jefferson et al. 1993). Not much is known about the seasonal distributions or movements of either *Kogia* species.

- Information Specific to the Japan and Okinawa Complexes OPAREA—Although it overlaps strongly in distributon with the dwarf sperm whale, the pygmy sperm whale generally prefers

more temperate waters (Plön 2004). It is found mostly offshore of the continental shelf (Plön 2004). Therefore, occurrence of pygmy sperm whales in the Japan and Okinawa Complexes OPAREA is expected seaward of the shelf break, north of the southern tip of the main islands of Japan (**Figure A-14**). There is a low or unknown occurrence elsewhere off the shelf break, including the Korean Strait and the Sea of Japan (**Figure A-14**). Pygmy sperm whales are not expected from the shoreline to the shelf break around the Okinawa, Amami, and Ogasawara Islands. Occurrence patterns are assumed to be the same throughout the year.

The dwarf sperm whale is found throughout the Japan and Okinawa Complexes OPAREA. Most records of this species in Japanese waters are also strandings (Sylvestre 1988). This species generally prefers more tropical waters than the pygmy sperm whale (Plön 2004). For example most records of *Kogia* spp. from the Hawaiian Islands are of *K. sima* (Baird 2005). Like the pygmy sperm whale, the dwarf sperm whale is primarily found off the continental shelf (Plön 2004). Most other tropical species of small cetacean in Japanese waters only range north to about 35°N. Therefore, dwarf sperm whales are expected to occur south of 35°N and offshore of the shelf break throughout the Japan and Okinawa Complexes OPAREA (**Figure A-15**). Expected occurrence also extends seaward of the shoreline in the Korean Strait and Sea of Japan. A low or unknown occurrence is expected north of 35°N and extending offshore from the shelf break (**Figure A-15**). Dwarf sperm whales are not expected from the shoreline to the shelf break around the Okinawa, Amami, and Ogasawara Islands. Occurrence patterns are assumed to be the same throughout the year.

There are numerous records of the *Kogia* spp. from Japan; most of these are strandings. For example, *Kogia* spp. have stranded in Hakui Takamachi and near Taiji along the coast of Honshū and in Okinawa (Yamada 1954; Omura and Takahashi 1981; Sylvestre 1988). There are also records of *Kogia* spp. catches off the coast of Japan, particularly at Taiji (Yamada 1954). *Kogi*a spp. have also been live-captured for public display off Hiratsuka and Miura (along the Sugami Bay) (Kasuya et al. 1984). Whaling catches off Japan indicate a possible seasonal migration of *Kogia* spp. in this area; however, specific movement patterns are not known (Yamada 1954).

Behavior and Life History—*Kogia* species have small group sizes (mean group size is usually 2 individuals; Willis and Baird 1998a). A recent study of *Kogia* in South Africa has determined that these two species have a much earlier attainment of sexual maturity and shorter life span than other similarly sized toothed whales (Plön and Bernard 1999). Sexual maturity is attained at around 3 to 5 years for males and at 5 years for females of both species (Plön 2004). *Kogia* feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998a; Wang et al. 2002; Plön 2004). Dwarf sperm whales consume a variety of fishes, particularly lanternfish, in Japanese waters (Fitch and Brownell 1968). *Kogia* species are known to feed on squid in Taiwanese waters; the primary prey of both species in this area is the squid *Enoploteuthis chunii* (Wang et al. 2002). A typical observation of this species is animals logging at the water surface for periods of up to a few minutes then slowly sinking or slow rolling out of sight and not being resighted (e.g., Baird 2005). Willis and Baird (1998a) reported that *Kogia* make dives of up to 25 min. Maximum dive times of 53 min were also recorded but may be due to missed surfacings of the animal (Willis and Baird 1998a). Breese and Tershy (1993) recorded dive times between 15 and 43 min. A satellite-tagged pygmy sperm whale released off Florida was found to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al. 2001). Fitch and Brownell (1968) suggested that dwarf sperm whales likely dive to depths of over 300 m while foraging.

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

- Beaked Whales (Family Ziphiidae)

Description—There are 7 species of beaked whales known to frequent the waters of Japan (**Table 3-1**). **Cuvier's beaked whales** are relatively robust compared to other beaked whale species. Male and female Cuvier's beaked whales may reach 7.5 and 7.0 m in length, respectively (Jefferson et al. 1993). This species has a relatively short beak, which along with the curved jaw, resembles a goose beak. The body is spindle-shaped, and the dorsal fin and flippers are small, as is typical for beaked whales. A useful diagnostic feature is a concavity on the top of the head, which becomes more prominent in older individuals. Cuvier's beaked whales are dark gray to light rusty brown in color, often with lighter color around the head. In adult males, the head and much of the back can be light gray to white in color, and they also often have many light scratches and circular marks on the body (Jefferson et al. 1993).

All *Mesplodon* species have a relatively small head, large thorax and abdomen, and short tail. *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually-dimorphic tusks, which erupt only in adult males. **Blainville's beaked whales** appear to reach a maximum of around 4.7 m in length and weights up to 1,033 kg (Jefferson et al. 1993). Adults are blue-gray on their dorsal side and white below (Jefferson et al. 1993). The lower jaw of the Blainville's beaked whale is highly arched and massive flattened tusks extend above the upper jaw in adult males (Jefferson et al. 1993). Some individuals often have diatoms growing on them that can change the coloration from a grayish-brown to tan/brown, particularly around the head and dorsal fin (Baird personal communication). Individuals in some areas can have large numbers of oval white scars indicative of cookie-cutter shark bite wounds (Baird personal communication). There is sexual segregation in scarring, with males having high levels of scarring and females having relatively little (MacLeod 1998). The maximum known sizes for **ginkgo-toothed beaked whales** are 4.9 m for females and 4.8 m for males (Jefferson et al. 1993). Adult male ginkgo-toothed whales appear to be dark gray over the entire body with a faint light patch on the anterior half of the rostrum and lower jaw, while females are apparently lighter in color (Mead 1989). They are not as heavily scarred as are other *Mesoplodon* spp. In the ginkgo-toothed beaked whale, the tusks of males are wide and flattened with a small denticle at their apex (Mead 1989). The **Hubbs' beaked whale** is medium-sized, reaching a maximum length of about 5.3 m and a weight of approximately 1,500 kg (Mead et al. 1982). The body coloration is medium to dark gray, with the underside of the flukes lighter than the dorsal side (Mead et al. 1982). The most prominent external feature of this species is the pigmentation of the head, particularly in the adult male, which has a white rostrum and a white "skull cap" or "beanie" in the melon in front of and around the blowhole (Mead et al. 1982). The male Hubbs' beaked whale has a massive flattened tusk in the middle of each side of the lower jaw, which protrudes above the level of the upper jaw (Heyning 1984). The **Stejneger's beaked whale** reaches lengths of at least 5.3 m (Jefferson et al. 1993). Stejneger's beaked whale 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).

The **Longman's beaked whale** was often referred to as the "tropical bottlenose whale" in the past. This was due to the fact that whales now known to be of this species had been sighted in various locations in the tropical/subtropical Indo-Pacific but not identified to species (Pitman et al. 1999). At the time, this species was known only from a handful of skulls, and the external appearance of the species was undescribed. Until several stranded specimens were identified as Longman's beaked whales based on skull morphology and genetics (Dalebout et al. 2003), the sighted whales were thought to be members of the *Hyperoodon* genus (either far-ranging southern bottlenose whales or possibly an undescribed tropical species). We now know these animals to be Longman's beaked whales. The Longman's beaked whale looks very much like the southern bottlenose whale (*Hyperoodon planifrons*) in general shape and coloration although it is more slender (Pitman et al. 1999; Dalebout et al. 2003). The estimated adult length is 7 to 8 m (Pitman et al. 1999). The tall, falcate dorsal fin is set far back on the body (Pitman et al. 1999; Dalebout et al. 2003). The head has a well-rounded melon in profile and the beak length is variable, suggesting developmental changes in

beak size (Pitman et al. 1999; Dalebout et al. 2003). This species has a single pair of teeth that are set close to the tip of the lower jaw; it is suspected that, like most other beaked whales species, only adult males will have erupted teeth (Dalebout et al. 2003). The body color has been described as variable but is dominated by tan to grayish-brown tones (Pitman et al. 1999). Young animals are distinctively patterned; they are darker gray-brown above with a conspicuous pale melon and white sides (Pitman et al. 1999). The light area on the head extends only as far back as the blowhole.

Baird's beaked whales are the largest beaked whales; males and females can attain lengths of 11.9 m and 12.8 m, respectively (Balcomb 1989). Body weight for an average whale 10 m in length is 8,000 to 10,000 kg (Balcomb 1989). Baird's beaked whales are dark brownish-gray, usually heavily scarred, with light scratches or splotches on the back and, often, on the undersides (Jefferson et al. 1993). The body is slender and has a small head, a low falcate dorsal fin, and small flippers. There is a pair of V-shaped throat grooves. There is a prominent rounded forehead with a long, tube-like beak (Balcomb 1989). There are 2 pairs of teeth 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; the second pair is smaller and peg-like in shape (Balcomb 1989).

Status—Cuvier's, Blainville's, ginkgo-toothed, Hubbs', and Stejneger's beaked whales are all designated as data deficient on the IUCN Red List (Reeves et al. 2003). Baird's beaked whale is designated as lower risk (conservation dependent) on the IUCN Red List (Reeves et al. 2003). There is no designation for Longman's beaked whale on the IUCN Red List, but like most of the other beaked whale species, it should also be designated as data deficient.

There are no abundance estimates for any of the beaked whales in this area, though it has been noted that the Stejneger's beaked whale is thought to the most abundant *Mesoplodon* species in Japanese waters (Yamada and Yamada 1999).

Baird's beaked whales appear to be relatively common in the waters around Japan (MacLeod et al. in press). It has been suggested that separate populations occur in the Sea of Japan, the Okhotsk Sea, and the Pacific Ocean off Japan between the fronts of the Kuroshio and Oyashio currents (Kasuya 1986; Reeves and Mitchell 1993). Abundance is estimated at 5,029 individuals for the Pacific coast of Japan, 1,260 for the eastern Sea of Japan, and 660 for the southern Okhotsk Sea (Kasuya 2002). The long-standing coastal fishery for Baird's beaked whales off Japan once took up to 400 animals a year, although more recent annual harvests have been approximately 20 whales (MMC 2005).

Habitat Preferences—Beaked whales normally inhabit deep oceanic waters (>2,000 m) or continental slopes (200 to 2,000 m) and may occur close to shore in areas where there is no continental shelf and deep waters are close to shore (Pitman 2002). Ferguson et al. (2001) noted that offshore waters beyond the continental slope are not often identified as beaked whale habitat, yet this may be a function of lack of survey effort rather than a reflection of the animals' true habitat. Beaked whale distribution is often recorded in association with areas of complex seabed topography, such as seamounts, escarpments, and drop-offs. **Cuvier's beaked whales** are generally sighted in waters with a bottom depth greater than 200 m and are frequently recorded at depths of 1,000 m or more (Gannier 2000; MacLeod et al. 2004). They are commonly sighted around seamounts, escarpments, and canyons. The **Blainville's beaked whale** has a continuous distribution throughout the tropical, subtropical and warm-temperate waters of the world's oceans, with occasional occurrences in cold-temperate areas (MacLeod et al. in press). Most of the ecological information for the Blainville's beaked whale comes from the northern Bahamas (MacLeod et al. 2004; MacLeod and Zuur 2005). In the northern Bahamas, this species was most often sighted in waters with a bottom depth of 200 to 1,000 m (MacLeod and Zuur 2005); the majority of its time was spent along the canyon wall, where water depth is less than 800 m (Claridge 2003; MacLeod et al. 2004; MacLeod and Zuur 2005). In the Society Islands, Blainville's beaked whales were observed in waters with a bottom depth of 300 to 1,400 m (Gannier 2000). Ritter and Brederlau (1999) reported sightings of this species in waters with a bottom depth less than 500 m, and as shallow as 100 m, off the island of La Gomera in the Canary Islands. In the eastern tropical Pacific, the mean bottom depth for Blainville's beaked whale sightings is just over 3,500 m and a maximum depth of 5,750 m (Ferguson 2005). Palacios (1996) suggested

that based on stranding records in the eastern Pacific Ocean, the **ginkgo-toothed beaked whale** may select relatively cool, upwelling-modified habitats, such as those found in the California and Perú Currents and along the equatorial front. The distribution of the **Hubbs' beaked whale** appears to be related to the deep subarctic current system (Mead et al. 1982). The **Stejneger's beaked whale** appears to prefer cold-temperate and subpolar waters (Loughlin and Perez 1985; MacLeod et al. in press). Off Alaska, this species has been observed in waters ranging in bottom depth from 730 to 1,560 m on the steep slope of the continental shelf as it drops off into the Aleutian Basin which exceeds 3,500 m in bottom depth (Loughlin et al. 1982; Loughlin and Perez 1985). **Longman's beaked whale** appears to have a preference for warm tropical water, with most sightings occurring in waters with a SST warmer than 26ºC (Pitman et al. 1999). **Baird's beaked whales** is endemic to cold waters of the North Pacific and occurs mainly in deep waters over the continental slope, oceanic seamounts and areas with submarine escarpments (Ohsumi 1983; Kasuya and Ohsumi 1984; Willis and Baird 1998a; Kasuya 2002). They may be seen close to shore where deep water approaches the coast (Jefferson et al. 1993) and in shallow waters in the central Okhotsk Sea (Kasuya 2002). Individuals have also has been observed in and near ice fields (Kasuya 2002).

Distribution—The **Cuvier's beaked whale** is the most widely distributed of all beaked whale species, occurring in all 3 major oceans and most seas (Heyning 1989). This species occupies almost all temperate, subtropical, and tropical waters, as well as subpolar and even polar waters in some areas (MacLeod et al. in press). In the western Pacific, records range from Japan to southern New Zealand (MacLeod et al. in press). The **Blainville's beaked whale** occurs in temperate and tropical waters of all oceans (Jefferson et al. 1993). Strandings have been recorded from Japan (Kasuya and Nishiwaki 1971). The distribution of *Mesoplodon* species in the western North Atlantic may relate to water temperature (Mead 1989; MacLeod 2000), with Blainville's beaked whale generally occurring in warmer southern waters (MacLeod 2000). The **ginkgo-toothed beaked whale** is known only from strandings (there are no confirmed sightings) in temperate and tropical waters of the Pacific and Indian Oceans (e.g., Mead 1989; Palacios 1996; Wang and Yang 2004; MacLeod et al. in press). Most records are from Japan, where this species was first described (Nishiwaki et al. 1972). The **Hubbs' beaked whale** appears to be restricted to the North Pacific Ocean (Mead et al. 1982; Houston 1990; MacLeod et al. in press). Nearly all records to date have been strandings along the west coast of North America and in Japan (Mead et al. 1982; MacLeod et al. in press). There have also been several sightings in relatively nearshore waters of the Pacific Northwest, and MacLeod et al. (in press) speculated that the distribution might actually be continuous across the North Pacific between about 30° and 45°N. This, however, remains to be confirmed. **Stejneger's beaked whales** are found in the North Pacific, from southern California north to the Bering Sea, and south to the Sea of Japan, as far south as the Miyagi Prefecture (Loughlin and Perez 1985; Yamada and Yamada 1999; MacLeod et al. in press). This species is common in the Sea of Japan (Honma et al. 1999; Hiraguchi et al. 2001). The **Longman's beaked whale** is known from tropical waters of the Pacific and Indian Oceans (Pitman et al. 1999; Dalebout et al. 2003). Pitman et al. (1999) suggested that this species is more common in the western than the eastern Pacific. Ferguson and Barlow (2001) reported that all Longman's beaked whale sightings were south of 25ºN, and there was a single stranding of this species in Japan in 2002 (Yamada 2002). **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). The best-known populations occur in the coastal waters around both the eastern and western coasts of Japan, with whales taken during whaling operations (e.g., Kasuya and Miyashita 1997). The southern limits on the Asian side are at 36°N on the Japanese coast in the Sea of Japan and at 34°N on the Pacific coast (Kasuya 2002). They occur year-round in the Okhotsk Sea and Sea of Japan (Kasuya 2002). Baird's beaked whales may be migratory, but movements by individuals have not been studied. Kasuya (1986) suggested that the population off the Pacific coast of Japan moves northward in summer in response to the seasonal expansion of the warm surface water of the Kuroshio Current.

- Information Specific to the Japan and Okinawa Complexes OPAREA—Beaked whales may be expected to occur in the area mostly seaward of the shelf break in this OPAREA, with the exception of expected occurrence in the shelf region of the southern Sea of Japan and East

China Sea, where deep waters are very close to shore (**Figures A-16** through **A-19**). Beaked whales are not expected on the shelf area around island groups, such as the Ogasawara Islands.

The Cuvier's beaked whale is expected to occur in deep waters seaward of the shelf break, as well as on the shelf in the Tsushima Strait, since deep waters are close to shore in this area (**Figure A-16**). Yamada (2001) reported that occurrence for this species is only confirmed from the Pacific coast of Japan; however, known habitat preferences of this species were considered for the occurrence patterns portrayed in **Figure A-16**. There is a low or unknown occurrence of this species seaward of this area. This species is not expected on the shelf area around island groups, such as the Ogasawara Islands. These occurrence patterns are anticipated to be similar year-round and also take into consideration information presented in Heyning (1989) and MacLeod et al. (in press). Brownell et al. (2004, 2005) noted that the atypical distribution of Cuvier's beaked whale strandings was similar to the beaked whale strandings in the Bahamas in 2000 during the deployment of active mid-frequency sonar; this suggests that the Japanese mass strandings had an acoustic origin.

Identification to species at sea is difficult for *Mesoplodon* spp., so occurrence patterns for the Blainville's, Hubbs', Stejneger's, and ginkgo-toothed beaked whales are combined occurrence for *Mesoplodon* spp. (**Figure A-17**). MacLeod et al. (in press) was consulted in determination of this combined representation. *Mesoplodon* spp. are expected to occur seaward of the shelf break, as as well as on the shelf in the Tsushima Strait, since deep waters are close to shore in this area (**Figure A-17**). This species is not expected on the shelf area around island groups, such as the Ogasawara Islands. Yamamoto et al. (2001) reported on recent live strandings of Blainville's and Hubbs' beaked whales in the OPAREA. 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 confirmed sightings. During the winter-spring season, strandings are frequent along the coasts of the Sea of Japan. The expected range for the Stejneger's beaked whale is as far south as Miyagi Prefecture (Yamada 2001). The occurrence patterns are anticipated to be similar year-round.

The Longman's beaked whale is expected to occur seaward of the shelf break south of 35°N, as as well as on the shelf in the Tsushima Strait, since deep waters are close to shore in this area (**Figure A-18**). This species is not expected on the shelf area around island groups, such as the Ogasawara Islands. The occurrence patterns are anticipated to be similar year-round. One of the few confirmed records for this species in the western North Pacific is an individual that stranded during July 2002 at Nishikata beach, Sendai-shi, Kagoshima-ken (Yamada 2002).

The occurrence patterns for the Baird's beaked whale are based primarily on published information. Small-type whaling for this species is based in Chiba, Miyagi and Hokkaidō (Yamada 2001). There is evidence of seasonal movements in and out of shelf break regions of Japan throughout the year (Kasuya and Miyashita 1997). It should be noted that there is limited data for December through April; this is the time of year that small-type coastal whaling does not occur for this species in Japanese waters. Occurrence patterns for winter-spring were based on records from summer-fall. During summer-fall, there is an expected occurrence of the Baird's beaked whale off the Pacific coast of Japan north of 36ºN from the shelf break to the 3,000 m isobath (**Figure A-19**), based on information presented in Kasuya and Miyashita (1997), Reeves and Mitchell (1993), and MacLeod et al. (in press). Off the Pacific coast of Japan, Baird's beaked whales appear in May in waters with a bottom depth of 1,000 to 3,000 m (Kasuya and Ohsumi 1984; Kasuya 1986; Kasuya and Miyashita 1997; Kasuya 2002). Their numbers increase toward summer when whaling commences and then decrease toward October (Kasuya and Miyashita 1997; Kasuya 2002). There is an area of low or unknown occurrence north of 36ºN in the Sea of Japan due to the known occurrence of the Baird's beaked whale in the Sea of Japan north of 36°N (Kasuya 2002). There is also an area of low or unknown occurrence in waters deeper than 3,000 m to account for the possibility of encountering Baird's beaked whales there. During the winter-spring, there is a low or unknown occurrence of the Baird's beaked whale north of 34ºN (seaward of the shelf break) along the Pacific coast of Japan. During this period, they are almost

absent in waters further offshore, leaving these waters during December (Kasuya and Miyashita 1997); the location of wintering grounds is not known (Kasuya 2002).

Behavior and Life History—Life history data are extremely limited for most beaked whale species, including those occurring in the Japan and Okinawa Complexes OPAREA. Most sightings of beaked whales are brief, since these whales are often difficult to approach and they actively avoid aircraft and vessels (e.g., Würsig et al. 1998). Observed group sizes for beaked whales are typically small; the Longman's and Baird's beaked whales are the exception. Blainville's beaked whale group sizes are generally small, with single individuals or pairs being the most common (Jefferson et al. 1993). The maximum group size from Hawaiian waters is nine individuals (Baird et al. 2004). In the northern Bahamas, groups of 1 to 7 individuals have been reported; groups in this area contain a number of adult females and juveniles, and it is rare for more than one adult male to be present (MacLeod et al. 2004). Stejneger's beaked whales have been observed in groups of 5 to 15 individuals, often containing individuals of mixed sizes (Jefferson et al. 1993). Longman's beaked whale groups are relatively large and range in size from one to 100 individuals; mean group size for this species is 18.5 individuals (Pitman et al. 1999). When traveling, Baird's beaked whales are found in groups of 1 to 30 individuals; groups of 2 to 9 individuals are most common (Kasuya 2002). The usual observed behavior for Baird's beaked whales is of a tight group drifting along the surface spouting low bushy blows for 3 to 10 min, and then diving (Balcomb 1989).

There is limited information on reproduction for most beaked whale species, the exception being the **Baird's beaked whale** which, as previously noted, is taken during Japanese whaling operations. Hubbs' beaked whale calving most probably takes place in summer (Mead et al. 1982; Willis and Baird 1998b). Stejneger's beaked whales in Japan likely give birth during spring between March and May off the central region of Honshū (Yamada and Yamada 1999). Baird's beaked whale sexual maturity occurs at about 10 to 15 years for females and 6 to 11 years for males (Kasuya et al. 1997a; Kasuya 2002). Mating for this species generally occurs in October and November, and with a gestation period of about 17 months, there is then a calving peak in March and April (Balcomb 1989; Kasuya et al. 1997a; Kasuya 2002).

All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod et al. 2003). Analyses of stomach contents from captured and stranded individuals suggest that beaked whales are deep-diving animals, predominantly feeding by suction on mesoplegic fish and squid or deepwater benthic invertebrates (Heyning 1989; Mead 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003).

Stomach contents of **Cuvier's beaked whales** primarily contain cephalopods, and rarely, fish (MacLeod et al. 2003). Nishiwaki and Oguro (1972) reported that deep-sea fish and squid are the prey of this species in the Pacific off Japan; Ohizumi and Kishiro (2003) analyzed the stomach contents of a Cuvier's beaked whale that stranded on Suruga Bay on the Pacific coast of central Japan and found squid (*Gonatus* spp. and *Taonius pavo* were the most important components), no fish, and some crab pieces. Cuvier's beaked whales off Japan dive to 300 to 1,000 m to forage (Ohizumi and Kishiro 2003). Johnson and Tyack (2004) documented dives to depths of almost 1,900 m and as long as 1.4 hr for the Cuvier's beaked whale (Johnson and Tyack 2004). The **Blainville's beaked whale** primarily preys on fish, with some squid also taken (MacLeod et al. 2003). Tagged Blainville's beaked whales have been recorded to dive to depths as great as 975 m (Baird et al. 2004; Johnson et al. 2004); dives exceeding 50 min have been documented for Blainville's beaked whales (Johnson and Tyack 2004). No feed or diving information is available for the **ginkgo-toothed beaked whale**. Stomach contents from stranded **Hubbs' beaked whale** consisted of squid beaks, fish otoliths, and fish bones (Nishiwaki and Kamiya 1959; Mead et al. 1982); no diving information is available for this species. **Stejneger's beaked whale** stomach contents include squids and pelagic fish (Yamada and Yamada 1999; Walker and Hanson 1999). There is very little information available regarding feeding behavior and preferred prey of the **Longman's beaked whale**. A Longman's beaked whale found stranded in Japan contained beaks and lenses of cephalopods (Yamada 2002). Individual dive times of 18 and 25 min have been reported for the Longman's beaked whale (Gallo-

Reynoso and Figueroa-Carranza 1995). **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 (Walker et al. 2002; Ohizumi et al. 2003a). Prolonged dives by Baird's beaked whales for periods of up to 67 min have been reported, although dives to 25 to 35 m for about 45 min are more typical (Kasuya 1986; Balcomb 1989; Von Saunder and Barlow 1999).

Acoustics and Hearing—Very little information is available on characteristics of sounds produced by beaked whales. MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Click pulses of **Cuvier's beaked whales** recorded by Frantzis et al. (2002) had a peak frequency between 13 and 17 kHz with an average click duration of 1.08 ms. Two whales tagged in the Liguirian Sea produced ultrasonic echolocation clicks that were FM pulses with durations of approximately 200 ms, center frequencies around 42 kHz, and a distinctive form of an FM up-sweep (Johnson et al. 2004; Zimmer et al. 2005b). Source levels of these clicks were up to 214 dB re 1 μPa-m (Zimmer et al. 2005b). 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 ultrasonic echolocation clicks with no significant energy below 20 kHz (Johnson et al. 2004). The source level of these clicks ranged from 200 to 220 dB re 1 μPa-m (Johnson et al. 2004). Madsen et al. (2005) reported interclick intervals of 300 to 400 ms. 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 durations of 156 to 450 ms (Lynn and Reiss 1992; Marten 2000). Both whistles and clicks have been recorded from **Baird's beaked whales** in the eastern North Pacific Ocean (Dawson et al. 1998). Whistles had fundamental frequencies between 4 and 8 kHz, with 2 to 3 strong harmonics within the recording bandwidth (Dawson et al. 1998). Pulsed sounds (clicks) had a dominant frequency around 23 kHz, with a second frequency peak around 42 kHz (Dawson et al. 1998). The clicks were most often emitted in irregular series of very few clicks; this acoustic behavior appears unlike that of many species that do echolocate (Dawson et al. 1998). There is no information available for **ginkgo-toothed**, **Stejnger's**, or **Longman's beaked whale** vocalizations.

There is no empirical information available on the hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low-frequency sounds; however, as noted earlier, there is no direct evidence to confirm this idea (MacLeod 1999).

- Rough-toothed Dolphin (*Steno bredanensis*)

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

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

Habitat Preferences—The rough-toothed dolphin is regarded as an offshore species that prefers deep waters; however, it can occur in waters with variable bottom depths (e.g., Gannier and West 2005). It rarely occurs close to land, except around islands with steep drop-offs nearshore (Reeves et al. 2002; Gannier and West 2005). In the Gulf of Mexico, the rough-toothed dolphin occurs primarily over the deeper waters off the continental shelf (bottom depths of 950 to 1,100 m) (Davis et al. 1998)

although off the Florida panhandle, they can be found over the continental shelf (Fulling et al. 2003). In some regions, this species may regularly frequent coastal waters and areas with shallow bottom depths. For example, there are reports of rough-toothed dolphins over the continental shelf in shallow waters around La Gomera, Canary Islands (Ritter 2002), Puerto Rico and the Virgin Islands (Mignucci-Giannoni 1998), and in coastal waters off Brazil, including even in a lagoon system (Flores and Ximenez 1997; Lodi and Hetzel 1999).

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—South of approximately 34ºN on the Pacific coast is the area of expected occurrence for the rough-toothed dolphin, seaward of the shelf break (**Figure A-20**). 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). Occurrence is expected from the shore to seaward of the OPAREA in the Tsushima Strait, since deep waters are very close to shore here. 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). There is a low or unknown occurrence for this species between the shore and the shelf break. This species is not expected to occur within the bays. Occurrence patterns are anticipated to be similar throughout the year.

Behavior and Life History—Small groups of 10 to 20 rough-toothed dolphins are most common, with herds up to 50 animals reported (Miyazaki and Perrin 1994; Reeves et al. 1999). Rough-toothed dolphins often associate with other cetacean species (Miyazaki and Perrin 1994; Nekoba-Dutertre et al. 1999; Ritter 2002; Wedekin et al. 2004). In the Society and Marquesas Islands, rough-toothed dolphins are sometimes sighted in association with large schools of melon-headed whales and Fraser's dolphins, short-finned pilot whales, as well as with humpback whales (Gannier 2000, 2002; Gannier and West 2005). Rough-toothed dolphins tend to associate with floating objects in the eastern tropical Pacific and Gulf of Mexico (Pitman and Stinchcomb 2002; Fulling et al. 2003). Cephalopods and fish, including large fish such as dorado, are taken as prey (Miyazaki and Perrin 1994; Reeves et al. 1999; Pitman and Stinchcomb 2002). Gannier and West (2005) observed rough-toothed dolphins feeding during the daytime on epipelagic fishes, including flying fishes. Female rough-toothed dolphins reach sexual maturity at about 10 years of age; males attain sexual maturity at about 14 years (Miyazaki and Perrin 1994). Rough-toothed dolphins may stay submerged for up to 15 min and are known to dive as deep as 70 m, but can probably dive much deeper (Miyazaki and Perrin 1994).

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

- Common Bottlenose Dolphin (*Tursiops truncatus*)

Description—Common bottlenose dolphins (*Tursiops truncatus*) are large, relatively robust dolphins that vary in color from light gray to charcoal. The bottlenose dolphin is named for its short, stocky snout that is distinctively set off from the melon by a crease (Jefferson et al. 1993). There is striking regional variation in body size within the genus; maximum body length for different populations ranges from about 2.6 to 3.8 m (Jefferson et al. 1993; Wells and Scott 1999). In Japanese waters, adults reach asymptotic lengths of around 2.9 to 3.1 m (Kasuya et al. 1997b).

Bottlenose dolphins exhibit tremendous amounts of geographic variation, and the taxonomy of *Tursiops* continues to be in flux. Two species are currently recognized, the common bottlenose dolphin and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (Rice 1998; IWC 2004), with more

likely to be recognized with additional genetic and morphometric analyses (see Natoli et al. 2004). In most areas, they occur as 2 morphotypes (also often called ecotypes or forms): a nearshore (coastal) and an offshore form (Hersh and Duffield 1990; Hoelzel et al. 1998). There is a clear distinction between the nearshore and offshore form of the bottlenose dolphin in the western North Atlantic and eastern North Pacific, for instance, suggesting that the 2 forms will probably be recognized as 2 different species in the future (Curry and Smith 1997; Hoelzel et al. 1998; Kingston and Rosel 2004).

Status—This species is designated as data deficient on the IUCN Red List (Reeves et al. 2003). There are estimated to be 168,791 common bottlenose dolphins in waters of Japan and the western North Pacific (Miyashita 1993a). Although about 37,000 of these were estimated to occupy more inshore waters, there are no stock-specific estimates for the inshore and offshore forms.

Habitat Preferences—The common bottlenose dolphin ranges beyond the tropics and subtropics into temperate waters (Reeves et al. 2002). These dolphins live in coastal areas of all continents, around many oceanic islands and atolls, and over shallow offshore banks and shoals. In the eastern and western tropical Pacific, and elsewhere, there are also pelagic populations that range far from land (Reeves et al. 2002; Miyashita 1993a). Hale et al. (2000) reviewed occurrence of *Tursiops* in the Indian and western Pacific oceans and determined that the common bottlenose dolphin occurs in near-coastal oceanic and offshore waters.

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

Distribution—The overall range of the common bottlenose dolphin is worldwide in tropical and temperate waters. They generally do not range poleward of 45º, except around the United Kingdom and northern Europe (Jefferson et al. 1993). 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 1982/83 El Niño event (Wells et al. 1990). Some dolphins remained in the northern waters following return to normal water temperatures, suggesting that the dolphins might have responded more to secondary effects of the warm-water incursion, such as changes in prey distribution, than to the temperature changes themselves (Wells and Scott 1999).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Based on information in Kasuya et al. (1997b) and Miyashita (1993a), common bottlenose dolphins in the western North Pacific occur in both coastal and far offshore waters. There is comparatively little specific information on bottlenose dolphins around Japan, 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 kept in mind when evaluating the species' distribution patterns.

  There is little or no evidence of major seasonal differences in distribution off Japan. The common bottlenose dolphin is expected to occur everywhere in the OPAREA (**Figure A-21**), due to evidence that there are both coastal (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) in the western North Pacific (Miyashita 1993a; Kishiro and Kasuya 1993). Occurrence patterns are expected to be similar throughout the year. Individuals radio-tracked after release off Taiji, Japan, tended to stay within 30 NM (56 km) of land, although 2 moved up to 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).

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

Along the Atlantic coast of the U.S., where the majority of detailed work on common bottlenose dolphins has been conducted, male and female bottlenose dolphins reach physical maturity at 13 years, with females reaching sexual maturity as early as 7 years (Mead and Potter 1990). Bottlenose dolphins are flexible in their timing of reproduction. Seasons of birth for bottlenose dolphin populations are likely responses to seasonal patterns of availability of local resources (Urian et al. 1996). For the same central U.S. Atlantic coast areas, Hohn (1980) reported one (spring) and possibly two calving seasons (spring and fall), whereas Mead and Potter (1990) reported a prolonged calving season with a spring peak. There is a gestation period of 1 year (Caldwell and Caldwell 1972). Calves of bottlenose dolphins typically remain with their mothers for 3 to 6 years (Wells et al. 1987). In the Pacific, there is clearly much geographical variation among various coastal and offshore populations (Walker 1981; Kasuya et al. 1997b). In Japanese waters, calves are born at a length of around 128 cm, with a calving peak in June (Kasuya et al. 1997b). Sexual maturity appears to be reached at similar ages as in the Atlantic (5 to 13 years for females and 9 to 11+ for males; Kasuya et al. 1997b).

Tursiops are opportunistic feeders, taking a wide variety of fishes, cephalopods, and shrimp (Wells and Scott 1999) using a wide variety of feeding strategies (Shane 1990). In addition to use of active echolocation to find food, bottlenose dolphins likely detect and orient to fish prey by listening for the sounds they produce—so-called passive listening (Barros and Myrberg 1987; Gannon 2003). Nearshore bottlenose dolphins prey predominately on coastal fish and cephalopods, while offshore individuals prey on pelagic cephalopods and a large variety of epi- and mesopelagic fish species (Walker 1981; Van Waerebeek et al. 1990; Mead and Potter 1995).

Navy bottlenose dolphins have been trained to reach maximum diving depths of about 300 m (Ridgway et al. 1969). Reeves et al. (2002) noted that the presence of deep-sea fish in the stomachs of some offshore individual bottlenose dolphins suggests that they dive to depths of more than 500 m. Tagged bottlenose dolphins dove deeper than 450 m off Bermuda (Klatsky 2004). Dive durations up to 15 min have been recorded for trained individuals (Ridgway et al. 1969). Typical dives, however, are more shallow and of a much shorter duration.

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

The bottlenose dolphin has a functional high-frequency hearing limit of 160 kHz (Au 1993) and can hear sounds at frequencies as low as 40 to 125 Hz (Turl 1993). Inner ear anatomy of this species has

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

- Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*)

Description—Indo-Pacific bottlenose dolphins are moderate-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 that of its congener, and it is set off from the melon by a deep crease (see Wells and Scott 1999). There appears to be much less regional variation in body size than for the common bottlenose dolphin; maximum adult body length typically ranges from around 2.5 to 2.6 m (Jefferson personal communication).

The taxonomy of *Tursiops* continues to be in flux; two species are currently recognized (Rice 1998; IWC 2004), with more likely to be recognized with the completion of additional morphometric and genetic analyses (Natoli et al. 2004). Indo-Pacific bottlenose dolphins can be distinguished from common bottlenose dolphins using genetic, osteological, and external morphometric data (Wang et al. 1999, 2000a, 2000b; Hale et al. 2000; Kemper 2004). There is some evidence that this species, like its congener, has a tendency to occur as two morphotypes: a nearshore (coastal) and an offshore form.

Status—This species is designated as data deficient on the IUCN Red List (Reeves et al. 2003). The only available abundance estimate for the Indo-Pacific bottlenose dolphin in Japanese waters appears to be that of Shirakihara et al. (2002) for the population in the coastal waters of Amakusa-Shimoshima Island, western Kyūshū. They estimated population size by mark-recapture analysis of identification photos, and derived an estimate of 218 dolphins. Abundance at Mikura Island has not been estimated, but there are 169 individuals in the photo-identification catalog (Kogi et al. 2004). It is likely that other populations are similarly small, consisting of no more than a few hundred individuals.

Habitat Preferences—The Indo-Pacific bottlenose dolphin and common bottlenose dolphin are sympatric in some locales worldwide (e.g., Bearzi 2005). 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 et al. 2002). Hale et al. (2000) reviewed occurrence of *Tursiops* in the Indian and western Pacific Oceans and determined that the Indo-Pacific bottlenose dolphin occurs in estuarine and near-coastal oceanic waters. In addition to coastal waters of the continental shelf, they occur around some coastal and offshore islands as well.

Distribution—The Indo-Pacific bottlenose dolphin is found throughout much of the warm temperate and tropical Indian Ocean and western Pacific Ocean. In the western North Pacific, this species occurs from central Japan southward (including mainland China and the Taiwan Strait), into the subtropical western South Pacific, in much of the Indo-Malay archipelago, along the northern coasts of Australia between New South Wales and Western Australia, and then along the entire rim of the Indian Ocean, including the Persian Gulf and Red Sea, south to South Africa (Reeves et al. 2002).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The distribution of the Indo-Pacific bottlenose dolphin in Japanese waters was summarized by Kasuya et al. (1997b). Information on the location of specific populations of the species comes mostly from Shirakihara et al. (2002, 2003), Kakuda et al. (2002), Uchida (1982, 1985), and Miyazaki and Nakajima (1989).

  This is a coastal species that inhabits primarily tropical waters, but extends into the warm temperate zone. There are 5 more or less disjunct populations known in Japanese waters, and these are each indicated with concentrated occurrence (and keyed to the numbers used below) (**Figure A-22**):

  1) Tachibana Bay (Shirakihara et al. (2002, 2003),
  2) Amami Islands (Miyazaki and Nakajima 1989),
  3) Okinawa (Uchida 1982, 1985),
  4) Ogasawara Islands (Shirakihara et al. 2003), and
  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 Tokyo Bay (34°N), and this includes the Tsushima Strait. There is a low or unknown occurrence of Indo-Pacific bottlenose dolphins seaward of each of these areas (out to 50 NM [93 km], except for the Ogasawara Islands where it is 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 A-23**). Occurrence patterns are assumed to be similar year-round.

Behavior and Life History—Most studies of the behavioral ecology of this species have been conducted in South Africa and Australia, and only recently has there been some ecological study of populations in Japanese waters (Shirakihara et al. 2002; Bearzi 2005). Group size tends to be relatively small (compared to oceanic dolphins), generally less than a few dozen individuals, but sometimes it can reach 100 animals or more (Shirakihara et al. 2002). As in their better-known congeners, group composition appears to be of a fission-fusion nature, and fluidity in associations is the rule (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 et al. 2003). Site fidelity has been studied using records of photo-identified individuals, and so far it has been found that small-scale residency is the rule in this species (Corkeron 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 et al. 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. 2005).

Life history has been studied based on specimens from South Africa and Australia. These dolphins can live to ages past 40 years (Cockcroft and Ross 1990). 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). In Japanese waters, there has also been some study of life history, based on 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. Sharks are important predators of populations in both South Africa (Cockcroft and Ross 1990) and Australia (Heithaus and Dill 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 (Heithaus 2001).

While there have been only a few feeding habits studies 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 cephalopds (Corkeron et al. 1990).

There are no published accounts 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 that they tend to use, it would not be surprising to find out that most of their dives are relatively shallow (e.g., to less than 100 m).

Acoustics and Hearing—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. Generally, whistles range in frequency from 4 to 20 kHz, although Schultz et al. (1995) described whistles with fundamental frequencies entirely below 2 kHz. Morisaka et al. (2005a) found geographic differences in the whistles of 3 of the Japanese populations. Additionally, ambient noise may drive the variation in whistles among different populations (Morisaka et al. 2005b). One unique type of sound made by Indo-Pacific bottllenose dolphin adult males is the “pop,” which apparently is used in formation of consortships among adult males (Connor and Smolker 1996). There has been much less study of the acoustics and hearing of this species than there has for the common bottlenose dolphin, but it is reasonable to assume that the sound production and hearing capabilities of the two species are quite similar.

- Pantropical Spotted Dolphin (*Stenella attenuata*)

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

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). Pantropical spotted dolphins may have several stocks in the western Pacific (Miyashita 1993a), although this is not confirmed at present. There are estimated to be about 440,000 spotted dolphins in the waters surrounding Japan (Miyashita 1993a).

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

Distribution—The pantropical spotted dolphin is distributed in tropical and subtropical waters worldwide (Perrin and Hohn 1994). In the western Pacific, pantropical spotted dolphins are found from the northern coast of Honshū in Japan south to Australia (Miyazaki et al. 1974).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Pantropical spotted dolphins regularly occur in the Japan and Okinawa Complexes OPAREA. They are hunted in several areas along the Pacific coast of Japan, including Taiji (Kii Peninsula), Arari (west Izu Peninsula), and Kawana and Futo (east Izu Peninsula) (Miyazaki et al. 1974). Pantropical dolphins have also been captured at Arari for public display (Nishiwaki et al. 1965). Occurrence patterns of the pantropical spotted dolphin in the Japan and Okinawa Complexes OPAREA are based on fishing and sighting data and this species' preference for pelagic and coastal waters influenced by the Kuroshio Current (Miyazaki et al. 1974).

  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 A-24**). A low or unknown occurrence is expected from the shoreline to the shelf break off the south coast of Kyūshū, the Ryuku Islands, and the Ogasawara Islands (**Figure A-24**). Pantropical spotted dolphins are not expected in enclosed bays and channels.

  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 A-24**). A low or unknown occurrence is predicted from the shoreline to the shelf break along the east coast of Japan, south coast of Kyūshū, the Ryuku Islands, and the Ogasawara Islands (**Figure A-24**). Pantropical spotted dolphins are not expected in the bays and channels.

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

Acoustics and Hearing—Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz (Ketten 1998). Click source levels between 197 and 220 dB have been recorded for pantropical spotted dolphins (Schotten et al. 2004). There are no published hearing data for pantropical spotted dolphins (Ketten 1998). Anatomy of the ear of the pantropical spotted dolphin has been studied (Ketten 1992, 1997). Like other delphinids studied, the pantropical spotted dolphin has a Type II cochlea with 2.5 turns (Ketten 1997).

- Spinner Dolphin (*Stenella longirostris*)

Description—This is a slender dolphin that has a very long, slender beak (Jefferson et al. 1993). Among different geographical forms of the spinner dolphin, the dorsal fin ranges from slightly falcate to triangular or even canted forward. The form that occurs in Japanese waters has a slightly falcate to triangular fin. The spinner dolphin generally has a dark eye-to-flipper stripe and dark lips and beak tip (Jefferson et al. 1993). This species typically has a three-part color pattern (dark gray cape, light gray sides, and white belly). Adults can reach 2.4 m in length (Jefferson et al. 1993). There are four known subspecies of spinner dolphins, and probably other undescribed ones (Perrin 1998; Perrin et al.

1999). These include a globally-distributed nominal subspecies, which occurs in Japanese waters (*S. l. longirostris*), as well as several forms with restricted distributions (*S. l. orientalis*, *S. l. centroamerica*, and *S. l. roseiventris*).

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for this species in Japan.

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

Spinner dolphins at islands and atolls rest during daytime hours in shallow, wind-sheltered nearshore waters and forage over deep waters at night (Norris et al. 1994; Östman 1994; Poole 1995; Gannier 2000, 2002; Mori et al. 2001; Lammers 2004; Östman-Lind et al. 2004). Suitable habitat for resting includes bay complexes around islands (Poole 1995), or shallow waters near the coast (Lammers 2004); Lammers (2004) noted a preference for the 10 fathom isobath. It should be noted, however, that while certain bays or shoal areas are repeatedly occupied, others are only infrequently visited, or not occupied at all (Norris et al. 1985; Poole 1995). Spinner dolphins often rest in lagoons (Gannier 2000; Trianni and Kessler 2002). Preferred resting habitat is usually more sheltered from prevailing tradewinds than adjacent areas and the bottom substrate is generally dominated by large stretches of white sand bottom rather than the prevailing reef and rock bottom along most other parts of the coast (Norris et al. 1994; Lammers 2004). These clear, calm waters and light bottom substrates provide a less cryptic backdrop for predators like tiger sharks (Norris et al. 1994; Lammers 2004).

Distribution—The spinner dolphin is found in tropical and subtropical waters worldwide. Limits are near 40ºN and 40ºS (Jefferson et al. 1993). These dolphins occur near islands such as Hawai‘i, the Mariana Islands, islands of the South Pacific, the Caribbean, and Fernando de Noronha Island off Brazil. Spinner dolphins have been documented to travel distances of 40 km between islands in the main Hawaiian Islands (Maldini 2003). Long-term studies of island-associated spinner dolphins in the Pacific have been conducted since the 1970s along the Kona coast of Hawai‘i (Norris et al. 1994; Östman 1994; Östman-Lind et al. 2004) and since the 1980s at Mo’orea, French Polynesia (Poole 1995). In Hawai‘i, spinner dolphins occur along the leeward coasts of all the major islands and around several of the atolls northwest of the main island chain. Long-term site fidelity has been noted for spinner dolphins along the Kona coast of the island of Hawai‘i, along O‘ahu, and off the island of Moorea in the Society Islands (Norris et al. 1994; Östman 1994; Poole 1995; Marten and Psarakos 1999), with some individuals being sighted for up to 12 years at Moorea (Poole 1995). In the western North Pacific, spinner dolphins are found off the southern coasts of Korea and Japan, particularly from Wakayama to Miyazaki and Fukyoka to Kagoshima (Gilpatrick et al. 1987).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Spinner dolphin occurrence in the Japan and Okinawa Complexes OPAREA 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, and on the shelf break in the East China Sea (**Figure A-25**). Spinner dolphins use the coastal waters of the Ogasawara Islands for resting during the daytime (Mori 1999). Therefore, there is an area of expected occurrence from the shoreline to the shelf break around the Ogasawara Islands (**Figure A-25**). A low or unknown

occurrence is expected from the shoreline to the shelf break of the southern part of Kyūsh and the Ryuku Islands (**Figure A-25**).

During the summer-fall period, spinner dolphins are expected to occur south of 35°N, seaward of the shelf break along the coast of Japan and Okinawa, and on the shelf break in the East China Sea (**Figure A-25**). Spinner dolphins use the coastal waters of the Ogasawara Islands for resting during the daytime (Mori 1999). Therefore, there is an area of expected occurrence from the shoreline to the shelf break around the Ogasawara Islands (**Figure A-25**). A low or uknown occurrence is expected from the shoreline to the shelf break along the east coast of Japan, southern part of Kyūsh (not including bays), and around the Ryuku Islands (**Figure A-25**).

Behavior and Life History—Group sizes range from less than 50 up to several thousand individuals (Jefferson et al. 1993). Reported group sizes in the Ogasawara Islands range from 20 to 200 individuals (Mori et al. 2001).

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

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

The behavior and life history of spinner dolphins in the western Pacific is not well known. The studies of spinner dolphins along the island of Hawai‘i provide the current framework for our understanding of spinner dolphin behavior and social organization; this was detailed first by Norris and Dohl (1980) and later by Norris et al. (1994), Östman (1994), and Lammers (2004). Spinner dolphins at different islands and atolls carry out their daily cycle in the same general behavior pattern in the sense that groups come into shallow waters to rest and socialize, and then move further offshore in the late afternoon or early evening to forage. There are typically groups of 20 to 100+ individual dolphins that enter the shallow waters in the morning and gradually descend into a state of lowered activity level for several hours (Norris and Dohl 1980; Norris et al. 1994; Östman 1994; Lammers 2004). Periods of rest are characterized by very cohesive group formations and an almost total absence of acoustic activity. In the late afternoon/early evening, following a period of renewed social and aerial activity, groups move offshore again towards their evening foraging grounds. The cycle is repeated almost daily, with the only seasonal changes being adjustments in the timing of events, which reflects shifts in day length. Similar patterns of spinner dolphin foraging and resting cycles also have observed at other island habitats such as Moorea in French Polynesia (Poole 1995), Midway Atoll (Karczmarski et al. 2001), the Ogasawara Islands (Mori et al. 2001), and off Brazil (Silva-Jr et al. 2004). Spinner dolphins are well known for their propensity to leap high into the air and spin before landing in the water; the purpose of this behavior is unknown. Calving peaks in different spinner dolphin populations range from late spring to fall (Jefferson et al. 1993).

Spinner dolphins feed primarily on small mesopelagic fishes, squids, and sergestid shrimps, diving to at least 200 to 300 m (Perrin and Gilpatrick 1994). Foraging takes place primarily at night when the mesopelagic community migrates vertically towards the surface and also horizontally towards the shore at night (Benoit-Bird et al. 2001; Benoit-Bird and Au 2004). Rather than foraging offshore for the entire night, spinner dolphins track the horizontal migration of their prey (Benoit-Bird and Au

2003). This tracking of the prey allows spinner dolphins to maximize their foraging time while foraging on the prey at its highest densities (Benoit-Bird and Au 2003; Benoit-Bird 2004). Spinner dolphins begin foraging at a protruding bank, most likely because the prey layer enters shallow waters here before anywhere else along the coast (Lammers 2004). Spinner dolphins dive to meet the rising layer of prey organisms and forage cooperatively (Benoit-Bird and Au 2003). Life history of the spinner dolphin has been well-described for the eastern tropical Pacific Ocean, where the species is killed in large numbers in tuna purse seine nets (reviewed in Perrin 1998). Gestation lasts about 10 months, length of lactation is about 1 to 2 years, and sexual maturity occurs at lengths and ages of 1.65 to 1.70 m and 4 to 7 years (females) and 1.60 to 1.80 m and 7 to 10 years (males). There is some geographic variation, but other spinner dolphin populations probably have life history characteristics similar to those listed.

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

- Striped Dolphin (*Stenella coeruleoalba*)

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

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). The stock structure of striped dolphins in the western Pacific is poorly-known; however, there is evidence of a coastal stock, a northern offshore stock, 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).

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—Striped dolphins are the most common dolphins found in Japanese waters; however, their numbers have decreased due to directed catches (Kasuya and Miyazaki 1982; Kasuya 1985). Drive fisheries at Kawana, Futo, and Taiji catch striped dolphins off the Pacific coast of Honshū (Miyazaki 1983). Striped dolphins

have a preference for pelagic and coastal waters influenced by the Kuroshio current (Miyazaki et al. 1974). The occurrence patterns portrayed in **Figure A-26** are based mostly on Miyazaki et al. (1974), Archer and Perrin (1999), and Kasuya (1999). The occurrence of striped dolphins throughout the Japan and Okinawa Complexes OPAREA 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 A-26**). There is a low or unknown occurrence from the shoreline to the shelf break along the east coast of Japan, the southern tip of Kyūshū, and the Ryuku and Ogasawara Islands (**Figure A-26**). Striped dolphins are not expected in bays.

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 (**Figure A-26**). Expected occurrence also extends into the southern part of the Sea of Japan and over the shelf break in the East China Sea. There is a low or unknown occurrence from the shoreline to the shelf break along the east coast of Japan, the southern tip of Kyūshū, and the Ryuku and Ogasawara Islands (**Figure A-26**). Striped dolphins are not expected in bays.

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

Life history information is based mostly on western North Pacific specimens (Archer and Perrin 1999). Males reach sexual maturity between 7 and 15 years of age, at an average body length of 2.2 m. Females become sexually mature between 5 and 13 years of age (Kasuya 1985; Archer and Perrin 1999). Off Japan, where their biology has been best studied, there are two calving peaks: one in summer and another in winter (Perrin et al. 1994a).

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

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

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

Description—Short-beaked common dolphins are moderately robust animals with a medium-length beak and a tall, slightly falcate dorsal fin (Heyning and Perrin 1994). They are distinctively marked with a V-shaped dark saddle that produces an hourglass pattern on the side of the body (Jefferson et al. 1993). The back is a dark, brownish gray; the belly is white; and the anterior flank patch is tan to cream in color. The lips are dark and there is a stripe running from the apex of the melon to encircle the eye. There is also a black to dark gray chin-to-flipper stripe. Adults can reach lengths of up to about 2.3 m, with some geographic variation among populations (Jefferson et al. 1993; Heyning and Perrin 1994).

Status—The short-beaked common dolphin is listed by the IUCN Red List as a species of least concern (Reeves et al. 2003). There appear to be no published abundance estimates for the short-beaked common dolphin in Japanese waters.

Habitat Preferences—Short-beaked common dolphins tend of occupy waters past the continental shelf break, and in some areas appear to aggregate over prominent underwater topography (e.g., seamounts; Hui 1979; Evans 1994) or in areas of strong upwelling (Au and Perryman 1985). Common dolphins in the southern California Bight appear to preferentially travel along bottom topographic features, such as escarpments and seamounts (Evans 1994). In oceanic tropical regions, where short-beaked common dolphins are routinely sighted, they are found in upwelling-modified waters (Au and Perryman 1985; Reilly 1990). Common dolphins in the ETP prefer areas with large seasonal changes in surface temperature and thermocline depth (Au and Perryman 1985).

Distribution—The short-beaked common dolphin is a very widely distributed species. It is found in temperate, tropical, and subtropical waters of the Atlantic and Pacific oceans, including appended seas, such as the Mediterranean and Black seas. It does not appear to occur in the Indian Ocean, except perhaps at the very edges (Jefferson and Van Waerebeek 2002). The range of the short-beaked common dolphin may extend entirely across the temperate North Pacific (Heyning and Perrin 1994; Ferrero and Walker 1995). All animals observed at sea and collected as specimens from the offshore eastern tropical Pacific, ranging as far south as northern Peru, have been of the short-beaked species (Heyning and Perrin 1994).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Unfortunately, most older records of common dolphins from Japanese waters do not specify whether long-beaked or short-beaked animals were involved. The following assessment 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.

  There are no known seasonal differences in distribution in Japanese waters. This is a relatively deepwater, cool-temperate species. There is an area of expected occurrence seaward of the shelf break to far offshore [ca. 500 NM (926 km)], but not including the Tsushima Strait (**Figure A-27**). There is a low or unknown occurrence for the short-beaked common dolphin that covers other areas (including the Tsushima Strait), with the exception of the bays and inland seas along the Japanese mainland. There is also a low or unknown occurrence on the shelf area around island groups, such as Okinawa and the Amami and Ogasawara islands.

Behavior and Life History—Group size ranges from several dozen to over 10,000 (Jefferson et al. 1993). Short-beaked common dolphins are fast-moving swimmers, active bowriders, and often jump in the air. Birth peaks differ from stock to stock. Calving peaks in spring and autumn, or spring and summer, have been reported for different parts of the range (Jefferson et al. 1993). Life history has not been studied in detail in Japan. However, two adult females from southern Japan were 186 and 179 cm long, and a mature male was 230 cm (Jefferson personal communication).

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

Acoustics and Hearing—Recorded short-beaked common dolphin vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998).

Popov and Klishin (1998) recorded auditory brainstem responses from a short-beaked common dolphin. The audiogram was U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz.

- Long-beaked Common Dolphin (*Delphinus capensis*)

Description—Long-beaked common dolphins are moderately slender animals with a long beak and a tall, slightly falcate dorsal fin (Heyning and Perrin 1994). They are distinctively marked; they have a V-shaped dark saddle that produces an hourglass pattern on the side of the body (Jefferson et al. 1993). As in the short-beaked species, the back is a dark, brownish gray; the belly is white; and the anterior flank patch is tan to cream in color. The lips are dark and there is a stripe running from the apex of the melon to encircle the eye. There is also a black to dark gray chin-to-flipper stripe, which may encompass the gape in this species. There are other color pattern and body shape differences between it and the short-beaked common dolphin. Adults can reach lengths of up to 2.6 m, although most populations are somewhat smaller (Jefferson and Van Waerebeek 2002).

Status—The long-beaked common dolphin is listed by the IUCN Red List as a species of least concern (Reeves et al. 2003). There are no known abundance estimates for the long-beaked common dolphin in this area.

Habitat Preferences—Long-beaked common dolphins occupy a wide range of habitats, including shallow bays and gulfs, and waters over the continental shelf and slope. This species appears to be restricted to waters relatively close to shore (Jefferson and Van Waerebeek 2002); there is no known occurrence for this species around oceanic archipelagos that are long distances from a continent (Jefferson personal communication). In the northwestern Indian Ocean, the extremely long-beaked Indo-Pacific common dolphin (*Delphinus capensis tropicalis*) is routinely found in upwelling-modified waters (Ballance and Pitman 1998).

Distribution—Long-beaked common dolphins are known from about seven more-or-less discrete tropical-warm temperate areas of the world (Jefferson and Van Waerebeek 2002). All are areas with extensive shallow water along continental margins; they are not known from around oceanic archipelagos. In the eastern North Pacific, all sightings of long-beaked common dolphins have been within about 100 NM (185 km) of shore (Heyning and Perrin 1994).

- Information Specific to the Japan and Okinawa Complexes OPAREA—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, the following can be surmised.

  There are no known seasonal differences for the long-beaked common dolphin in Japanese waters. This is a relatively shallow-water, warm-temperate to tropical species. There is an expected occurrence 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 A-28**). The species is also expected to occur in the Tsushima Strait. There is a low or unknown occurrence of the long-beaked common dolphin in bays and inshore seas, as the species apparently does not often come into enclosed shallow bays such as these. Occurrence patterns are assumed to be similar throughout the year.

Behavior and Life History—Group size may range from just a few to many hundreds or even thousands (Jefferson et al. 1993). Long-beaked common dolphins are fast-moving swimmers, active bowriders, and often jump in the air. Calving peaks appear to differ from area to area (Jefferson et al. 1993). Little is known of their social organization and association patterns. Likewise, virtually nothing is known of the reproductive biology of the species in Japan.

In the Indian Ocean, this species has been documented to feed on squids and mackerels, but no detailed feeding habits studies have been done. Off South Africa, long-beaked common dolphins feed opportunistically on those species most abundant locally and change their diet according to fluctuations in the abundance and availability of prey (Young and Cockcroft 1994). Based on a small sample size from the eastern North Pacific, the long-beaked common dolphin may feed less extensively on squid than the short-beaked form (Heyning and Perrin 1994).

Acoustics and Hearing—Although these were apparently from the short-beaked common dolphin, recorded *Delphinus* vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Most of the acoustic work on common dolphins has been done on the short-beaked species, but it is reasonable to assume that the sound production and hearing capabilities of the long-beaked species are similar.

- Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

Description—The Pacific white-sided dolphin is dark gray or black on the back and upper sides, as well as on the short snout, 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 (Van Waerebeek and Würsig 2002). The largest reported male and female specimens from the eastern North Pacific were 2.5 m and 2.36 m, respectively (Brownell et al. 1999). The heaviest weights were 145 kg for a female and 198 kg for a male (Brownell et al. 1999).

Status—The Pacific white-sided dolphin is designated as a species of least concern by the IUCN Red List (Reeves et al. 2003). There are two geographical forms of Pacific white-sided dolphins that have been described for the western North Pacific Ocean (Miyazaki and Shikano 1989, 1997). However, they are not readily distinguishable and are not recognizable from each other in the field. The abundance of Pacific white-sided dolphins in the area northeast of Japan was estimated from 1987-1990 data to be 219,000 (Miyashita 1993b). The estimate for the larger area of the North Pacific Ocean was 931,000 animals (Buckland et al. 1993).

Habitat Preferences—The Pacific white-sided dolphin is most common in temperate waters over the outer continental shelf and slope. Sighting records and captures in pelagic driftnets indicate that this species also occurs in oceanic waters well beyond the shelf and slope (Leatherwood et al. 1984; Ferrero and Walker 1999).

Distribution—The Pacific white-sided dolphin occurs across temperate North Pacific waters, to latitudes as low as (or lower than) 38°N, and northward to the Bering Sea and coastal areas of southeast Alaska (Leatherwood et al. 1984). 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 (Sleptsov 1961; Brownell et al. 1999; Reeves et al. 2002). There is little information about different populations in the western North Pacific. However, recent studies suggest that there may be two distinct populations in Japan, one in coastal waters of Japan and one offshore in the North Pacific (Hayano et al. 2004). Off Japan, 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 (Green et al. 1992; Forney 1994; Carretta et al. 2005).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Pacific white-sided dolphins prefer waters with cold temperatures. They are found throughout Japanese waters (Brownell et al. 1999). The occurrence patterns portrayed in **Figure A-29** are based mostly on Brownell et al. (1999) and Springer et al. (1999).

  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 (**Figure A-29**).

There is a low or unknown occurrence from the shoreline to the shelf break (not including bays) along the east coast of Japan (**Figure A-29**).

During the summer-fall period, Pacific white-sided dolphins are expected to occur north of 35°N and seaward of the shelf break (**Figure A-29**). There is an area of low or unknown occurrence south of 35°N to the southern tip of Kyūshū, including the southern edge of the Sea of Japan (Tsushima Strait) (**Figure A-29**). An area of low or unknown occurrence also extends from the shoreline to the shelf break along the east coast of Japan that is north of 35°N.

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). This species has also been caught for public display off the central Pacific coast of Japan and the southern Sea of Japan (Kasuya et al. 1984).

Behavior and Life History—This is a gregarious species; group sizes range from tens of individuals to thousands (Leatherwood et al. 1984). Pacific white-sided dolphins frequently are found in mixed-species aggregations (Brownell et al. 1999). Calving peaks occur during June through August (Heise 1997a). Pacific white-sided dolphins feed primarily on epipelagic fishes and cephalopods (e.g., Miyazaki et al. 1991; Schwartz et al. 1992; Black 1994; Heise 1997b; Brownell et al. 1999; Morton 2000). This does not appear to be an especially deep-diving species. Based on feeding habits, Fitch and Brownell (1968) inferred that Pacific white-sided dolphins dive to at least 120 m. The majority of foraging dives last less than 15 to 25 s (Black 1994; Heise 1997b).

Acoustics and Hearing—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). Tremel et al. (1998) measured the underwater hearing sensitivity of the Pacific white-sided dolphin from 75 Hz through 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 other toothed whales.

- Northern Right-whale Dolphin (*Lissodelphis borealis*)

Description—The northern right whale dolphin, plus its congener the southern right whale dolphin, are the only members of the Family Delphinidae without a dorsal fin. This 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 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 larger than females (Leatherwood and Walker 1979). Weights of up to 116 kg have been recorded (Jefferson et al. 1994).

Status—The northern right whale dolphin is designated as a species of least concern by the IUCN Red List (Reeves et al. 2003). The abundance of northern right whale dolphins in the area northeast of Japan was estimated from 1987-1990 data to be 57,000 (Miyashita 1993b). The estimate for the larger area of the North Pacific Ocean was 68,000 animals (Buckland et al. 1993).

Habitat Preferences—This species occurs in oceanic waters, normally colder than 20°C (Leatherwood and Walker 1979). It appears to prefer deep water habitats (e.g., Leatherwood and Walker 1989; Baird and Stacey 1991). Northern right whale dolphins generally come nearshore only in areas where the continental shelf is narrow or where productivity on the shelf is especially high (e.g., the California Current System: Smith et al. 1986). Leatherwood and Walker (1979) reported sighting this species frequently around prominent banks and sea mounts.

Distribution—The northern right whale dolphin occurs in cool temperate and subarctic waters of the North Pacific Ocean. It is distributed approximately from 30°N to 55°N and 145°W to 118°E.

Occasional movements south of 30°N are associated with anomalous cold-water temperatures (Leatherwood and Walker 1979). Occurrence patterns in the eastern Pacific generally coincide with peaks in abundance of market squid, *Loligo opalacens*, a major prey item (Leatherwood and Walker 1989). In the western Pacific, northern right whale dolphins range from Cape Nojima, Japan in the south to Paramushir Island, Russia in the north (Sleptsov 1961; Nishiwaki 1967). 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).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence patterns portrayed in **Figure A-30** are based mostly on Jefferson and Newcomer (1993). Northern right whale dolphins are regularly found along the Pacific coast of Japan; there are no records of this species in the Sea of Japan (Jefferson and Newcomer 1993). Northern right whale dolphins prefer cool waters; their distribution throughout the Japan and Okinawa Complexes OPAREA 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 (**Figure A-30**). An area of low or unknown occurrence is from the shoreline to the shelf break in this region north of 35°N.

  During the summer-fall period, the occurrence of northern right whale dolphins shifts north of 38°N and includes the area seaward of the shelf break (**Figure A-30**). An area of low or unknown occurrence is expected from the shoreline to the shelf break north of 38°N and seaward of the shelf break between 35°N and 38°N (**Figure A-30**).

Behavior and Life History—The northern right whale dolphin is gregarious, traveling in groups as large as 2,000 individuals (Leatherwood and Walker 1979). Interspecific interactions are common; the Pacific white-sided dolphin, short-finned pilot whale, and Risso's dolphin are frequent associates (Leatherwood and Walker 1979). Onset of sexual maturity is approximately 9.9 years for males and 9.7 years for females (Ferrero and Walker 1993). Calving seasonality is unknown, though small calves are seen in winter or early spring (Jefferson et al. 1994). The northern right whale dolphin feeds primarily on squid and mesopelagic fishes (especially lanternfish, family Myctophidae) (Leatherwood and Walker 1979; Jefferson et al. 1994; Chou et al. 1995). There is no information on diving depths for northern right whale dolphins.

Acoustics and Hearing—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). There are no published data on the hearing abilities of this species.

- Risso's Dolphin (*Grampus griseus*)

Description—Risso's dolphins are moderately large, robust dolphins reaching at least 3.8 m in length (Jefferson et al. 1993). Average size of Risso's dolphins taken by small-type whaling off the Pacific coast of Japan was reported by Kishiro (2001) to be 2.8 m for males and 2.7 m for females, but they can grow to 3.8 m (Jefferson et al. 1993). The head is blunt, without a distinct beak, and there is a vertical crease on the front of the melon. The dorsal fin is tall and falcate and the flippers are sickle-shaped. Young Risso's dolphins range from light gray to dark brownish gray and are relatively unmarked (Jefferson et al. 1993). Adults range from dark gray to nearly white and are covered with white scratches and splotches. Kishiro (2001) noted that mature males tend to be the whitest.

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

Habitat Preferences—A number of studies have noted that Risso's dolphins are most commonly found along the continental slope (CETAP 1982; Baumgartner 1997; Davis et al. 1998; Mignucci-

Giannoni 1998; Kruse et al. 1999). Baumgartner (1997) hypothesized that the strong correlation between Risso's dolphin distribution and the steeper portions of the upper continental slope in the Gulf of Mexico is most likely the result of cephalopod (their major prey type) distribution in the same area.

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—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 A-31**), taking into consideration the occurrence map shown in the review by Kruse et al. (1999). There is a low or unknown occurrence further offshore, which takes into consideration occurrence records mentioned in Miyashita et al. (1996). There is also a low or unknown for the Risso's dolphin between the shore and the shelf break, except enclosed bays (**Figure A-31**). Occurrence patterns are currently presented as similar 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, with no data, there is not enough information here to depict those seasonal shifts.

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

Acoustics and Hearing—Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and simultaneous whistle and burst-pulse sounds (Corkeron and van Parijs 2001). The combined whistle and burst pulse sound appears to be unique to Risso's dolphin (Corkeron and van Parijs 2001). Corkeron and van Parijs (2001) recorded five different whistle types, ranging in frequency from 4 to 22 kHz. Broadband clicks had a frequency range of 6 to greater than 22 kHz. Low-frequency narrowband grunt vocalizations had a frequency range of 0.4 to 0.8 kHz. A recent study established empirically that Risso's dolphins echolocate; estimated source levels were up to 216 dB re 1 µPa-m (Philips et al. 2003).

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

- Melon-headed Whale (*Peponocephala electra*)

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

cape (which dips much lower below the dorsal fin than that of pygmy killer whales). Melon-headed whales reach a maximum length of 2.75 m (Jefferson et al. 1993).

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

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The melon-headed whale is a deepwater species found in warm-temperate to tropical waters. There are not enough records to determine this species' occurrence in this OPAREA with great certainty (Jefferson personal communication). Expected occurrence for the melon-headed whale in the Japan and Okinawa Complexes OPAREA is south of 32ºN, seaward of the shelf break (**Figure A-32**). There is a low/unknown occurrence of this species from about 35ºN that angles southward, representing the extension of the northern range of the warm Kurishio current. This species is more likely to be present in the northern area of the OPAREA when water temperatures are higher. There is an additional low or unknown occurrence in the Tsushima Strait and around the Ogasawara and Izu Islands. The first record for Japan was an individual killed by fishermen in the shallows of Hiratsuka Beach, Sugami Bay (=Sagami Bay) during August 1963 (Nakajima and Nishiwaki 1965). Additional records for this OPAREA include about 500 individuals sighted in Suruga Bay (Nishiwaki and Norris 1966), 104 captured at Okinawa (Miyazaki et al. 1998), some mass strandings (Miyazaki 1983; Miyazaki et al. 1998), and a mixed school of 500 Fraser's dolphins and melon-headed whales driven into cove during January 1991 (Amano et al. 1996). The occurrence patterns are expected to be similar year-round.

Behavior and Life History—Melon-headed whales are typically found in large groups, ranging between 150 and 1,500 individuals (Perryman et al. 1994; Gannier 2002) although Watkins et al. (1997) described smaller groupings of 10 to 14 individuals. These animals often log at the water's surface in large schools composed of noticeable subgroups. Melon-headed whales are often found in mixed-species aggregations, commonly with Fraser's dolphins (Miyazaki and Wada 1978a; Perryman et al. 1994; Amano et al. 1996; Jefferson and Barros 1997; Reeves et al. 1999; Gannier 2000), as well as on occasion, spinner, bottlenose, and rough-toothed dolphins (Reeves et al. 1999; Gannier 2000; Perryman 2002).

Very few data are available on life history. It is unclear whether there is significant seasonality in calving (Jefferson and Barros 1997). Females reach sexual maturity at about 11.5 years and males at 16.5 years; these life history parameters are estimated from work on a single school of melon-headed whales that mass-stranded at Aoshima, southern Japan (Miyazaki et al. 1998), and therefore must be taken as highly preliminary. Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mesopelagic forms found in waters up to 1,500 m deep, suggesting that feeding takes place deep in the water column

(Jefferson and Barros 1997). There is no information on specific diving depths for melon-headed whales.

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

- Fraser's Dolphin (*Lagenodelphis hosei*)

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

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

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The expected occurrence for the Fraser's dolphin in this OPAREA is just to the south of 30ºN, seaward of the shelf break (**Figure A-33**), which is based on the distribution of occurrence records presented by Perrin et al. (1994b). Miyazaki and Wada (1978b) list records of sporadic whaling catches for this species that include this OPAREA; and Amano et al. (1996) reported on catches at Taiji of this species in the dolphin fishery there. The area of low or unknown occurrence is essentially a swath, beginning north of Taiji in Honshū on the Kii Prefecture, following the warm water current that moves past this area. There is also a low or unknown occurrence for the Fraser's dolphin from the shore to the shelf break around Okinawa. In some locales, as noted earlier, Fraser's dolphins do approach closer to shore, particularly in locations where the shelf is narrow and deep waters are nearby, so there is also a low or unknown occurrence from the shore to the to the shelf break at Okinawa (**Figure A-33**). Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Fraser's dolphins are usually seen in large, fast-moving groups. Most sightings have been of groups ranging between 100 and 1,000 individuals. Fraser's dolphins have been seen in mixed-species aggregations with melon-headed whales off Japan, in the eastern tropical Pacific, South Pacific, and in the Gulf of Mexico (Jefferson and Leatherwood 1994; Amano et al. 1996; Reeves et al. 1999; Gannier 2000). Very little is known of the natural history of this species, including reproduction. Available data do not show strong evidence of calving seasonality. Sexual maturity for both sexes occurs at about 7 years of age (Jefferson and Leatherwood 1994). Fraser's

dolphins feed on mid-water fishes, squids, and shrimps (Jefferson and Leatherwood 1994; Perrin et al. 1994b). There is no information available on depths to which Fraser's dolphins dive, but based on prey species, they are thought to be capable of deep dives.

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

- Pygmy Killer Whale (*Feresa attenuata*)

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

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

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—Occurrence patterns are anticipated to be similar to those of the melon-headed whale, a species with which the pygmy killer whale is often mistaken. The pygmy killer whale is a deepwater species found in warm-temperate to tropical waters. There are not enough records to determine this species' occurrence in this OPAREA with great certainty (Jefferson personal communication). There are only a dozen or so stranding records for this species in Japan (Terasawa et al. 1997). Expected occurrence for the pygmy killer whale in the Japan and Okinawa Complexes OPAREA is south of 32ºN, seaward of the shelf break (**Figure A-34**). There is a low/unknown occurrence of this species from about 35ºN that angles southward, representing the extension of the northern range of the warm Kurishio current. This species is more likely to be present in the northern area of the OPAREA when water temperatures are higher. The occurrence patterns are expected to be similar year-round.

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

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

- False Killer Whale (*Pseudorca crassidens*)

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

Status—This species is designated as least concern on the IUCN Red List (Reeves et al. 2003). Little is known of the stock structure of false killer whales in the North Pacific Ocean; recent genetic analyses indicate that the Hawaiian stock is reproductively isolated from false killer whales found in the eastern tropical Pacific Ocean (Carretta et al. 2005). There are estimated to be about 6,000 false killer whales in the area surrounding (mostly north of) the Mariana Islands (Miyashita 1993a).

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

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence patterns for the false killer whale in this OPAREA were derived by consulting records reviewed by Odell and McClune (1999) as well as records reported by Miyashita et al. (1996). The area of expected occurrence for the false killer whale is from the shelf break to 200 NM (370 km) offshore (**Figure A-35**). Expected occurrence extends into the Tsushima Strait in waters up to the shoreline, since deep water occurs close to shore here. There is a low or unknown occurrence for the false killer whale between the shore and the shelf break (not including shallow bays) elsewhere in the OPAREA. Occurrence patterns are assumed to be similar throughout the year.

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

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

- Killer Whale (*Orcinus orca*)

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

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates available for the killer whale in this area. Little is known of stock structure of killer whales in the North Pacific, with the exception of the northeastern Pacific where resident, transient, and offshore stocks have been described for coastal waters of Alaska, British Columbia, and Washington to California (Carretta et al. 2005).

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

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

Sightings in most tropical waters, although not common, are widespread (e.g., Visser and Bonoccorso 2003). Japanese tuna longline fishermen and Japanese whaling or whale sighting vessels reported killer whale presence in Pacific equatorial waters (Iwashita et a. 1963; Miyashita et al. 1995), although Reeves et al. (1999) noted that records from fishermen have reliability issues, since they are often not sufficiently well-documented. Observations from Japanese whaling or whale sighting vessels are more credible (Miyashita et al. 1995, 1996) and indicate concentrations of killer whales north of the Northern Mariana Islands.

- Information Specific to the Japan and Okinawa Complexes OPAREA—There is an expected occurrence for the killer whale from the shore out to 200 NM (370 km) offshore (**Figure A-36**). 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) to be about a 200 NM (370 km) swath from the Japanese coastline. This is also supported by recent events during 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; 5 individuals were sold for captivity and the others were released (Perry and Thornton 2000). There is a low or unknown occurrence elsewhere in the OPAREA, including bays. Spong (2000) reported that a lone male killer whale made its way from the harbor into the canal that runs through Nagoya during February 2000, as well as two individuals that were seen at the entrance to the Fuji River

in Surunga Bay during May 2000. Occurrence patterns are anticipated to be similar throughout the year.

Additionally, there are a number sightings north of the Japan and Okinawa Complexes OPAREA off northern Hokkaidō around the Rishiri and Rebun islands (Nishiwaki and Handa 1958; Jefferson personal communication). Most famously, during early February 2005, 12 individuals were found trapped in pack ice in the Nemuro Strait off Hokkaidō's Shiretoko Peninsula (Anonymous 2005).

Behavior and Life History—Killer whales have the most stable social system known among all cetaceans. In all areas where longitudinal studies have been carried out, there appear to be long-term associations between individuals and limited dispersal from maternal groups called pods (Baird 2000). Nishiwaki and Handa (1958) speculated that the calving season might be May through July.

Killer whales have a diverse diet, feeding on bony fishes, elasmobranchs, cephalopods, seabirds, sea turtles, and other marine mammals (Nishiwaki and Handa 1958; Jefferson et al. 1991; Fertl et al. 1996). Diet is specific to the type of killer whale. Transients are primarily mammal-eaters, residents are mostly fish-eaters, and offshores appear to eat mostly fish as well. Killer whales use passive listening as a primary means of locating prey and use different echolocation patterns for different hunting strategies (Barrett-Lennard et al. 1996). For example, they mask their clicks and encode their signals in background noise when hunting other cetaceans, prey that can hear their high-frequency clicks. In contrast, killer whales do not mask their high-frequency signals when hunting fish that are not capable of hearing in this frequency range.

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

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

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

- Short-finned Pilot Whale (*Globicephala macrorhynchus*)

Description—There are two species of pilot whales worldwide; only the short-finned pilot whale is expected to occur in the Japan and Okinawa Complexes OPAREA. Pilot whales are among the largest members of the family Delphinidae. In general, the short-finned pilot whale reaches lengths of 5.5 m (females) and 6.1 m (males) (Jefferson et al. 1993). The Japanese northern form is the larger of the two forms of Japanese pilot whales (Kasuya and Tai 1993).

Pilot whales have bulbous heads, with a forehead that sometimes overhangs the rostrum; there is little or no beak (Jefferson et al. 1993). The dorsal fin is distinctive, being generally broader-based than it is tall. It is falcate and usually rounded at the tip, and is set well forward of the middle of the

back. The flippers of the short-finned pilot whale are long and sickle-shaped and range from 16% to 22% of the total body length (Jefferson et al. 1993). This species is black on the back and sides; in many individuals, there is a light gray saddle patch located behind the dorsal fin. Only the Japan northern form has a distinct saddle mark (Miyashita et al. 1990). Pilot whales also have a white to light gray anchor-shaped patch on the chest (Jefferson et al. 1993).

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). The abundance of the southern form of short-finned pilot whale off the Pacific coast of Japan was estimated at 53,608 individuals (Miyashita 1993b). 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 et al. 1988; Miyazaki and Amano 1994). These forms are also segregated geographically and genetically (Wada 1988; Kasuya and Tai 1993).

Habitat Preferences—Pilot whales are found over the continental shelf break, in slope waters, and in areas of high topographic relief (Olson and Reilly 2002). While pilot whales are typically distributed along the continental shelf break, movements over the continental shelf are commonly observed in the northeastern U.S. (Payne and Heinemann 1993) and close to shore at oceanic islands, where the shelf is narrow and deeper waters are nearby (Mignucci-Giannoni 1998; Gannier 2000). A number of studies in different regions suggest that the distribution and seasonal inshore/offshore movements of pilot whales coincide closely with the abundance of squid, their preferred prey (Hui 1985; Waring et al. 1990; Payne and Heinemann 1993; Waring and Finn 1995; Bernard and Reilly 1999). Short-finned pilot whale occurrence in the Caribbean seems to coincide with the inshore movement of spawning octopus (Mignucci-Giannoni 1998). Short-finned pilot whale distribution off southern California changed dramatically after the El Niño event in 1982 through 1983, when squid did not spawn as usual in the area, and pilot whales virtually disappeared from the area for nine years (Shane 1994). The Japanese northern form is found in waters with a SST below 24ºC during the summer or 8 to 21ºC during the winter (Kasuya and Tai 1993). The southern form is found in waters with SST of over 24ºC during the summer or over 20ºC during the winter (Kasuya and Tai 1993).

Distribution—The short-finned pilot whale is found worldwide in tropical to warm-temperate seas, generally in deep offshore areas. The short-finned pilot whale usually does not range north of 50ºN or south of 40ºS (Jefferson et al. 1993). The long-finned pilot whale (*Globicephala melas*) is not known to presently occur in the North Pacific (Kasuya 1975); the range of the short-finned pilot whale appears to be expanding to fill the former range of the long-finned pilot whale (Bernard and Reilly 1999). The northern short-finned form is found in cold coastal waters between 34ºN and 43ºN, while the southern form is observed in coastal and offshore waters south of the Kuroshio Front (south of 39ºN), in the Ryukyu Islands.

- Information Specific to the Japan and Okinawa Complexes OPAREA—The short-finned pilot whale is expected to occur seaward of the shelf break (**Figure A-37**). In the area of the Tsushima Strait, there is a low or unknown occurrence for this species. The known preference of this species globally for steep bottom topography, which is most probably related to distribution of squid, was considered, as well as the distribution of published sighting and whaling records. There is a low or unknown occurrence of this species between the shoreline and the shelf break, including within the bays, as well as around Okinawa and the Amami and Ogasawara islands. Occurrence patterns are anticipated to be similar year-round. Seasonal shifts in occurrence for this species are known (e.g., Miyashita 1986; Kasuya et al. 1988; Kasuya and Tai 1993), but without actual plotted data, it is currently not possible to accurately portray these shifts for this MRA.

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

Average age at sexual maturity for short-finned pilot whales is 9 years for females, and 17 years for males (Bernard and Reilly 1999). The gestation period for short-finned pilot whales is 15 to 16 months, with a mean calving interval of 4.6 to 5.7 years (Kauya and Tai 1993; Bernard and Reilly 1999). Calving peaks in the Northern Hemisphere vary by stock (Jefferson et al. 1993); the Japan southern form has a calving peak during July/August, while the northern form peaks during December/January (Kasuya and Tai 1993).

Pilot whales feed primarily on squid, but also take fish (Bernard and Reilly 1999; Kasuya and Tai 1993). Stomach content analyses of the southern form of the short-finned pilot whale off the Pacific coast of central Japan found that fishes were a significant component of the diet, in addition to squid (Ohizumi et al. 2003b). Pilot whales are not generally known to prey on other marine mammals; however, records from the eastern tropical Pacific suggest that the short-finned pilot whale does occasionally chase, attack, and may eat dolphins during fishery operations (Perryman and Foster 1980), and they have been observed harassing sperm whales in the Gulf of Mexico (Weller et al. 1996). Pilot whales are deep divers; the maximum dive depth measured is 971 m (Baird personal communication).

Acoustics and Hearing—Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and a source level of 180 dB re 1 μPa-m (Ketten 1998). Nakahara et al. (2003) compared vocalization patterns of the northern and southern forms of the short-finned pilot whale off Japan and found that the calls of the northern form were longer in duration and wider in frequency range than the southern form. There are no published hearing data available for this species.

- Harbor Porpoise (*Phocoena phocoena*)

Description—Harbor porpoises are among the smallest cetaceans occurring in the western North Pacific; they reach a maximum length of about 2 m (Jefferson et al. 1993). The body is stocky, dark gray to nearly black on the back and white on the belly. There may be a dark stripe from the mouth to the flipper. The head is blunt with an indistinct beak. The flippers are small and pointed, and the dorsal fin is short and triangular, with a wide base, and is located slightly behind the middle of the back.

Status—The harbor porpoise is listed by the IUCN as a vulnerable species (Reeves et al. 2003). While there are nine stocks of harbor porpoise recognized along the U.S. Pacific Coast, much less is known about the status of harbor porpoises in Japan. Clearly, animals off the coast of Japan are not from the same stocks as those in the eastern North Pacific (Miyazaki et al. 1987). Gaskin et al. (1993) reviewed the available information on the species in Japan, but no population estimates were provided.

Habitat Preferences—Harbor porpoises are generally found in waters over the continental shelf, and they are common in some bays and other inshore waters (Read 1999). This is a coolwater species that is seldom found in waters warmer than 17°C (Read 1999). In the eastern North Pacific, harbor porpoises occur south only to about Point Conception. The reasons for this cut-off in distribution are not known (Barlow and Hanan 1995).

Distribution—Harbor porpoises occur in cool-temperate to subpolar waters around both the North Atlantic and North Pacific Oceans (Read 1999). In the Pacific, harbor porpoise are found in coastal and inland waters from Point Conception, California to Alaska and across to southern Honshū, Japan.

- Information Specific to the Japan and Okinawa Complexes OPAREA—Gaskin et al. (1993) summarized all available information on the distribution of the harbor porpoise in Japanese waters. Records are quite sparse, and it would seem that the species is less common there than in many other parts of its range. Strandings, incidental fisheries bycatch, captures, and sightings occur from Hokkaidō south to Taiji on the Pacific coast of Japan, and to Nishiyama on the Sea of Japan coast.

There is no specific evidence of a significant seasonal difference in range, although the main density might be expected to occur further south in the winter. This is a cool temperate, coastal species. There is an area of expected occurrence from the shore (including bays) to 20 NM (37 km) offshore of the shelf break, extending north from Taiji on the Pacific coast (**Figure A-38**). Occurrence patterns are assumed to be similar year-round.

Behavior and Life History—Harbor porpoises are not known to form stable social groupings (Read 1999), which is the typical situation for species in the porpoise family. In most areas, harbor porpoises are found in small groups consisting of just a few individuals.

In contrast to other toothed whales, harbor porpoises mature at an earlier age, reproduce more frequently, and live for shorter periods (Read and Hohn 1995). In the Gulf of Maine, females mature at 3 years of age and give birth to one calf each year (Read and Hohn 1995). In Japan, calving occurs in May to June in northern Japanese waters (Gaskin et al. 1993). Many females may be pregnant and lactating simultaneously (Read 1990; Read and Hohn 1995). Relative to other cetaceans, harbor porpoises seem to allocate a larger percentage of their total body mass to blubber (McLellan et al. 2002), which helps them meet the energetic demands of living in a cold-water environment.

Harbor porpoises feed on a variety of small, schooling clupeoid (herring-like) and gadoid (cod-like) fishes up to 40 cm in length, and usually less than 30 cm (Read 1999). In Japan, they appear to feed mostly on sardines, anchovy, hake, herring, and squid (Gaskin et al. 1993). Harbor porpoises make brief dives, generally lasting less than 5 min (Westgate et al. 1995). Tagged harbor porpoise individuals spend 3 to 7% of their time at the surface and 33 to 60% in the upper 2 m (Westgate et al. 1995; Read and Westgate 1997). Otani et al. (1998) reported that 70% of recorded diving time was at depths less than 20 m. Average dive depths range from 14 to 41 m with a maximum dive of 226 m, and average dive durations range from 44 to 103 s (Westgate et al. 1995). Westgate and Read (1998) noted that dive records of tagged porpoises did not reflect the vertical migration of their prey; porpoises made deep dives during both day and night.

Acoustics and Hearing—Harbor porpoise vocalizations include clicks and pulses (Ketten 1998), as well as whistle-like signals (Verboom and Kastelein 1995). The dominant frequency range is 110 to 150 kHz, with source levels of 135 to 177 dB re 1 μPa-m (Ketten 1998). Echolocation signals include one or two low-frequency components in the 1.4 to 2.5 kHz range (Verboom and Kastelein 1995). A behavioral audiogram of a harbor porpoise indicated the range of best sensitivity is 8 to 32 kHz at levels between 45 and 50 dB re 1 μPa-m (Andersen 1970); however, auditory-evoked potential studies showed a much higher frequency of approximately 125 to 130 kHz (Bibikov 1992). The auditory-evoked potential method suggests that the harbor porpoise actually has two frequency ranges of best sensitivity. More recent psycho-acoustic studies found the range of best hearing to be 16 to 140 kHz, with a reduced sensitivity around 64 kHz (Kastelein et al. 2002). Maximum sensitivity occurs between 100 and 140 kHz (Kastelein et al. 2002).

- Dall's Porpoise (*Phocoenides dalli*)

Description—The Dall's porpoise is the largest member of the porpoise family; this species reaches maximum lengths and weights of about 239 cm and 200 kg (Jefferson 2002). The Dall's porpoise has a stock body with a wide-based triangular dorsal that is slightly recurved at the tip; in mature males, the fin can become extremely canted (Jefferson 1990a). The caudal peduncle is strongly deepened, and there may be a pronounced post-anal hump, especially in adult males (Jefferson 1990a). The teeth are extremely small, the smallest of any cetacean species (Jefferson 2002).

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 2002). Frosting variations of the dorsal fin and flukes can be used to discern the general age of the individual (Jefferson 1990a). Some other light patches may exist, particularly around the base of the tail stock (Jefferson 2002). There are two major color morphs 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 (Kasuya 1978). However, a single *truei*-type Dall's porpoise was found stranded in San Mateo County, California (Szczepaniak and Webber 1992).

Status—The Dall's porpoise is listed by the IUCN as a species of least concern (Reeves et al. 2003). Three separate Dall's porpoise stocks have been identified in Japanese waters (Amano and Miyazaki 1996; Hayano et al. 2003), although the small degree of genetic variation suggests that they are recently-evolved. There is one *truei*-type population and two of the *dalli*-type (although one of these inhabits northern offshore waters beyond the scope of the current study area). The *truei*-type stock was estimated to number around 58,000 individuals, and there were thought to be at least an additional 46,000 *dalli*-type individuals in the mid-1980s (Miyashita and Kasuya 1988). 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 there have been no more recent population assessments.

Habitat Preferences—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 (Jefferson 1988; Ferrero et al. 2002; Carretta et al. 2005).

Distribution—Dall's porpoise is endemic to the North Pacific. It is found from northern Baja California, Mexico, north to the southern Chukchi Sea, and south to central Japan (Jefferson et al. 1993; Houck and Jefferson 1999). The species is only common between 32°N and 62°N in the eastern North Pacific (Morejohn 1979; Houck and Jefferson 1999). North-south movements in California, Oregon, and Washington have also been suggested to occur as oceanographic conditions change, both on seasonal and inter-annual time scales; Dall's porpoises shift their distribution southward during cooler-water periods (Forney and Barlow 1998). Norris and Prescott (1961) reported finding Dall's porpoise in southern California waters only in the winter, generally when the water temperature was less than 15°C. Inshore/offshore movements off southern California have been reported, with individuals remaining inshore in fall and moving offshore in the late spring (Norris and Prescott 1961; Houck and Jefferson 1999). Inshore/offshore and north/south shifts in abundance have also been reported for Japanese waters (Miyashita and Kasuya 1988).

- Information Specific to the Japan and Okinawa Complexes OPAREA—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, there is an area of expected occurrence north of 35°N, beyond the shelf break off the Pacific coast of Japan (**Figure A-39**). A buffer of low or unknown 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 there is good evidence of a northward shift in density in summer months. This takes into account the migration of animals from the Sea of Japan to the Pacific coast in summer months (Amano and Kuramochi 1992). Therefore, the expected occurrence only extends south to about 40°N during this time of year.

Behavior and Life History—Groups of Dall's porpoise are generally small (less than 10 individuals) and fluid, and are composed of very small subgroups, which may aggregate, especially for feeding (Jefferson 1990b; Jefferson 1991; Houck and Jefferson 1999). Large aggregations of up to several thousand are very rarely sighted (Houck and Jefferson 1999). Groups of over 20 to 30 porpoise are rather uncommon (Jefferson 2002). Dall's porpoise are fast-swimming and active animals that are avid bowriders. When bowriding or moving quickly, they produce a distinctive V-shaped or "rooster-tail" splash (Jefferson 2002). Dall's porpoise have even been observed to "snout ride" on bow raves pushed forward by the heads of large whales (Jefferson 2002).

In Japanese waters, life history has been quite well-studied (reviewed by Houck and Jefferson 1999). Calving occurs in August-September off the Pacific coast of Japan, and in May-June in the Sea of Japan/Okhotsk Sea (reviewed by Houck and Jefferson 1999). Very little information is available on Dall's porpoise reproduction in the eastern North Pacific (Jefferson 1990b; Forney 1994). There is apparently a very strong summer calving peak in the months of June through August, and possibly a smaller peak in March (Jefferson 1989). Length at birth is about 100 cm, and gestation lasts about 10 to 12 months (Jefferson 2002); the lactation period is unknown, but it thought to be very short, perhaps 2 to 4 months (Jefferson 1990b). Females reach sexual maturity from 4 to 7 years of age, while males are considered sexually mature at 3.5 to 8 years (Houck and Jefferson 1999).

Dall's porpoises feed primarily on small fish and squid (Houck and Jefferson 1999; Ohizumi et al. 2000). In some areas they appear to feed preferentially at night on vertically-migrating fish and squid associated with the deep scattering layer (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). 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 (±S.D. 23.9) m for a mean duration of 1.29 (±S.D. 0.84) min.

Acoustics and Hearing—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 microseconds [μs]), high-frequency, narrow band clicks, with peak energies between 120 and 160 kHz (see Jefferson 1988). There are no empirical data on hearing ability of this species; however, based on the morphology of the cochlea, it is estimated that the upper hearing threshold is about 170 to 200 kHz (Awbrey et al. 1979).

- Finless Porpoise (*Neophocaena phocaenoides*)

Description—The finless porpoise is the only porpoise species without a dorsal fin. In place of the fin, there is a highly variable dorsal ridge, covered with a series of small denticles (or bumps), running along the back from about 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.

Finless porpoises are generally colored various shades of gray, with extensive geographic variation in adult coloration (Jefferson and Hung 2004). Animals in Japanese waters are much lighter than individuals in more tropical parts of the species' range which may appear nearly black. Although the maximum known length is 227 cm, most finless porpoises are less than 2 m in length (Jefferson and Hung 2004). There are two apparently distinct forms that may merit separate species status: wide-ridged and narrow-ridged morphotypes (see Jefferson 2002).

Status—The finless porpoise is listed by the IUCN as data deficient (Reeves et al. 2003). The finless porpoise is currently recognized as one species with three geographical forms (subspecies) but may actually consist of two species, each with additional subspecies (MMC 2005; Jefferson personal communication).

There are recent abundance estimates available for all 5 known finless porpoise populations in Japanese waters: Omura Bay (289 individuals), Araike Sound and Tachibana Bay (3,807), the Inland Sea (7,593), Ise and Mikawa Bays (3,743), and Tokyo Bay to Sendai Bay (3,233) (Amano et al. 2003; Shirakihara 2005; Kasuya and Shirakihara 2005). Little is known about the abundance trends of most populations; however, the status of the Inland Sea population is known to have declined dramatically since the 1970s, as there have been two sets of surveys for the species in this area, separated by a period of about 22 years (Kasuya et al. 2002).

Habitat Preferences—The finless porpoise occurs in tropical to warm temperate waters. It is found in coastal and some shallow offshore waters (still over continental shelf water depths), including many bays, gulfs, swamps, and estuaries (and one freshwater river) (Jefferson and Hung 2004). This

species appears to prefer estuaries in many parts of its range, but in at least Hong Kong, it avoids estuarine waters and remains in more saline environments (Jefferson et al. 2002). In the Yangtze River, finless porpoises congregate in shallow water areas near the river banks and in confluences where fish tend to aggregate (Wei et al. 2002). Distribution offshore is apparently limited more by water depth (<40 m), rather than by actual distance from the coast (Shirakihara 2005).

Distribution—The finless porpoise is found in the Indo-Pacific region, from central Japan, south to the western islands of the Indo-Malay Archipelago, and from there around the rim of the Indian Ocean to the Persian Gulf (Jefferson and Hung 2004). Records of its occurrence exist for nearly all countries within its known range. One exception is the Philippines, which mostly consists of islands separated by deep waters (which are not considered suitable habitat for this species; Jefferson and Hung 2004). The known distribution is largely coastal, and the one area where the range is known to extend for several hundreds of kilometers offshore is the shallow shelf waters of the Yellow and East China seas (see Jefferson and Hung 2004).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The distribution of the finless porpoise has been relatively well-studied in Japanese waters. Finless porpoises apparently occur in distinct areas, but some regions of the coast are not as well studied as others. There are currently no known records from Okinawa, although Kasuya (1999c) reported several finless porpoises from the stomach of a great white shark caught there (however, these may have been ingested elsewhere). **Figure A-40** is based mostly on recent summaries provided by Yoshida (2002) and Kasuya et al. (2002).

  There is no evidence of significant seasonal differences in the overall pattern of distribution. This is a coastal, tropical species that extends into the warm temperate zone. There are 5 known populations in Japanese waters and these are each indicated with a concentrated occurrence (and keyed to the numbers used below; Kasuya et al. 2002; Yoshida 2002):

  1) Omura Bay,
  2) Araike Sound and Tachibana Bay,
  3) Inland Sea,
  4) Ise and Mikawa bays, and
  5) Tōkyō Bay to Sendai Bay.

  These 5 populations are distinct stocks with documented genetic and morphological differences (see review in Yoshida 2002). However, finless porpoises are known also from other locations, and these areas are given an expected occurrence (along the shelf off the Pacific coast and in a band of 50 NM (93 km) offshore off the Sea of Japan coast. Finally, there are some records of finless porpoises in the shallow, offshore waters of the East China Sea; therefore, these areas are marked as low or unknown occurrence for the species. Occurrence patterns are considered to be similar throughout the year.

Behavior and Life History—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 (see Jefferson and Hung 2004). Little is know of their group structure, as no detailed studies have been conducted of identified individuals, but it is thought that (other than mother-calf pairs), most groups are probably fluid, with only short-lasting associations (Jefferson personal communication). 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 many other small cetacean species do. They tend to be most active when feeding or socializing. Most dives appear to be short, generally less than 30 s, but dives of up to 4 min in duration have been noted (see Jefferson and Hung 2004). Dive depths have only been measured directly in the Yangtze River; since no marine tagging studies have been done, there is virtually nothing known about diving depth in marine waters.

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 thereafter begins to level-off. Some animals in southern China appear to live as long as 33 years (Jefferson et al. 2002). Calving is broadly seasonal, with the calving peak varying widely among populations, and probably being largely associated with local periods of highest productivity. Newborns range from about 70 to 85 cm, and gestation is a bit less than one year. 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 (Jefferson et al. 2002; Jefferson and Hung 2004).

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 dermersal fishes, cephalopods, and crustaceans (Jefferson and Hung 2004). Squids often appear to be a very important part of the diet. There is no evidence that they feed regularly on deepwater organisms, such as myctophid fishes. Not much is known of their feeding behavior, although land-based observations in Hong Kong and elsewhere have shown that they can be quite active and agile when pursuing fish, and there is some evidence that suggests they may sometimes feed in association with commercial fishing vessels (Barros et al. 2002).

Acoustics and Hearing—Much of what is known of the acoustic capabilities of finless porpoises comes from studies of captive animals and those in a semi-natural reserve in the Yangtze River, China. They make clicks, presumably used for echolocation (Akamatsu et al. 2005a), as well as some low-frequency continuous-tone sounds (Wang personal communication). Click sounds are the typical narrow-band, high-frequency (87 to 145 kHz) pulses produced by members of the porpoise family (Akamatsu et al. 2005b; Kamminga et al. 1986; Li et al. 2005). Pulse durations are 30 to 122 μs (Li et al. 2005). The sounds pressure level of clicks was measured at 162 dB re 1 μPa-m peak-to-peak (Akamatsu et al. 2005b). In Hong Kong waters, both narrow band clicks (peak energy at 142 kHz), as well as broader-band click sounds have been reported (Goold and Jefferson 2002). 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).

- Spotted Seal (*Phoca largha*)

Description—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 et al. 1993). 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 et al. 1993). Spotted seals are often confused with harbor seals; they are similar in build and proportions but somewhat smaller (Jefferson et al. 1993).

Status—There is no designation for this species on the IUCN Red List. The abundance of spotted seals in the Okhotsk Sea along the northern coast of Hokkaidō has been estimated to be around 13,653 individuals during the breeding season (Mizuno et al. 2002).

Habitat Preferences—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 is dependent on favorable sea ice conditions (Burns 2002). Pups utilize ice blocks and caverns in the ice as shelter from weather and protection from predators (Fay 1974). 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).

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 (Fay 1974; 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 (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 and Nishiwaki 1972; Naito 1976; Naito and Konno 1979). Haul out sites are located along the northern and central coasts of Hokkaidō (Mizuno et al. 2001).

- Information Specific to the Japan and Okinawa Complexes OPAREA—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 and Okinawa Complexes OPAREA throughout the year. They haulout along the coast of Hokkaidō and have been sighted along the coasts of Honshū and Shikoku (Naito 1976). The southern range of spotted seals extends to South Korea and the Yellow and Bohai Seas of China (Peilie 1986; Zhou 1991; Won and Yoo 2004). 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). Based on sighting records and known distribution patterns, 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; **Figure A-41**). There is a low or unknown area of occurrence that extends further offshore of the southern tip of Kyūshū and west into the East China Sea. There is another low or unknown occurrence in the bays (**Figure A-41**). Occurrence patterns are the same throughout the year.

Behavior and Life History—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). Spotted seals are annually monogamous and territorial (Burns 2002).

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 more southernly parts of the species' range (Burns 2002). The birth season lasts one to two months; lactation lasts from two to six weeks (Bigg 1981). Delayed implantation occurs. Pups are weaned after four weeks (Quakenbush 1988). Along the coast of Hokkaidō, pupping occurs during the middle and end of March, and pups are weaned within three weeks (Naito and Nishiwaki 1972; Mizuno et al. 2002). In this area, spotted seals mainly haul out between January and April with peak numbers during the breeding season (March) (Mizuno et al. 2001).

During ice-free months, seals spend about 16% of their time at haulout sites (Lowry et al. 1998). The rest of the 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). Spotted seals feed on a wide variety of prey including fishes, crustaceans, and cephalopods; there are major seasonal and regional differences in diet due to the wide ranging distribution of this species (Burns 2002). Spotted seals off Hokkaidō are known to feed on fishes, cephalopods, euphasiids, decapods, squid, and octopus (Kato 1982). Feeding most frequently occurs in the morning and evening (Burns 2002). Spotted seals are capable of diving to depths of 500 m (Burns 2002).

Acoustics and Hearing—Spotted seal calls appear to be relatively similar to those of harbor seals (Schevill et al. 1963; Southall personal communication). 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). Beir and Wartzok (1979) reported that a captivity 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).

Spotted seal hearing is presumed to be similar to that of the closely-related harbor seal (Southall personal communication). 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 (Terhune and Turnball 1995; Kastak and Schusterman 1998; Wolski et al. 2003). Kastak and Schusterman (1996) observed a TTS of 8 dB at 100 Hz, with complete recovery approximately one week following exposure. Kastak et al. (1999) determined that underwater noise of moderate intensity (65 to 75 dB source level) and duration (20 to 22 min) is sufficient to induce TTS in harbor seals.

- Harbor Seal (*Phoca vitulina*)

Description—The harbor seal (or common seal) is a small- to medium-sized seal. Adult males attain a maximum length of 1.9 m and weigh 70 to 150 kg; females reach 1.7 m in length and weigh between 60 and 110 kg (Jefferson et al. 1993). The harbor seal has a dog-like head with nostrils that form a broad V-shape; this is one of the characteristics that distinguish them from immature gray seals (Baird 2001). Adult harbor seals exhibit considerable variability in the color and pattern of their pelage; the background color is tannish-gray overlaid by small darker spots, ring-like markings, or blotches (Shaughnessy and Fay 1977; Bigg 1981).

Status—There is no designation for the harbor seal on the IUCN Red List. There are five recognized subspecies of harbor seal (Shaughnessy and Fay 1977; Rice 1998). Three subspecies are found in the North Atlantic Ocean (two are found along the coasts of the North Atlantic Ocean and occasionally enter rivers and lakes while the other permanently resides in certain freshwater rivers and connecting lakes; Rice 1998). The other two subspecies are found in the eastern and western North Pacific Ocean; their ranges overlap near the southern Bering Sea (Shaughnessy and Fay 1977; Quakenbush 1988). The western North Pacific subspecies, the Kuril seal (*Phoca vitulina stejnegeri*), occurs in northern Japan (Shaughnessy and Fay 1977). Since the 1960s, the Kuril seal population has decreased due to hunting and incidental catch mortality (Naito 1976; Wada et al. 1991; Woodley and Lavigne 1991). The population of Kuril seals along the eastern coast of Hokkaidō is estimated to be approximately 350 individuals (Wada et al. 1991).

Habitat Preferences—Harbor seals, while primarily aquatic, also utilize the coastal terrestrial environment, where they haul out of the water periodically. Harbor seals are a coastal species, rarely found more than 20 km from shore, and frequently occupying bays, estuaries, and inlets (Baird 2001). Individual seals have been observed miles upstream in coastal rivers (Baird 2001).

Ideal harbor seal habitat includes suitable haulout sites, shelter during the breeding periods, and sufficient food within proximity to haulout sites to sustain the population throughout the year (Bjørge 2002). Haulout substrate varies but includes intertidal and subtidal rock outcrops, sandbars, sandy beaches, and even peat banks in salt marshes (Wilson 1978; Prescott 1982; Schneider and Payne 1983; Gilbert and Guldager 1998).

Distribution—The harbor seal is one of the most widespread of the pinniped species. Its distribution stretches from the east Baltic Sea, west across the Atlantic and Pacific Oceans to southern Japan (Stanley et al. 1996). In the North Pacific Ocean, harbor seals are distributed along coastal and insular habitats from Hokkaidō to Baja California during the breeding season (Shaughnessy and Fay 1977). The Kuril seal ranges from the coasts of Kamchatka, the Commander Islands, and the western Aleutian Islands, southwest to the Okhtosk Sea and through the Kuril Islands to the Pacific coast of

Hokkaidō (Shaughnessy and Fay 1977; Rice 1998). Harbor seals primarily occur within 20 km from shore (Baird 2001). Harbor seals exhibit a distinctive annual cycle of abundance, but many seals remain close to their haulout sites throughout the year (Bonnell and Dailey 1993; Koski et al. 1998).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Peak abundance on Hokkaidō occurs during the molting period in July (Hayama 1988). The southern limit of distribution in Japan is Cape Erimo on the southern tip of Hokkaidō (Hayama 1988). There are no published records for the harbor seal in the Japan and Okinawa Complexes OPAREA. Any sightings of this species in the OPAREA would be considered extralimital.

Behavior and Life History—On land, harbor seals tend to congregate in small groups of about 30 to 80 individuals, although larger groups are found in areas where food is plentiful (Ronald and Gots 2003). This species is gregarious on land (although individuals do not lie in close contact with one another), but there is no developed social structure and in the water they tend to disperse and forage for food alone (Baird 2001; Ronald and Gots 2003). Harbor seals inhabiting rock haulout sites create hierarchies based on size and sex, with territorial adult males dominating all other sex and age classes (Baird 2001).

Tidal stage is probably one of the more important daily influences on haulout behavior (Kovacs et al. 1990). Seals begin coming ashore either individually or in groups with the low tide to form loose assemblages for the duration of low tide (Gilbert and Guldager 1998; Zamon 2001; DeHart 2002). With the high tide, the animals disperse into the water and usually spend the period of high tide foraging individually. There is apparently site fidelity by individuals to specific haulout sites within seasons. Human disturbance can affect haulout choice (Harris et al. 2003). Harbor seals are not known to migrate throughout the year (Naito 1976).

The timing of harbor seal pupping varies geographically (Temte et al. 1991). On Hokkaidō, pups are born in late May and weaned within four weeks (Naito and Nishiwaki 1972). Suckling harbor seal pups spend as much as 40% of their time in the water (Bowen et al. 1999). The nursing period is approximately 24 days (Thompson et al. 1994). Mating takes place in the water shortly after the pups are weaned. Delayed implantation occurs. Harbor seals haul out on nine main sites along the southeastern coast of Hokkaidō (Ohtaishi and Yoneda 1981). Males remain on these haulout sites throughout the year; however, adult females only appear during breeding season (Hayama 1988).

Harbor seals are opportunistic feeders; they adjust their feeding patterns to take advantage of locally and seasonally abundant prey (Payne and Selzer 1989; Baird 2001; Bjørge 2002). Diet consists of fish and invertebrates (Bigg 1981); but generally, schooling or bottomfish species are taken. Feeding most frequently occurs during high tide. Individual seals utilize different foraging habitats, repeatedly returning to the same habitat; this may be a result of intraspecific competition for foraging sites and fish resources in close proximity to haulout sites (Bjørge 2002).

Harbor seals are generally shallow divers. About 50% of their diving is shallower than 40 m, and 95% is shallower than 250 m (Gjertz et al. 2001; Krafft et al. 2002; Eguchi and Harvey 2005). Dive durations are typically shorter than 10 min, with about 90% lasting less than 7 min (Gjertz et al. 2001). A tagged harbor seal in Monterey Bay dove as deep as 481 m (Eguchi and Harvey 2005). Harbor seal pups swim and dive with their mothers, although they dive for short periods compared with their mothers (Bowen et al. 1999; Jørgensen et al. 2001; Bekkby and Bjørge 2003). Recorded dive durations for older individuals may be as long as 32 min (Eguchi and Harvey 2005).

Acoustics and Hearing—Harbor seals produce a variety of airborne vocalizations including snorts, snarls, and belching sounds (Bigg 1981). Adult males produce low-frequency vocalizations underwater during the breeding season (Hanggi and Schusterman 1994; Van Parijs et al. 2003). Male harbor seals produce communication sounds in the frequency range of 100 to 1,000 Hz (Thomson and Richardson 1995).

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 (Terhune and Turnball 1995; Kastak and Schusterman 1998; Wolski et al. 2003). Kastak and Schusterman (1996) observed a TTS of 8 dB at 100 Hz, with complete recovery approximately one week following exposure. Kastak et al. (1999) determined that underwater noise of moderate intensity (65 to 75 dB source level) and duration (20 to 22 min) is sufficient to induce TTS in harbor seals.

- Ringed Seal (*Pusa hispida*)

Description—The ringed seal is one of the smallest pinnipeds. Adults can reach 1.65 m in length and weigh 50 to 110 kg. Ringed seals resemble harbor seals but are decidedly plumper. The ringed seal's coloration is its most distinctive feature. Ringed seal fur is light gray with black spots circled with rings of lighter color (Jefferson et al. 1993).

Status—There is no designation for this species on the IUCN Red List (IUCN 2004). The ringed seal is the most numerous seal in the Northern Hemisphere (Frost and Lowry 1981). There are five subspecies of the ringed seal; three occur in marine waters, while two are found in freshwater lakes (Amano et al. 2002). The subspecies, *Phoca hispida ochotensis*, inhabits the Okhotsk Sea and ranges south to the northern coast of Hokkaidō and Kamchatka (Rice 1998). The population of *Phoca hispida ochotensis* is estimated to be around 800,000 to 1,000,000 animals (Reijnders et al. 1993).

Habitat Preferences—The ringed seal occupies stable fast ice and waters covered with pack ice throughout the winter (Kingsley 1990). The preferred habitat is areas that freeze to stable ice in winter (Kingsley 1990; Teilmann et al. 1999; Simpkins et al. 2003). Ringed seals will only haul out at holes or narrow cracks in fast ice or in the middle of very large floes (>48 m in diameter), not on the edge of wide leads or ice floes (Kingsley 1990; Simpkins et al. 2003). Subadults winter in shear zones and areas of unconsolidated ice not suitable for breeding and are subject to intense predation by polar bears (Kingsley 1990). By late spring when the snow cover melts, ringed seals haul out in the open at their breathing holes or at newly formed cracks to molt and bask (Kingsley and Stirling 1991).

Distribution—The ringed seal has a circumpolar distribution throughout the Arctic Ocean, Hudson Bay, and Baltic and Bering seas (Reeves et al. 2002). Ringed seals range as far south as the Okhotsk Sea and Japan (Frost and Lowry 1981). Ringed seals are able to cover long distances in relatively short times, with extralimital strays occasionally found as far south as Portugal in the Atlantic Ocean and California in the Pacific (Dudley 1992; van Bree 1996; Ridoux et al. 1998; Lucas and McAlpine 2002). These extralimital strays are not necessarily lost to the population, since at least one individual is known to have returned to the vicinity of known normal ringed seal distribution (Ridoux et al. 1998).

- Information Specific to the Japan and Okinawa Complexes OPAREA—In Japan, ringed seals occur along the coast of Hokkaidō. Sightings along the coast of other islands of Japan are scarce, but there are a few records of ringed seals near the OPAREA along the west coast of Honshū, east coast of Honshū and Shikoku, and near Fukuoka-city on Kyūshū (Naito 1976). Ringed seals have also been sighted as far south as China (Zhou 1991). Any sightings in the OPAREA would be considered extralimital.

Behavior and Life History—Adult ringed seals are solitary, except for loose feeding aggregations that form in the water in summer (Kingsley 1990). The ringed seal establishes breathing holes in the unbroken ice as the ice forms during the fall. Seals of this species maintain the holes throughout the winter by constantly scratching away the ice with claws on their foreflippers. In early spring, the ringed seal occupies lairs in the overlying snow. These lairs are used as pupping and resting sites (Smith and Stirling 1975). Ringed seals scratch the lairs out of the snow (these are known as subnivean lairs) above the breathing hole in the ice to shelter themselves from predators and severe weather conditions (Smith and Stirling 1975). Hammill and Smith (1991) suggested that the lair evolved primarily in response to predation by polar bears (*Ursus maritimus*) (particularly, of the pups), and the

thermal protection that they provide is a secondary benefit. Females give birth and leave their pups in the lairs between nursings. Pups are born in late March to early May; they are nursed for 4 to 6 weeks (Frost and Lowry 1981). Pups have been observed to enter the water, dive to over 10 m, and return to the lair as early as 10 days after birth, suggesting that pups can survive the cold water temperatures at a very early age (CPA 2003). Most mating occurs in late April and May; delayed implantation takes place (Kingsley 1990). From mid-May through July, ringed seals haul out to bask in the sun. They molt from late March until the ice breaks up, which usually occurs in July.

Ringed seals feed on a variety of amphipods, euphausiids, mysids, shrimps, cephalopods, and fish (Weslawski et al. 1994). In shallow, inshore waters, these seals feed near the bottom, chiefly on polar cod (*Boreogadus saida*) and on the small crustacean *Mysis*, whereas ringed seals in the deeper offshore waters catch the planktonic amphipod *Themisto libellula* (Weslawski et al. 1994). During the summer, ringed seals feed on swarming aggregations of krill (*Thysanoessa inermis*) (Weslawski et al. 1994). Food consumption rates vary seasonally; the general pattern is for seals to feed intensively from late summer to early spring. During the molt, the seals feed less intensively and spend proportionately more time hauled out.

Median dive duration is less than 10 min for ringed seals (Lydersen 1991; Teilmann et al. 1999; Gjertz et al. 2000). Ringed seals occasionally dive up to 50 min or longer and at depths of more than 250 m although most dives are shallower than 100 m (Lydersen 1991; Teilmann et al. 1999; Gjertz et al. 2000).

Acoustics and Hearing—Ringed seals produce clicks with a fundamental frequency of 4 kHz and varying harmonics up to 16 kHz (Schevill et al. 1963). Stirling (1973) described barks, high-pitched yelps, and low and high-pitched growls. Ringed seals appear to be most vocal during the breeding season (Stirling et al. 1983). Ringed seals are sensitive to underwater sounds in the 8 to 60 kHz range (Terhune and Ronald 1975, 1976). The hearing ability of ringed seals has not been tested below 1 kHz (Terhune and Ronald 1975).

- Ribbon Seal (*Histriophoca fasciata*)

Description—Ribbon seals are easily identified by their color pattern. Adults have reddish-brown to black coats with white to yellowish-white bands encircling the neck, hips, and fore-flippers (Reeves et al. 1992). Adult females have lighter coats and less distinct banding than males. Pups are born with a thick, white coat that is replaced by a dark, bluish-gray pelage after 4 to 5 weeks. The banding pattern emerges after 2 years (Reeves et al. 1992). Adults reach a maximum length of around 1.8 m and weigh 90 to 148 kg (Jefferson et al. 1993).

Status—There is no designation for this species on the IUCN Red List (IUCN 2004). There are three populations of ribbon seals: two in the Okhotsk Sea and one in the Bering Sea (Fedoseev 2002).

Habitat Preferences—Ribbon seals prefer firm pack ice far offshore and along regions with an abrupt continental shelf for breeding, molting, and nursing (Fay 1974; Fedoseev 2002). These areas are characterized by small ice floes (less than 20 m wide) separated by water or slush ice and are subject to rapid dispersal or compaction by winds and ocean currents (Burns 1970). Ribbon seals cannot make breathing holes in thick ice (10 to 15 cm) and, therefore, avoid areas of solid ice fields (Fedoseev 2002). Prey resources are also highly concentrated near the ice floes allowing easy access for ribbon seals (Fedoseev 2002).

Distribution—Ribbon seals inhabit the Arctic regions of the Pacific, from the East Siberian Sea and Chukchi Sea southeast to Bristol Bay and Unalaska Island, and southwest along the coast of Kamchatka and the Kuril Islands as far north as Hokkaidō, including the Okhotsk Sea south to Tatarskiy Proliv (Nishiwaki and Nagasaki 1960; Rice 1998). Vagrants have been sighted in Cordova, Alaska, and Morro Bay, California (Roest 1964; Rice 1998).

Ribbons seals are closely associated with ice. They give birth, nurse pups, mate, and molt along the ice edge during late winter and early spring (Frost and Lowry 1980). When the sea ice melts (July through November), ribbon seals become pelagic and probably spend most of their time foraging (Frost and Lowry 1980). Ribbon seals typically do not haul out on land (Burns 1981a). The distribution and range of ribbon seals at sea is not fully known (Burns 1970). During the breeding season, ribbon seals are found only on the pack ice of the Okhotsk and Bering Seas (Kelly 1988a). The occurrence of ribbon seals off the northern coast of Hokkaidō coincides with the movement of ice floes from the Okhotsk Sea in February (Naito and Konno 1979). Ribbon seals are abundant in northern Hokkaidō during years of heavy ice formation. They drift south during the spring with ice from the Okhotsk Sea (Burns 1981a).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The normal range of ribbon seals does not extend south of Hokkaidō. Not much is known about their distribution at sea; ribbon seals have been sighted far from their normal range. However, based on their association with sea ice and their normal distribution patterns, ribbon seals are not expected to occur in the Japan and Okinawa Complexes OPAREA. Any sightings in the OPAREA would be considered extralimital.

Behavior and Life History—Ribbon seals are largely solitary animals, forming groups only during the breeding season (Naito and Konno 1979; Ronald and Gots 2003). Pupping primarily occurs in early and mid-April (Reeves et al. 1992). The lactation period is about 4 weeks. Pups remain on the ice until they shed their natal pelage at around 3 to 4 weeks after birth (Burns 1970). Mating occurs in April and May near the time when pups are weaned; delayed implantation takes place (Reeves et al. 1992) and the gestation period is 11 months (Wynne 1992). Males are sexually mature at 3 to 5 years of age. Although females reach sexual maturity between 2 and 4 years of age, many do not give birth until around the age of 4 or 5 (Reeves et al. 1992).

Prey composition and size vary among ribbon seal age classes. This is probably due to differences in foraging technique and diving ability (Deguchi et al. 2004). Pups less than one year old feed on small euphausiids but eat mostly shrimp between one and two years of age (Fedoseev 2002). In contrast, adult diets consist primarily of cephalopods and fish (Fedoseev 2002; Deguchi et al. 2004). They also eat eelpout, mysids, crabs, saffron cod, herring, capelin, and a variety of other fish and cephalopods (Frost and Lowry 1980; Reeves et al. 1992). In Hokkaidō, ribbon seals mainly feed on walleye pollock and magistrate armhook squid (*Berryteuthis magister*) (Deguchi et al. 2004). Ribbon seals usually forage in the deep intermediate-bottom layer of the continental slope (Deguchi et al. 2004). The ribbon seal is well adapted for diving and is known to dive to depths of 600 m (Fedoseev 2002).

Acoustics and Hearing—Ribbon seal vocalizations are downward frequency sweeps and puffing sounds. These frequency sweeps are in the range of 0.1 to 7.1 kHz and a source level of 160 dB re 1 µPa-m (Watkins and Ray 1977). There are no published data on the hearing abilities of the ribbon seal.

- Northern Elephant Seal (*Mirounga angustirostris*)

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

Status—There is no designation for this species on the IUCN Red List (IUCN 2004). The northern elephant seal population has recovered dramatically after being reduced to several dozen to perhaps no more than a few animals in the 1890s (Bartholomew and Hubbs 1960; Stewart et al. 1994). Although movement and genetic exchange continues between rookeries, most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

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

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

The effects of El Niño events on some pinniped species in the North Pacific can be severe. Stewart and Yochem (1991) studied the effects of the strong 1982/83 ENSO on northern elephant seals breeding in the southern California Channel Islands. They found that females arrived 5 to 8 days later, gave birth earlier, and spent less overall time ashore nursing their pups during that winter season. Females appeared to be in poorer physical condition and to be less productive over the next year. However, these effects were not particularly severe and were of short duration. Stewart and Yochem (1991) speculated that the deep-diving habits of elephant seals make them less vulnerable to the negative effects of El Niño events than other, more shallow-water, pinnipeds.

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

Northern elephant seals breed on island and mainland rookeries from central Baja California, Mexico, to northern California (Stewart and Huber 1993). Breeding occurs primarily on offshore islands (Stewart et al. 1994). The major rookeries in Mexico are Isla Cedros, Isla Benito del Este, and Isla Guadalupe, while in California, they are the Southern California Channel Islands, Piedras Blancas, Cape San Martin, Año Nuevo Island and peninsula, the Farallon Islands, and Point Reyes (Stewart et al. 1994; Carretta et al. 2005).

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

- Information Specific to the Japan and Okinawa Complexes OPAREA—The elephant seal is known to make long-distance movements, including as far west as the Hawaiian Islands and Japan (NWAFC 1978; Antonelis and Fiscus 1980; Tomich 1986; Kiyota et al. 1992; Fujimori 2002). Japan is not within the normal range of this species; however, one vagrant was recorded on Niijima Island in the Japan and Okinawa Complexes OPAREA (Kiyota et al. 1992). Researchers suspect that occurrence of elephant seals in the western Pacific may become more

common as the population in California continues to grow (Bartholomew and Hubbs 1960). Any sightings of this species in the OPAREA are expected to be extralimital.

Behavior and Life History—Elephant seals are gregarious during the breeding season, but appear to be relatively solitary at sea. Adult elephant seals spend from 8 to 10 months at sea and undertake two annual migrations between haulout and feeding areas (Stewart and DeLong 1995). They haul out on land to give birth and breed, and after spending time at sea to feed (post-breeding migration), they generally return to the same areas to molt (Stewart and Yochem 1984; Stewart and DeLong 1995). The different age and sex classes have somewhat differing annual cycles and migration patterns (Stewart 1997). After weaning their pups in late winter, adult females forage at sea for about 70 days before returning to land to molt their pelage. Following one month ashore, the females return to sea for 8 months (coincident with gestation), before returning to the rookery to give birth. Elephant seals do not necessarily return to the same beaches for breeding and molting. For example, Huber et al. (1991) found that female northern elephant seals often molt on one island and breed on another. Adult males spend approximately 4 months at sea following the breeding season, returning to shore in summer to molt. After one month ashore, they return to sea for 4 months before returning to the rookery for the breeding season.

In December, male elephant seals haul out for the breeding season; many individuals remain there continuously until March. In January, after many males have been on land for several weeks, the adult females come ashore, give birth, suckle their young for about 27 days, breed, and depart (Le Boeuf and Peterson 1969; Stewart and Huber 1993). Gestation is about 11 months, but there is a 2 to 3 month period of delayed implantation. During the breeding season, elephant seals congregate in large numbers on their breeding rookeries. Animals of all ages and both sexes are present on these beaches, although yearlings generally do not return during the breeding season, and are rare at rookeries. Large rookeries, such as those on Año Nuevo Island and peninsula and the Channel Islands, may contain thousands of seals, which mostly arrange themselves in harems consisting of up to several dozen breeding females, a single dominant (alpha) male, and the newborn pups. Other animals, especially other bulls seeking to challenge the alpha male or sneak copulations, often surround the harems.

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

During the molting period, which is at different times of the year for different age classes, seals lose their fur in large patches with the underlying epidermis. This is called a “catastrophic molt” and molting seals look very ragged (Stewart and Huber 1993). Adults return to land between March and August to molt, with males returning later than females (Carretta et al. 2005).

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

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

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

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

- Bearded Seal (*Erignathus barbatus*)

Description—The bearded seal is the largest northern phocid species (Burns 1981b). Adults reach a maximum length of 2.5 m; females are slightly longer than males (Jefferson et al. 1993). In the Bering Sea, adult males weigh 262 kg whereas females weigh 361 kg (Jefferson et al. 1993). The weight of bearded seals is subject to extreme variation due to seasonal changes in feeding activity (Burns 1981b). The bearded seal has a small head and relativey short foreflippers. The whiskers are long and densely packed and resemble a beard, hence the common name “bearded seal” (Jefferson et al. 1993). Adult coloration varies from light or dark grey to brown; the face and flippers are usually rust-colored (Jefferson etal. 1993).

Status—There is no designation for this species on the IUCN Red List (IUCN 2004). Abundance estimates are incomplete. The North Pacific population has been estimated at approximately 300,000 to 450,000 animals (Reijnders et al. 1993).

Habitat Preferences—The preferred habitat of the bearded seal is in areas where sea ice shifts and is thinned or kept open by strong currents (Kingsley and Stirling 1991). Bearded seals haul out on sea ice to rest, give birth, and molt. They are strongly associated with pack ice year-round but may occassionally haul out on land (Fay 1974; Lydersen et al. 1994). They are capable of maintaining breathing holes in thick (10 cm) ice and prefer medium-coverage sea ice and mixed-floes habitat (Fay 1974; Kingsley and Stirling 1991; Simpkins et al. 2003). Bearded seals tend to avoid large ice floes (>48 m in diameter; Simpkins et al. 2003). Bearded seals feed in the shallower waters of the continental shelf (Burns 1981b; Kelly 1988b).

Distribution—Bearded seals have a circumpolar range associated with sea ice and are capable of moving great distances during the year (Burns 1981b; Trites et al. 1999). Many bearded seals are widely distributed throughout pack ice in the northern Bering and Chukchi Seas during late winter and early spring (Burns 1970). They are most abundant north of the ice edge zone and south of the Bering Strait (Burns 1970). In spring (mid April to June) they migrate northward through the Bering Strait. In the summer, they are mostly found along the wide, fragmented margin of multi-year ice but may also occur in the open sea (Burns 1981b). They migrate south in late fall through winter (Burns 1981b).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The bearded seal does not normally occur south of Hokkaidō; therefore, any sightings in the OPAREA would be extralimital. Bearded seals are mostly found off the southern coast of Hokkaidō and in the Okhotsk Sea (Nishiwaki and Nagasaki 1960; Mizuno et al. 2002). In 1968 and 1970, two bearded seals were recorded at Akita and Niigata along the west coast of northern Honshū (Naito 1976). Vagrant bearded seals have also been recorded as far south as the Boso Peninsula on the Pacific coast of Japan and in the Greater Tōkyō area (Naito 1979; Asakura 2002). There are a few records of bearded seals in the Sea of Japan and along the Pacific coast of Japan (Naito 1976, 1979). One vagrant bearded seal, in particular, has become a national celebrity since showing up in the Tama River near Tōkyō in 2002 (Asakura 2002; Anonymous 2004). This bearded seal is regularly seen in the Greater Tōkyō area throughout the year (Anonymous 2004).

Behavior and Life History—Bearded seals do not usually form herds but are known to congregate in favorable areas (Burns 1970). Individuals usually haul out on adjacent ice floes and position their heads within inches of a hole or crack through which they can esape if disturbed (Burns 1981b).

Bearded seal pups are usually born between April and May; they enter the water a few days after birth (Burns 1970). Pups are weaned around 24 days after birth (Lydersen and Kovacs 1999). Females with pups spend approximately 92% of their time in the water during the lactation period. Most of this time is spent foraging and caring for the pups (Krafft et al. 2000). Mating takes place in the water after pups are weaned. Males vocalize underwater to attract females and also fight with other males during the breeding season (Kovacs 2002). Implantation is delayed for about two months (Burns 1981b). Female bearded seals reach sexual maturity around 5 years of age, while males are sexually mature at 6 or 7 years (Kovacs 2002).

Bearded seals mainly feed on bottom-living invertebrates such as crustaceans, mollusks, and polychaetes; shrimps, crabs, and clams are the most important prey (Lowry et al. 1980). Their diet also consists of fish including sculpin, flounder, and Arctic cod (Lowry et al. 1980).

Bearded seals are shallow divers; most dives are less than 100 m deep (Burns 1981b; Kovacs 2002). The deepest recorded dive was greater than 488 m (Kovacs 2002). Most dives are less than 10 min in duration, but bearded seals can dive up to 25 min (Kovacs 2002). Females with pups are known to dive for about 20 min and to depths of up to 288 m (Krafft et al. 2000). Pups can dive to depths greater than 90 m and remain submerged for over 5 min (Kovacs 2002).

Acoustics and Hearing—Bearded seal calls are loud, long, and trill-like (Ray et al. 1969; Stirling et al. 1983; Cleator et al. 1989) and often described as a song. These calls make up a dominant component of the ambient noise in many arctic regions during spring (Thomson and Richardson 1995). Bearded seal calls are primarily a series of prolonged frequency downsweeps; the frequency range is 0.02 to 6.0 kHz, with dominant frequencies between 1 and 2 kHz (Ray et al. 1969; Stirling et al. 1983). Call duration can be up to at least 1 min; these sounds can be heard for distances of 25 km or more underwater (Stirling et al. 1983; Cleator et al. 1989; Terhune 1999). They are heard between March and June and evidence suggests that only males produce these calls, perhaps to advertise breeding condition and/or territoriality (Stirling et al. 1983; Cleator et al. 1989; Van Parijs et al. 2003). In many locales, bearded seals call simultaneously (Cleator et al. 1989; Terhune 1999). Three call types have been identified (Cleator et al. 1989; Terhune 1999). The source level of the calls can reach 178 dB re 1 μPa-m (Thomson and Richardson 1995).

There is no direct data published on the hearing capabilities of the bearded seal. It would be reasonable to assume that they are similar to other phocid seals, such as harbor seals (Southall personal communication).

- Northern Fur Seal (*Callorhinus ursinus*)

Description—Northern fur seals are extremely sexually-dimorphic; males are a maximum of 4.5 times larger than females (Gentry 2002). Males can grow up to 2.1 m and 270 kg, while females can reach 1.5 m and 50 kg or more (Jefferson et al. 1993). Adult females are gray-brown with a light underbelly. Males are much darker, with black to reddish coats (Gentry 2002). They also have long, coarse guard hairs with silver-grey or yellowish tinting (Jefferson et al. 1993). Pups are generally black with a light belly (Gentry 2002). Northern fur seals have relatively small heads and short, pointed snouts with very long ear flaps (Reeves et al. 1992).

Status—The northern fur seal is designated as vulnerable by the IUCN Red List (IUCN 2004). There are at least five separate stocks of northern fur seals based on geographic separation during the breeding season. Individuals from these stocks are considered one biological species (NMFS 1993). The abundance of northern fur seals in the North Pacific Ocean was estimated at 190,000 individuals in 1987-1990 (Buckland et al. 1993).

Habitat Preferences—The northern fur seal is an extremely oceanic species spending all but 35 to 45 days per year at sea (Gentry 2002). 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).

Distribution—Northern fur seals occur from southern California, north to the Bering Sea and west to the Okhotsk Sea and Honshū, Japan (Carretta et al. 2005). 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).

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). 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). The northward migration begins in March (Antonelis and Fiscus 1980).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Northern fur seals regularly occur in the OPAREA between November and July when they migrate off Japan. 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) (Gentry 2002); however, some seals migrate as far south as the southern Sea of Japan, along the east coast of Korea (Nishiwaki and Nagasaki 1960). There are extralimital records as far south as Chinese waters (Zhou 1991). 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). In spring or early summer, northern fur seals return to their northern breeding areas in and around the Bering Sea (Nishiwaki and Nagasaki 1960). They are usually sighted offshore (70 to 130 km from land) and along the continental shelf and slope where they typically forage (Kajimura 1984). The northern fur seal is a cold water species and it does not typically migrate south of about 35°N. Therefore, there is an area of expected occurrence north of 35°N in the Japan and Okinawa Complexes OPAREA (**Figure A-42**). There is a low or unknown occurrence further south in the East Japan study area and West Japan study area. Northern fur seals are not expected to occur in the Okinawa study area. Occurrence patterns are the same throughout the year.

Behavior and Life History—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 and must fast throughout the breeding season (Gentry 2002). They establish territories in early to mid-May; females arrive in late May and give birth a few days later (Bonnell et al. 1980). Northern fur seals exhibit strong site fidelity for mating and pupping; males will defend only one territorial location in their reproductive lifetime and females bear their young within 8 to 10 m of a particular site in successive years (Gentry 2002). In late July, males abandon their territories, allowing subadult males to mate with females during the rest of the summer breeding season (Gentry 2002). Females alternate between nursing on land for about 2 days and feeding at sea for around 4 days (DeLong 1982). Pups are weaned at around 4 months (Gentry 1998).

Northern fur seals are solitary at sea but tend to congregate in food-rich areas where as many as 100 individuals have been sighted (Antonelis and Fiscus 1980; Kajimura 1984). 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). The principal prey species off Japan is the Pacific squid and pollock (Panin and Panina 1971; Mori et al. 2001).

The average dive time of northern fur seals is 2.6 min, with a maximum between 5 and 7 min. The deepest recorded dive is 207 m, but most are between 20 and 140 m and are probably associated with feeding (Kooyman et al. 1976; Gentry et al. 1986).

Acoustics and Hearing—Northern fur seals produce underwater clicks, and in-air bleating, barking, coughing, and roaring sounds (Schusterman 1978; Thomson and Richardson 1995). Males vocalize (roar) almost continuously at rookeries (Gentry 1998). There are in-air and underwater audiograms available for the northern fur seal. 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). The underwater hearing range of the northern fur seal ranges from 0.5 Hz to 40 kHz (Moore and Schusterman 1987; Babushina et al. 1991); the threshold is 50 to 60 dB re 1 μPa-m (Moore and Schusterman 1987). The underwater hearing threshold is 90 to 100 dB re 1 μPa-m at 1 kHz; best underwater hearing occurs between 4 and 17 to 28 kHz (Moore and Schusterman 1987; Babushina et al. 1991). The underwater hearing sensitivity of this species is 15 to 20 dB better than in the air (Babushina et al. 1991). The maximum sensitivity in-air is at 3 to 5 kHz (Babushina et al. 1991), after which there is an anomalous hearing loss at around 4 or 5 kHz (Moore and Schusterman 1987; Babushina 1999).

3.1.3 Literature Cited

Aburto, A., D.J. Rountry, and J.L. Danzer. 1997. Behavioral response of blue whales to active signals. Technical Report 1746. San Diego: Naval Command, Control and Ocean Surveillance Center. 75 pp.

Acevedo, A., and M.A. Smultea. 1995. First records of humpback whales including calves at Golfo Dulce and Isla del Coco, Costa Rica, suggesting geographical overlap of northern and southern hemisphere populations. Marine Mammal Science 11(4):554-559.

Agler, B.A., R.L. Schooley, S.E. Frohock, S.K. Katona, and I.E. Seipt. 1993. Reproduction of photographically identified fin whales, *Balaenoptera physalus*, from the Gulf of Maine. Journal of Mammalogy 74(3):577-587.

Akamatsu, T., D. Wang, K. Wang, and Y. Naito. 2005a. Biosonar behaviour of free-ranging porpoises. Proceedings of the Royal Society of London, Part B 272:797-801.

Akamatsu, T., D. Wang, and K. Wang. 2005b. 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 117:3325-3330.

Aketa, K. 2002. Stomach contents of dugongs from Okinawa, southern Japan, from 1992 to 2000. SireNews 37:8.

Allen, M.C., A.J. Read, J. Gaudet, and L.S. Sayigh. 2001. Fine-scale habitat selection of foraging bottlenose dolphins *Tursiops truncatus* near Clearwater, Florida. Marine Ecology Progress Series 222:253-264.

Amaha, A. 1994. Geographic variation of the common dolphin, *Delphinus delphis* (Odontoceti: Delphinidae). Ph.D. thesis, Tokyo University of Fisheries.

Amano, M., and T. Kuramochi. 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 N. Miyazaki. 1996. Geographic variation in external morphology of Dall's porpoise, *Phocoenoides dalli*. Aquatic Mammals 22:167-174.

Amano, M., and M. Yoshioka. 2003. Sperm whale diving behavior monitored using a suction-cup-attached TDR tag. Marine Ecology Progress Series 258:291-295.

Amano, M., N. Miyazaki, and F. Yanagisawa. 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., A. Hayano, and N. Miyazaki. 2002. Geographic variation in the skull of the ringed seal, *Pusa hispida*. Journal of Mammalogy 83(2):370-380.

Amano, M., F. Nakahara, A. Hayano, and K. Shirakihara. 2003. Abundance estimate of finless porpoises off the Pacific coast of eastern Japan based on aerial surveys. Mammal Study 28:103-110.

Amir, O.A., P. Berggren, S.G.M. Ndaro, and N.S. Jiddawi. 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.

Andersen, S. 1970. Auditory sensitivity of the harbour porpoise *Phocoena phocoena*. Pages 255-259 in G.Pilleri, ed. Investigations on Cetacea. Volume 2. Berne, Switzerland: University of Berne.

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 R.M.R. Barclay. 1995. Acoustic signals of solitary dugongs: Physical characteristics and behavioral correlates. Journal of Mammalogy 76(4):1226-1237.

Angliss, R.P., and R. Outlaw, eds. 2005. Draft Alaska marine mammal stock assessments: 2005. NOAA Technical Memorandum NMFS-AFSC. 234 pp.

Anonymous. 2004. Tama-chan battles flab, sassy new rival. Japan Times, 20 April. Accessed 25 July 2005. http://www.japantimes.co.jp/cgi-bin/makeprfy.p15?nn20040420b8.htm.

Anonymous. 2005. Killer whale escapes Hokkaido ice floes. Japan Times, 9 February. Accessed 1 August 2005.

Antonelis, G.A., Jr., and C.H. Fiscus. 1980. The pinnipeds of the California Current. CalCOFI Reports XXI:68-78.

Antonelis, G.A., M.S. Lowry, C.H. Fiscus, B.S. Stewart, and R.L. DeLong. 1994. Diet of the northern elephant seal. Pages 211-223 in B.J. Le Boeuf and R.M. Laws, eds. Elephant seals: Population ecology, behavior, and physiology. Berkeley: University of California Press.

Archer, F.I., II, and W.F. Perrin. 1999. *Stenella coeruleoalba*. Mammalian Species 603:1-9.

Aruga, Y., Y. Yokohama, and M. Nakanishi. 1968. Primary productivity studies in February-March in the northwestern Pacific off Japan. Journal of the Oceanographical Society of Japan 21(6):275-280.

Asakura, T. 2002. Seal checks into Hotel Tamagawa. Japan Times, 17 August. Accessed 31 July 2005. http://www.japantimes.co.jp/cgi-bin/makeprfy.p15?nn20020817a5.htm.

Au, D.W.K., and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. Fishery Bulletin 83(4):623-643.

Au, W.W.L. 1993. The sonar of dolphins. New York: Springer-Verlag.

Au, W.W.L., A.N. Popper, and R.R. Fay, eds. 2000. Hearing by whales and dolphins. Volume 12. New York: Springer-Verlag.

Au, W., J. Darling, and K. Andrews. 2001. High-frequency harmonics and source level of humpback whale songs. Journal of the Acoustical Society of America 110(5):2770.

Au, W.W.L., J.K.B. Ford, J.K. Horne, K.A. Newman Allman. 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(2):901-909.

Awbrey, F.T., J.C. Norris, A.B. Hubbard, and W.E. Evans. 1979. The bioacoustics of the Dall porpoise-salmon drift net interaction. H/SWRI (Hubbs/Sea World Research Institute) Technical Report 79-120. Submitted to National Marine Fisheries Service, Seattle, Washington 41 pp.

Babushina, E.S. 1999. Sound reception in marine mammals: Effects of stimulus parameters and transmission pathways. Biophysics 44(6):1064-1071. Translated from Biofizika 44(6):1101-1108.

Babushina, E.S., G.L. Zaslavsky, and L.I. Yurkevich. 1991. Air and underwater hearing of the northern fur seal audiograms and auditory frequency discrimination. Biofizika 36(5):904-907. (In Russian with English abstract).

Baird, R.W. 2000. The killer whale: Foraging specializations and group hunting. Pages 127-153 in J. Mann, R.C. Connor, P.L. Tyack and H. Whitehead, eds. Cetacean societies: Field studies of dolphins and whales. Chicago: University of Chicago Press.

Baird, R.W. 2001. Status of harbour seals, *Phoca vitulina*, in Canada. Canadian Field-Naturalist 115(4):663-675.

Baird, R.W. 2002. False killer whale *Pseudorca crassidens*. Pages 411-412 in W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Baird, R.W. 2005. Sightings of dwarf (*Kogia sima*) and pygmy (*K. breviceps*) sperm whales from the main Hawaiian Islands. Pacific Science 59(3):461-466.

Baird, R.W. 2005. Personal communication between Dr. Robin W. Baird, Cascadia Research, Olympia, Washington, and Ms. Dagmar Fertl, Geo-Marine, Inc., Plano, Texas, 13 September.

Baird, R.W., and P.J. Stacey. 1991. Status of the northern right whale dolphin, *Lissodelphis borealis*, in Canada. Canadian Field-Naturalist 105(2):243-250.

Baird, R.W., K.M. Langelier, and P.J. Stacey. 1989. First records of false killer whales, *Pseudorca crassidens*, in Canada. Canadian Field-Naturalist 103:368-371.

Baird, R.W., P.J. Stacey, and H. Whitehead. 1993. Status of the striped dolphin, *Stenella coeruleoalba*, in Canada. Canadian Field-Naturalist 107(4):455-465.

Baird, R.W., D. Nelson, J. Lien, and D.W. Nagorsen. 1996. The status of the pygmy sperm whale, *Kogia breviceps*, in Canada. Canadian Field-Naturalist 110(3):525-532.

Baird, R.W., A.D. Ligon, and S.K. Hooker. 2000. Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: A preliminary report. Report prepared under Contract # 40ABNC050729 from the Hawaiian Islands Humpback Whale National Marine Sanctuary, Kihei, HI, to the Hawaii Wildlife Fund, Paia, Hi. 18 pp.

Baird, R.W., A.D. Ligon, S.K. Hooker, and A.M. Gorgone. 2001. Subsurface and nighttime behaviour of pantropical spotted dolphins in Hawaii. Canadian Journal of Zoology 79:988-996.

Baird, R.W., D.J. McSweeney, D.L. Webster, A.M. Gorgone, and A.D. Ligon. 2003. Studies of odontocete population structure in Hawaiian waters: Results of a survey through the main Hawaiian Islands in May and June 2003. Report prepared for the National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, Washington.

Baird, R.W., D.J. McSweeney, A.D. Ligon, and D.L. Webster. 2004. Tagging feasability and diving of Cuvier's beaked whales (*Ziphius cavirostris*) and Blainville's beaked whales (*Mesoplodon densirostris*) in Hawai'i. Prepared under Order No. AB133F-03-SE-0986. La Jolla, California: NMFS, Southwest Fisheries Science Center. Prepared for Hawai'i Wildlife Fund. 15 pp.

Baird, R.W., A.M. Gorgone, D.L. Webster, D.J. McSweeney, J.W. Durban, A.D. Ligon, D.R. Salden, and M.H. Deakos. 2005a. False killer whales around the main Hawaiian Islands: An assessment of inter-island movements and population size using individual photo-identification. Report prepared under Order No. JJ133F04SE0120 from the Pacific Islands Fisheries Science Center, National Marine Fisheries Service, Honolulu, HI. 24 pp.

Baird, R.W., M.B. Hanson, and L.M. Dill. 2005b. 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.

Baker, C.S., and L.M. Herman. 1984. Aggressive behavior between humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters. Canadian Journal of Zoology 62:1922-1937.

Baker, C.S., A. Perry, J.L. Bannister, M.T. Weinrich, R.B. Abernethy, J. Calambokidis, J. Lien, R.H. Lambertsen, J. Urban Ramirez, O. Vasquez, P.J. Clapham, A. Alling, S.J. O'Brien, and S.R. Palumbi. 1993. Abundant mitochondrial DNA variation and world-wide population structure in humpback whales. Proceedings of the National Academy of Sciences 90:8239-8243.

Baker, C.S., L. Medrano-Gonzalez, J. Calambokidis, A. Perry, F. Pichler, H. Rosenbaum, J.M. Straley, J. Urban-Ramirez, M. Yamaguchi, and O. von Ziegesar. 1998. Population structure of nuclear and mitochondrial DNA variation among humpback whales in the North Pacific. Molecular Ecology 7:695-707.

Balcomb, K.C. 1987. The whales of Hawaii including all species of marine mammals in Hawaiian and adjacent waters. San Francisco, California: Marine Mammal Fund.

Balcomb III, K.C. 1989. Baird's beaked whale *Berardius bairdii* Stejneger, 1883: Arnoux's beaked whale *Berardius arnuxii* Duvernoy, 1851. Pages 261-288 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. San Diego: Academic Press.

Ballance, L.T., and R.L. Pitman. 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.

Barlow, J. 1999. Trackline detection probability for long-diving whales. Pages 209-221 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. Rotterdam, Netherlands: A.A. Balkema.

Barlow, J., and D. Hanan. 1995. An assessment of the status of the harbour porpoise in central California. Reports of the International Whaling Commission (Special Issue 16):123-140.

Barrett-Lennard, L.G., J.K.B. Ford, and K.A. Heise. 1996. The mixed blessing of echolocation: Differences in sonar use by fish-eating and mammal-eating killer whales. Animal Behaviour 51:553-565.

Barros, N.B., and A.A. Myrberg, Jr. 1987. Prey detection by means of passive listening in bottlenose dolphins (*Tursiops truncatus*). Journal of the Acoustical Society of America 82 (Supplement 1):S65. Abstract number EE8.

Barros, N.B., T.A. Jefferson, and E.C.M. Parsons. 2002. Food habits of finless porpoises (*Neophocaena phocaenoides*) in Hong Kong waters. Raffles Bulletin of Zoology Supplement 10:115-123.

Bartholomew, G.A., and N.E. Collias. 1962. The role of vocalization in the social behavior of the northern elephant seal. Animal Behaviour 10(1-2):7-14.

Bartholomew, G.A., and C.L. Hubbs. 1960. Population growth and seasonal movements of the northern elephant seal, *Mirounga angustirostris* (1). Mammalia 24(3):313-324.

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 B.R. Mate. 2003. Summertime foraging ecology of North Atlantic right whales. Marine Ecology Progress Series 264:123-135.

Baumgartner, M.F., K.D. Mullin, L.N. May, and T.D. Leming. 2001. Cetacean habitats in the northern Gulf of Mexico. Fishery Bulletin 99:219-239.

Bazúa-Durán, C., and W.W.L. Au. 2002. The whistles of Hawaiian spinner dolphins. Journal of the Acoustical Society of America 112(6):3064-3072.

Beamish, P., and E. Mitchell. 1973. Short pulse length audio frequency sounds recorded in the presence of a minke whale (*Balaenoptera acutorostrata*). Deep-Sea Research 20(4):375-386.

Beardsley, R.C., A.W. Epstein, C. Chen, K.F. Wishner, M.C. Macaulay, and R.D. Kenney. 1996. Spatial variability in zooplankton abundance near feeding right whales in the Great South Channel. Deep-Sea Research 43(7-8):1601-1625.

Bearzi, M. 2005. Dolphin sympatric ecology. Marine Biology Research 1:165-175.

Beier, J.C., and D. Wartzok. 1979. Mating behaviour of captive spotted seals (*Phoca largha*). Animal Behaviour 27:772-781.

Bekkby, T., and A. Bjørge. 2003. Joint diving behaviour of harbour seal (*Phoca vitulina*) females and pups in the lactation period. Sarsia 88:369-372.

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., and W.W.L. Au. 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.

Benoit-Bird, K.J., and W.W.L. Au. 2004. Diel migration dynamics of an island-associated sound-scattering layer. Deep-Sea Research I 51:707-719.

Benoit-Bird, K.J., W.W.L. Au, R.E. Brainard, and M.O. Lammers. 2001. Diel horizontal migration of the Hawaiian mesopelagic boundary community observed acoustically. Marine Ecology Progress Series 217:1-14.

Benson, S.R., D.A. Croll, B.B. Marinovic, F.P. Chavez, and J.T. Harvey. 2002. Changes in the cetacean assemblage of a coastal upwelling ecosystem during El Niño 1997-98 and La Niña 1999. Progress in Oceanography 54:279-291.

Bernard, H.J., and S.B. Reilly. 1999. Pilot whales *Globicephala* Lesson, 1828. Pages 245-279 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Best, P.B. 1994. Seasonality of reproduction and the length of gestation in southern right whales *Eubalaena australis*. Journal of Zoology, London 232:174-189.

Best, P.B., and C.H. Lockyer. 2002. Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa in the 1960s. South African Journal of Marine Science 24:111-133.

Bibikov, N.G. 1992. Auditory brainstem responses in the harbor porpoise (*Phocoena phocoena*). Pages 197-211 in J.A. Thomas, R.A. Kastelein and A.Y. Supin, eds. Marine mammal sensory systems. New York: Plenum Press.

Bigg, M. 1981. Harbour seal *Phoca vitulina* and *P. largha*. Pages 55-87 in S. H. Ridgway and R.J. Harrison, eds. Handbook of Marine Mammals. Volume 2: Seals. San Diego, CA: Academic Press.

Biggs, D.C., R.R. Leben, and J.G. Ortega-Ortiz. 2000. Ship and satellite studies of mesoscale circulation and sperm whale habitats in the northeast Gulf of Mexico during GulfCet II. Gulf of Mexico Science 18(1):15-22.

Bjørge, A. 2002. How persistent are marine mammal habitats in an ocean of variability? Pages 63-91 in P.G.H. Evans and J.A. Raga, eds. Marine mammals: Biology and conservation. New York: Kluwer Academic/Plenum Publishers.

Black, N.A. 1994. Behavior and ecology of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in Monterey Bay, California. Master's thesis in Marine Science, San Francisco State University.

Bonnell, M.L., and M.D. Dailey. 1993. Marine mammals. Pages 604-681 in M.D. Dailey, D.J. Reish and J.W. Anderson, eds. Ecology of the Southern California Bight: A synthesis and interpretation. Berkeley: University of California Press.

Bonnell, M.L., B.J. LeBoeuf, M.O. Pierson, D.H. Dettman, G.D. Farrens, C.B. Heath, R.F. Gantt, and D.J. Larsen. 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. Santa Cruz, CA: University of California. Final Report to the Bureau of Land Management, under Contract AA550-CT7-367. 535 pp.

Borggaard, D., J. Lien, and P. Stevick. 1999. Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). Aquatic Mammals 25(3):149-161.

Bowen, W.D., D.J. Boness, and S.J. Iverson. 1999. Diving behaviour of lactating harbour seals and their pups during maternal foraging trips. Canadian Journal of Zoology 77:978-988.

Bowen, W.D., C.A. Beck, and D.A. Austin. 2002. Pinniped ecology. Pages 911-921 in W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Boyd, I.L., C. Lockyer, and H.D. Marsh. 1999. Reproduction in marine mammals. Pages 218-286 in J.E. Reynolds and S.A. Rommel, eds. Biology of marine mammals. Washington, D.C.: Smithsonian Institution Press.

Braham, H.W. 1984. Distribution and migration of gray whales in Alaska. Pages 249-266 in M. L. Jones, S.L. Swartz and S. Leatherwood, eds. The gray whale *Eshcrichtius robustus*. San Diego, CA: Academic Press, Inc.

Brown, D.H., D.K. Caldwell, and M.C. Caldwell. 1966. Observations on the behavior of wild and captive false killer whales, with notes on associated behavior of other genera of captive delphinids. Contributions in Science, Natural History Museum of Los Angeles County 95:1-32.

Brownell, R.L., Jr. 2005. Personal communication via email between Dr. R.L. Brownell, Jr., National Marine Fisheries Service, La Jolla, California, and Ms. Vanessa Pepi, Navy Facilities Engineering Command Pacific, Pearl Harbor, Hawaii, 30 December.

Brownell, R.L., Jr., and T. Kasuya. 1999. Western gray whale captured off western Hokkaido, Japan. Scientific working document SC/51/AS25 presented to the IWC. Grenada, WI: International Whaling Commission Scientific Committee. 5 pp.

Brownell, R.L., Jr., D.W. Weller, B. Würsig, S.A. Blokhin, and A.M. Burdin. 1999. The Asian or western gray whale population: Past exploitation, current status, and new threats. Scientific working document SC/51/AS26 presented to the IWC. Grenada, WI: International Whaling Commission Scientific Committee. 13 pp.

Brownell, R.L., Jr., P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. Journal of Cetacean Research and Management. Right whales: Worldwide status. (Special Issue 2):269-286.

Brownell, R.L., Jr., T. Yamada, J.G. Mead, and A.L. van Helden. 2004. Mass strandings of Cuvier's beaked whales in Japan: U.S. naval acoustic link? International Whaling Commission scientific program working document SC/56/E37. 10 pp.

Brownell, R.L., Jr., J.G. Mead, A.L. Van Helden, T.K. Yamada, and A. Frantzis. 2005. Worldwide mass strandings of beaked whales: Retrospective review and causes. Pages 17-18 in Abstracts, 19th Annual Conference of the European Cetacean Society and Associated Workshops. 2–7 April 2005. La Rochelle, France.

Buckland, S.T., K.L. Cattanach, and R.C. Hobbs. 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(III):387-407.

Burgess, W.C., P.L. Tyack, B.J. Le Boeuf, and D.P. Costa. 1998. A programmable acoustic recording tag and first results from free-ranging northern elephant seals. Deep-Sea Research II 45:1327-1351.

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. 1981a. Ribbon seal *Phoca fasciata* Zimmermann, 1783. Pages 89-109 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 2: Seals. London: Academic Press.

Burns, J.J. 1981b. Bearded seal, *Erignathus barbatus* Erxleben, 1777. Pages 145-170 in S.H. Ridgway and R.J. Harrison, eds. Handbook of marine mammals. Volume 2: Seals. London: Academic Press.

Burns, J.J. 2002. Harbor seal and spotted seal *Phoca vitulina* and *P. largha*. Pages 552-560 in W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Burtenshaw, J.C., E.M. Oleson, J.A. Hildebrand, M.A. McDonald, R.K. Andrew, B.M. Howe, and J.A. Mercer. 2004. Acoustic and satellite remote sensing of blue whale seasonality and habitat in the Northeast Pacific. Deep-Sea Research II 51:967-986.

Calambokidis, J., G.H. Steiger, J.M. Straley, T.J. Quinn II, L.M. Herman, S. Cerchio, D.R. Salden, M. Yamaguchi, F. Sato, J. Urban, J. Jacobsen, O. Von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, N. Higashi, S. Uchida, J.K.B. Ford, Y. Miyamura, P.L. de Guevara P., S.A. Mizroch, L. Schlender, and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final Report. Olympia WA: Cascadia Research Collective. Submitted to Southwest Fisheries Science Center. 72 pp.

Calambokidis, J., G.H. Steiger, K. Rasmussen, J. Urbán R., K.C. Balcomb, P.L. de Guevara P., M. Salinas Z., J.K. Jacobsen, C.S. Baker, L.M. Herman, S. Cerchio, and J.D. Darling. 2000. Migratory destinations of humpback whales that feed off California, Oregon, and Washington. Marine Ecology Progress Series 192:295-304.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urban, J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P. Ladron de Guevara P., M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T.J. Quinn II. 2001. Movements and population structure of humpback whales in the North Pacific. Marine Mammal Science 17(4):769-794.

Calambokidis, J., E. Oleson, M. McDonald, B. Burgess, J. Francis, G. Marshall, M. Bakhtiari, and J. Hildebrand. 2003. Feeding and vocal behavior of blue whales determined through simultaneous visual-acoustic monitoring and deployment of suction-cap attached tags. Page 27 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14-19 December, 2003. Greensboro, NC, USA.

Calambokidis, J., G.H. Steiger, D.K. Ellifrit, B.L. Troutman, and C.E. Bowlby. 2004. Distribution and abundance of humpback whales (*Megaptera novaeangliae*) and other marine mammals off the northern Washington coast. Fishery Bulletin 102:563-580.

Caldwell, D.K., and M.C. Caldwell. 1972. The world of the bottlenosed dolphin. Philadelphia: J.B. Lippincott Company.

Caldwell, D.K., and M.C. Caldwell. 1989. Pygmy sperm whale *Kogia breviceps* (de Blainville, 1838): Dwarf sperm whale *Kogia simus* Owen, 1866. Pages 253-260 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. London: Academic Press.

Campbell, G.S., R.C. Gisiner, D.A. Helweg, and L.L. Milette. 2002. Acoustic identification of female Steller sea lions (*Eumetopias jubatus*). Journal of the Acoustical Society of America 111(6):2920-2928.

Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker, and M. Lowry. 2005. U.S. Pacific marine mammal stock assessments: 2004. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-375.

CETAP (Cetacean and Turtle Assessment Program). 1982. Characterization of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. outer continental shelf. NTIS PB83-215855. Final report to the U.S. Bureau of Land Management, Washington, D.C., from the Graduate School of Oceanography, University of Rhode Island, Kingston 570 pp.

Charif, R.A., D.K. Mellinger, K.J. Dunsmore, K.M. Fristrup, and C.W. Clark. 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 N.J. Gales. 1992. Growth, sexual maturity and food intake of Australian Indian Ocean bottlenose dolphins, *Tursiops truncatus*, in captivity. Australian Journal of Zoology 40:215-223.

Chilvers, B.L. and P.J. Corkeron. 2002. Association patterns of bottlenose dolphins (*Tursiops aduncus*) off Point Lookout, Queensland, Australia. Canadian Journal of Zoology 80:973-979.

Chilvers, B.L., P.J. Corkeron, and M.L. Puotinen. 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., S. Delean, N.J. Gales, D.K. Holley, I.R. Lawler, H. Marsh, and A.R. Preen. 2004. Diving behaviour of dugongs, *Dugong dugon*. Journal of Experimental Marine Biology and Ecology 304:203-224.

Clapham, P.J. 1996. The social and reproductive biology of humpback whales: An ecological perspective. Mammal Review 26(1):27-49.

Clapham, P.J. 2000. The humpback whale: Seasonal feeding and breeding in a baleen whale. Pages 173-196 in J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead, eds. Cetacean societies: Field studies of dolphins and whales. Chicago: University of Chicago Press.

Clapham, P.J. 2002. Humpback whale *Megaptera novaeangliae*. Pages 589-592 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Clapham, P.J., and D.K. Mattila. 1990. Humpback whale songs as indicators of migration routes. Marine Mammal Science 6(2):155-160.

Clapham, P.J., and J.G. Mead. 1999. *Megaptera novaeangliae*. Mammalian Species 604:1-9.

Clapham, P.J., S. Leatherwood, I. Szczepaniak, and R.L. Brownell, Jr. 1997. Catches of humpback and other whales from shore stations at Moss Landing and Trinidad, California, 1919-1926. Marine Mammal Science 13(3):368-394.

Clapham, P.J., P. Berggren, S. Childerhouse, N.A. Friday, T. Kasuya, L. Kell, K.-H. Kock, S. Manzanilla-Naim, G. Notarbartolo di Sciara, W.F. Perrin, A.J. Read, R.R. Reeves, E. Rogan, L. Rojas-Bracho, T.D. Smith, M. Stachowitsch, B.L. Taylor, D. Thiele, P.R. Wade, and R.L. Brownell, Jr. 2003. Whaling as science. BioScience 53(3):210-212.

Clapham, P.J., C. Good, S.E. Quinn, R.R. Reeves, J.E. Scarff, and R.L. Brownell, 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.

Claridge, D. 2003. Examining distribution and habitat preferences of deep-diving cetaceans, including beaked whales, in Northwest Providence Channel, the Bahamas using Geographic Information System (GIS) mapping techniques. Page 33 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December 2003. Greensboro, NC, USA.

Clark, C.W., and P.J. Clapham. 2004. Acoustic monitoring on a humpback whale (*Megaptera novaeangliae*) feeding ground shows continual singing into late spring. Proceedings of the Royal Society of London Part B 271:1051-1057.

Clark, C.W., and W.T. Ellison. 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: Evidence from models and empirical measurements. Pages 564-582 in J.A. Thomas, C.F. Moss and M. Vater, eds. Echolocation in bats and dolphins. Chicago, Illinois: University of Chicago Press.

Clark, C.W., and J.H. Johnson. 1984. The sounds of the bowhead whale, *Balaena mysticetus*, during the spring migrations of 1979 and 1980. Canadian Journal of Zoology 62:1436-1441.

Clarke, M.R. 1996. Cephalopods as prey. III. Cetaceans. Philosophical Transactions of the Royal Society of London, Part B 351:1053-1065.

Cleator, H.J., I. Stirling, and T.G. Smith. 1989. Underwater vocalizations of the bearded seal (*Erignathus barbatus*). Canadian Journal of Zoology 67:1900-1910.

Cockcroft, V.G., and G.J.B. Ross. 1990. Age, growth, and reproduction of bottlenose dolphins *Tursiops truncatus* from the east coast of southern Africa. Fishery Bulletin 88**:**289-302.

Condit, R., and B.J. Le Boeuf. 1984. Feeding habits and feeding grounds of the northern elephant seal. Journal of Mammalogy 65(2):281-290.

Conlan, R., and R. Service. 2000. El Niño and La Niña: Tracing the dance of ocean and atmosphere. Accessed 4 August 2005. http://www7.nationalacademies.org/opus/elnino.html.

Connor, R.C., and R.A. Smolker. 1996. "Pop" goes the dolphin: A vocalization male bottlenose dolphins make during consortships. Behaviour 133**:**643-662.

Connor, R.C., M.R. Heithaus, and L.M. Barre. 2001. Complex social structure, alliance stability and mating access in a bottlenose dolphin 'super-alliance'. Proceedings of the Royal Society of London, Part B 268**:**263-267.

Corkeron, P.J. 1990. Aspects of the behavioral ecology of inshore dolphins *Tursiops truncatus* and *Sousa chinensis* in Moreton Bay, Australia. Pages 285-293 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego: Academic Press.

Corkeron, P.J., and R.C. Connor. 1999. Why do baleen whales migrate? Marine Mammal Science 15(4):1228-1245.

Corkeron, P.J., and S.M. Van Parijs. 2001. Vocalizations of eastern Australian Risso's dolphins, *Grampus griseus*. Canadian Journal of Zoology 79(1):160-164.

Corkeron, P.J., M.M. Bryden, and K.E. Hedstrom. 1990. Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia. Pages 329-336 in S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. San Diego: Academic Press.

CPA (ConocoPhillips Alaska, Inc.). 2003. Application for incidental harassment authorization for on-ice seismic operations in the Beaufort Sea. Prepared by ConocoPhillips Alaska, Inc. for the National Marine Fisheries Service, Office of Protected Resources. 15 pp.

Craig, A.S., and L.M. Herman. 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.

Craig, A.S., L.M. Herman, C.M. Gabriele, and A.A. Pack. 2003. Migratory timing of humpback whales (*Megaptera novaeangliae*) in the central North Pacific varies with age, sex and reproductive status. Behaviour 140:981-1001.

Crane, N.L., and K. Lashkari. 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.

Croll, D.A., B.R. Tershy, R.P. Hewitt, D.A. Demer, P.C. Fiedler, S.E. Smith, W. Armstrong, J.M. Popp, T. Kiekhefer, V.R. Lopez, J. Urban, and D. Gendron. 1998. An integrated approch [sic] to the foraging ecology of marine birds and mammals. Deep-Sea Research II 45:1353-1371.

Croll, D.A., B.R. Tershy, A. Acevedo, and P. Levin. 1999. Marine vertebrates and low frequency sound. Technical report for LFA EIS.

Croll, D.A., A. Acevedo-Gutiérrez, B.R. Tershy, and J. Urbán-Ramírez. 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., C.W. Clark, A. Acevedo, B. Tershy, S. Flores, J. Gedamke, and J. Urban. 2002. Only male fin whales sing loud songs. Nature 417:809.

Cummings, W.C. 1985. Bryde's whale *Balaenoptera edeni* Anderson, 1878. Pages 137-154 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. San Diego: Academic Press.

Cummings, W.C., and J.F. Fish. 1971. A synopsis of marine animal underwater sounds in eight geographic areas. Special Report. Naval Undersea Research and Development Center, Code 5054. Prepared for NUC Code 14. 97 pp.

Cummings, W.C., and D.V. Holliday. 1987. Sounds and source levels from bowhead whales off Pt. Barrow, Alaska. Journal of the Acoustical Society of America 82(3):814-821.

Cummings, W.C., and P.O. Thompson. 1971. Gray whales, *Eschrichtius robustus*, avoid the underwater sounds of killer whales, *Orcinus orca*. Fishery Bulletin 69(3):525-530.

Cummings, W.C., P.O. Thompson, and R. Cook. 1968. Underwater sounds of migrating gray whales, *Eschrichtius glaucus* (Cope). Journal of the Acoustical Society of America 44(5):1278-1281.

Curry, B.E., and J. Smith. 1997. Phylogeographic structure of the bottlenose dolphin (*Tursiops truncatus*): Stock identification and implications for management. Pages 227-247 in A.E. Dizon, S.J. Chivers and W.F. Perrin, eds. Molecular genetics of marine mammals (Special Publication 3). Lawrence, Kansas: Society for Marine Mammalogy.

Dahlheim, M.E., and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). Pages 281-322 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Dahlheim, M.E., and D.K. Ljungblad. 1990. Preliminary hearing study on gray whales (*Eschrichtius robustus*) in the field. Pages 335-346 in J. Thomas and R. Kastelein, eds. Sensory abilities of cetaceans: Laboratory and field evidence. New York and London: Plenum Press.

Dahlheim, M.E., S. Leatherwood, and W.F. Perrin. 1982. Distribution of killer whales in the warm temperate and tropical eastern Pacific. Reports of the International Whaling Commission 32:647-653.

Dahlheim, M.E., H.D. Fisher, and J. Schempp. 1984. Sound production by the gray whale and ambient noise levels in Laguna San Ignacio, Baja California Sur, Mexico. Pages 511-541 in M.L. Jones, S.L. Swartz, and S. Leatherwood, eds. The gray whale, *Eschrichtius robustus*. San Diego, CA: Academic Press, Inc.

Dalebout, M.L., G.M. Lento, F. Cipriano, N. Funahashi, and C.S. Baker. 2002. How many protected minke whales are sold in Japan and Korea? A census by microsatellite DNA profiling. Animal Conservation 5:143-152.

Dalebout, M.L., G.J.B. Ross, C.S. Baker, R.C. Anderson, P.B. Best, V.G. Cockcroft, H.L. Hinsz, V. Peddemors, and R.L. Pitman. 2003. Appearance, distribution, and genetic distinctiveness of Longman's beaked whale, *Indopacetus pacificus*. Marine Mammal Science 19(3):421-461.

Darling, J.D., and S. Cerchio. 1993. Movement of a humpback whale (*Megaptera novaeangliae*) between Japan and Hawaii. Marine Mammal Science 9(1):84-89.

Darling, J.D., and K. Mori. 1993. Recent observations of humpback whales (*Megaptera novaeangliae*) in Japanese waters off Ogasawara and Okinawa. Canadian Journal of Zoology 71:325-333.

Darling, J.D., J. Calambokidis, K.C. Balcomb, P. Bloedel, K. Flynn, A. Mochizuki, K. Mori, F. Sato, H. Suganuma, and M. Yamaguchi. 1996. Movement of a humpback whale (*Megaptera novaeangliae*) from Japan to British Columbia and return. Marine Mammal Science 12(2):281-287.

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. 7/04. 44 pp.

Davis, R.W., and G.S. Fargion, eds. 1996. Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico, final report. Volume 2: Technical report. OCS Study MMS 96-0027. New Orleans: Minerals Management Service.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 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., W.E. Evans, and B. Würsig, eds. 2000. Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: Distribution, abundance and habitat associations. Volume 2: Technical report. 360 pp. New Orleans: Minerals Management Service.

Davis, R.W., J.G. Ortega-Ortiz, C.A. Ribic, W.E. Evans, D.C. Biggs, P.H. Ressler, R.B. Cady, R.R. Leben, K.D. Mullin, and B. Würsig. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. Deep-Sea Research I 49:121-142.

Dawson, S., J. Barlow, and D.K. Ljungblad. 1998. Sounds recorded from Baird's beaked whale, *Berardius bairdii*. Marine Mammal Science 14(2):335-344.

Defran, R.H., and D.W. Weller. 1999. Occurrence, distribution, site fidelity, and school size of bottlenose dolphins (*Tursiops truncatus*) off San Diego, California. Marine Mammal Science 15(2):366-380.

Deguchi, T., Y. Goto, and Y. Sakurai. 2004. Importance of walleye pollock (*Theragra chalcogramma*) to wintering ribbon seals (*Phoca fasciata*) in Nemuro Strait, Hokkaido Japan. Mammal Study 29:55-63.

DeHart, P.A.P. 2002. The distribution and abundance of harbor seals (*Phoca vitulina concolor*) in the Woods Hole region. M.A., Boston University Graduate School of Arts and Sciences.

Dehnhardt, G., B. Mauck, W. Hanke, and H. Bleckmann. 2001. Hydrodynamic trail-following in harbor seals (*Phoca vitulina*). Science 293:102-104.

DeLong, R.L. 1982. Population biology of northern fur seals at San Miguel Island, California. Ph.D. diss., University of California, Berkeley.

DeLong, R.L., and B.S. Stewart. 1991. Diving patterns of northern elephant seal bulls. Marine Mammal Science 7(4):369-384.

DeMaster, D.P., C.W. Fowler, S.L. Perry, and M.F. Richlen. 2001. Predation and competition: The impact of fisheries on marine-mammal populations over the next one hundred years. Journal of Mammalogy 82(3)**:**641-651.

Deutsch, C.J, D.E. Crocker, D.P. Costa, and B.J. Le Boeuf. 1994. Sex- and age-related variation in reproductive effort of northern elephant seals. Pages 169-210 in B.J. Le Boeuf and R.M. Laws, eds. Elephant seals: Population ecology, behavior, and physiology. Berkeley, California: University of California Press.

Dietz, R., J. Teilmann, M.-P.H. Jørgensen, and M.V. Jensen. 2002. Satellite tracking of humpback whales in West Greenland. NERI Technical Report 411. Roskilde, Denmark: National Environmental Research Institute. 40 pp.

DNO (Dugong Network Okinawa). 2001. For the protection of dugongs offshore Okinawa (Material II). Okinawa, Japan: University of Okinawa. 49 pp.

Dolar, M.L.L. 2002. Fraser's dolphin *Lagenodelphis hosei*. Pages 485-487 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen*,* eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Dolphin, W.F. 1987. Ventilation and dive patterns of humpback whales, *Megaptera novaeangliae*, on their Alaskan feeding grounds. Canadian Journal of Zoology 65:83-90.

Donaldson, T.J. 1983. Further investigations of the whales *Peponocephala electra* and *Globicephala macrorhynchus* reported from Guam. Micronesica 19(1-2):173-181.

Donovan, G.P. 1991. A review of IWC stock boundaries. Reports of the International Whaling Commission (Special Issue 13):39-69.

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., S.J. Stern, A.R. Hoelzel, and J. Jacobsen. 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.

Dudley, M. 1992. First Pacific record of a hooded seal, *Cystophora cristata* Erxleben, 1777. Marine Mammal Science 8(2):164-168.

D'Vincent, C.G., R.M. Nilson, and R.E. Hanna. 1985. Vocalization and coordinated feeding behavior of the humpback whale in southeastern Alaska. Scientific Reports of the Whales Research Institute 36:41-47.

Edds-Walton, P.L. 1997. Acoustic communication signals of mysticete whales. Bioacoustics 8:47-60.

Eguchi, T., and J.T. Harvey. 2005. Diving behavior of the Pacific harbor seal (*Phoca vitulina richardii*) in Monterey Bay, California. Marine Mammal Science 21(2): 283-295.

Ersts, P.J., and H.C. Rosenbaum. 2003. Habitat preference reflects social organization of humpback whales (*Megaptera novaeangliae*) on a wintering ground. Journal of Zoology, London 260:337-345.

Evans, P.G.H. 2002. Habitat pressures. Pages 545-548 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen*,* eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Evans, W.E. 1994. Common dolphin, white-bellied porpoise *Delphinus delphis* Linnaeus, 1758. Pages 191-224 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Fahner, M., J. Thomas, K. Ramirez, and J. Boehm. 2004. Acoustic properties of echolocation signals by captive Pacific white-sided dolphins (*Lagenorhynchus obliquidens*). Pages 53-59 in J.A. Thomas, C.F. Moss and M. Vater, eds. Echolocation in bats and dolphins. Chicago, Illinois: University of Chicago Press.

Fay, F.H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399 in D.W. Hood and E.J. Kelley, eds. Oceanography of the Bering Sea. Fairbanks, Alaska: Institute of Marine Sciences and Oceanography, Publications No. 2, University of Alaska.

Fedoseev, G. 2002. Ribbon seal, *Histriophoca fasciata.* Pages 1027-1030 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Feldkamp, S.D., R.L. DeLong, and G.A. Antonelis. 1991. Effects of El Niño 1983 on the foraging patterns of California sea lions (*Zalophus californianus*) near San Miguel Island, California. Pages 146-155 in F. Trillmich and K.A. Ono, eds. Pinnipeds and El Niño: Responses to environmental stress. Berlin, Heidelberg, New York: Springer-Verlag.

Ferguson, M.C. 2005. Cetacean population density in the eastern Pacific Ocean: Analyzing patterns with predictive spatial models. Ph D. diss., University of California, San Diego.

Ferguson, M.C., and J. Barlow. 2001. Spatial distribution and density of cetaceans in the eastern tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-1996. Administrative Report. LJ-01-04. La Jolla, California: SWFSC. 61 pp.

Ferguson, M.C., J. Barlow, T. Gerrodette, and P. Fiedler. 2001. Meso-scale patterns in the density and distribution of ziphiid whales in the eastern Pacific Ocean. Pages 5-9 in Summary of the Workshop on the Biology and Conservation of Beaked Whales, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 2001. Vancouver, British Columbia.

Ferrero, R.C., and W.A. Walker. 1995. Growth and reproduction of the common dolphin, *Delphinus delphis* Linnaeus, in the offshore waters of the North Pacific Ocean. Fishery Bulletin 93:483-494.

Ferrero, R.C., and W.A. Walker. 1999. Age, growth, and reproductive patterns of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) taken in high seas drift nets in the central North Pacific. Canadian Journal of Zoology 74:1673-1687.

Fertl, D., A. Acevedo-Guitiérrez, and F.L. Darby. 1996. A report of killer whales (*Orcinus orca*) feeding on a carcharhinid shark in Costa Rica. Marine Mammal Science 12(4):606-611.

Fiedler, P.C. 2002. Ocean environment. Pages 824-830 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Fiedler, P.C., S.B. Reilly, R.P. Hewitt, D. Demer, V.A. Philbrick, S. Smith, W. Armstrong, D.A. Croll, B.R. Tershy, and B.R. Mate. 1998. Blue whale habitat and prey in the California Channel Islands. Deep-Sea Research II 45:1781-1801.

Field, I., M. Hindell, D. Slip, and K. Michael. 2001. Foraging strategies of southern elephant seals (*Mirounga leonina*) in relation to frontal zones and water masses. Antarctic Science 13(4):371-379.

Fish, J.F., and C.W. Turl. 1976. Acoustic source levels of four species of small whales. NUC TP 547. San Diego, CA: Naval Undersea Center. 14 pp.

Fitch, J.E., and R.L. Brownell, Jr. 1968. Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. Journal of the Fisheries Research Board of Canada 25(12):2561-2574.

Fletcher, S., B.J. Le Boeuf, D.P. Costa, P.L. Tyack, and S.B. Blackwell. 1996. Onboard acoustic recording from diving northern elephant seals. Journal of the Acoustical Society of America 100(4):2531-2539.

Flores, P.A.C., and A. Ximenez. 1997. Observations on the rough-toothed dolphin *Steno bredanensis* off Santa Catarina Island, southern Brazilian coast. Biotemas 10(1):71-79.

Forcada, J. 2002. Distribution. Pages 327-333 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Ford, J.K.B. 2002. Killer whale *Orcinus orca*. Pages 669-676 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Forney, K.A. 1994. Recent information on the status of odontocetes in Californian waters. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-202. La Jolla, California: U.S. Department of Commerce. 87 pp.

Frantzis, A., J.C. Goold, E.K. Skarsoulis, M.I. Taroudakis, and V. Kandia. 2002. Clicks from Cuvier's beaked whales, *Ziphius cavirostris* (L). Journal of the Acoustical Society of America 112(1):34-37.

Frost, K.J., and L.F. Lowry. 1981. Ringed, Baikal and Caspian seals: *Phoca hispida* Schreber, 1775; *Phoca sibirica* Gmelin, 1788 and *Phoca caspica* Gmelin, 1788. Pages 29-53 in S. Ridgway and R.J. Harrison, eds. Handbook of marine mammals. Volume 2: Seals. London, England: Academic Press.

Fujimori, L. 2002. Elephant seal visits Hawaii shores: The young male is the first of its kind to be seen in the islands. Honolulu Star Bulletin, 18 January 2002. Accessed 7 February 2005. http://starbulletin.com /2002/01/18/news/story7.html

Fulling, G.L., K.D. Mullin, and C.W. Hubard. 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. Fishery Bulletin 101:923-932.

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.

Gabriele, C.M. J.M. Straley, L.M. Herman, and R.J. Coleman. 1996. Fastest documented migration of a North Pacific humpback whale. Marine Mammal Science 12(3):457-464.

Gales, N., R.D. McCauley, J. Lanyon, and D. Holley. 2004. Change in abundance of dugongs in Shark Bay, Ningaloo and Exmouth Gulf, western Australia: Evidence for large-scale migration. Wildlife Research 31:283-290.

Gallo-Reynoso, J.-P., and A.-L. Figueroa-Carranza. 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. Pages 155-170 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. San Diego: Academic Press.

Gannier, A. 1999. Diel variations of the striped dolphin (*Stenella coeruleoalba*) distribution off the French Riviera (northwestern Mediterranean Sea). Aquatic Mammals 25(3):123-134.

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., and K.L. West. 2005. Distribution of the rough-toothed dolphin (*Steno bredanensis*) around the Windward Islands (French Polynesia). Pacific Science 59(1):17-24.

Gannon, D. 2003. Behavioral ecology of an acoustically mediated predator-prey system: Bottlenose dolphins and sciaenid fishes. Ph.D. diss., Duke University.

Garrigue, C., and J. Greaves. 2001. Cetacean records for the New Caledonian area (Southwest Pacific Ocean). Micronesica 34(1):27-33.

Gaskin, D.E. 1982. The ecology of whales and dolphins. Portsmouth, New Hampshire: Heinemann.

Gaskin, D.E., S. Yamamoto, and A. Kawamura. 1993. Harbor porpoise, *Phocoena phocoena* (L.), in the coastal waters of northern Japan. Fishery Bulletin 91:440-454.

Gedamke, J., D.P. Costa, and A. Dunstan. 2001. Localization and visual verification of a complex minke whale vocalization. Journal of the Acoustical Society of America 109(6):3038-3047.

Gentry, R.L. 1998. Behavior and ecology of the northern fur seal. Princeton, New Jersey: Princeton University Press.

Gentry, R.L. 2002. Northern fur seal, *Callorhinus ursinus*. Pages 813-817 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Gentry, R.L., G.L. Kooyman, and M.E. Goebel. 1986. Feeding and diving behavior of northern fur seals. Pages 61-78 in R.L. Gentry and G.L. Kooyman, eds. Fur seals--Maternal strategies on land and at sea. Princeton, New Jersey: Princeton University Press.

Gilbert, J.R., and N. Guldager. 1998. Status of harbor and gray seal populations in northern New England. Woods Hole, MA: National Marine Fisheries Service. 13 p.

Gill, P.C. 2002. A blue whale (*Balaenoptera musculus*) feeding ground in a southern Australian coastal upwelling zone. Journal of Cetacean Research and Management 4(2):179-184.

Gillespie, D., and R. Leaper, eds. 2001. Report of the workshop on right whale acoustics: Practical applications in conservation. Yarmouth Port, Massachusetts: IFAW (International Fund for Animal Welfare). 27 pp.

Gilpatrick, J.W., Jr., W.F. Perrin, S. Leatherwood, and L. Shiroma. 1987. Summary of distribution records of the spinner dolphin, *Stenella longirostris*, and the pantropical spotted dolphin, *S. attenuata*, from the western Pacific Ocean, Indian Ocean and Red Sea. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFC-89. La Jolla, California: U.S. Department of Commerce. 42 pp.

Gjertz, I., K.M. Kovacs, C. Lydersen, and Ø. Wiig. 2000. Movements and diving of adult ringed seals (*Phoca hispida*) in Svalbard. Polar Biology 23:651-656.

Gjertz, I., C. Lydersen, and Ø. Wiig. 2001. Distribution and diving of harbour seals (*Phoca vitulina*) in Svalbard. Polar Biology 24:209-214.

Goddard, P., and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. Marine Mammal Science 14(2):344-349.

Goodyear, J.D. 1993. A sonic/radio tag for monitoring dive depths and underwater movements of whales. Journal of Wildlife Management 57(3):503-513.

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 T.A. Jefferson. 2002. Acoustic signals from free-ranging finless porpoises (*Neophocaena phocaenoides*) in the waters around Hong Kong. Raffles Bulletin of Zoology Supplement No. 10:131-139.

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

Goto, Y., and K. Shimazaki. 1998. Diet of Steller sea lion off the coast of Rausa, Hokkaido, Japan. Biosphere Conservation 1(2):141-148.

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. Cambridge, United Kingdom: International Whaling Commission (IWC). 2 pp.

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, C.E. Bowlby, M.L. Bonnell, and K.C. Balcomb III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Pages 1-1 to 1-100 in Oregon and Washington marine mammal and seabird surveys. MMS OCS Study 91-0093.

Greene, C.H., and A.J. Pershing. 2004. Climate and the conservation biology of North Atlantic right whales: The right whale at the wrong time? Frontiers in Ecology and the Environment 2(1):29-34.

Gregr, E.J., and A.J. Trites. 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.

Griffin, R.B. 1999. Sperm whale distributions and community ecology associated with a warm-core ring off Georges Bank. Marine Mammal Science 15(1):33-51.

Guan, S., A. Takemura, and T. Koido. 1999. An introduction to the structure of humpback whale, *Megaptera novaeangliae*, song off Ryukyu Islands, 1991/1992. Aquatic Mammals 25(1):35-42.

Hain, J.H.W., M.A.M. Hyman, R.D. Kenney, and H.E. Winn. 1985. The role of cetaceans in the shelf-edge region of the northeastern United States. Marine Fisheries Review 47(1):13-17.

Hain, J.H.W., M.J. Ratnaswamy, R.D. Kenney, and H.E. Winn. 1992. The fin whale, *Balaenoptera physalus*, in waters of the northeastern United States continental shelf. Reports of the International Whaling Commission 42:653-669.

Hale, P. T., A.S. Barreto, and G.J.B. Ross. 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):920-937.

Hamilton, P.K., M.K. Marx, and S.D. Kraus. 1995. Weaning in North Atlantic right whales. Marine Mammal Science 11(3):386-390.

Hammill, M.O., and T.G. Smith. 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.

Hanggi, E.B., and R.J. Schusterman. 1994. Underwater acoustic displays and individual variation in male harbour seals, *Phoca vitulina*. Animal Behaviour 48:1275-1283.

Hanson, M.B., and R.W. Baird. 1998. Dall's porpoise reactions to tagging attempts using a remotely-deployed suction-cup tag. Marine Technology Society Journal 32(2):18-23.

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

Hare, S.H. 1996. Low frequency climate variability and salmon production. Ph.D. diss., University of Washington.

Harris, D.E., B. Lelli, and S. Gupta. 2003. Long-term observations of a harbor seal haul-out site in a protected cove in Casco Bay, Gulf of Maine. Northeastern Naturalist 10(2):141-148.

Harvey, J.T., and B.R. Mate. 1984. Dive characteristics and movements of radio-tagged gray whales in San Ignacio Lagoon, Baja California Sur, Mexico. Pages 561-575 in M.L. Jones, S.L. Swartz, and S. Leatherwood, eds. The gray whale, *Eschrichtius robustus*. San Diego, CA: Academic Press.

Harwood, J. 2001. Marine mammals and their environment in the twenty-first century. Journal of Mammalogy 82(3):630-640.

Hayama, S.-I. 1988. Kuril seal—Present status in Japan. Ambio 17(1):75-78.

Hayano, A., M. Amano, and M. Miyazaki. 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., M. Yoshioka, M. Tanaka, and M. Amano. 2004. Population differentiation in the Pacific white-sided dolphin *Lagenorhynchus obliquidens* inferred from mitochondrial DNA and microsatellite analyses. Zoological Science 21:989-999.

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

Heise, K. 1997a. Life history and population parameters of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*). Reports of the International Whaling Commission 47:817-825.

Heise, K. 1997b. Diet and feeding behaviour of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) as revealed through the collection of prey fragments and stomach content analyses. Reports of the International Whaling Commission 47:807-815.

Heithaus, M.R. 2001. Predator-prey and competitive interactions between sharks (Order Selachii) and dolphins (Suborder Odontoceti): A review. Journal of Zoology, London 253:53-68.

Heithaus, M.R., and L.M. Dill. 2002. Food availability and tiger shark predation risk influence bottlenose dolphin habitat use. Ecology 83(2):480-491.

Helweg, D.A., A.S. Frankel, J.R. Mobley, Jr., and L.M. Herman. 1992. Humpback whale song: Our current understanding. Pages 459-483 in J.A. Thomas, R.A. Kastelein and A.Y. Supin, eds. Marine mammal sensory systems. New York: Plenum Press.

Herman, L.M., C.S. Baker, P.H. Forestell, and R.C. Antinoja. 1980. Right whale *Balaena glacialis* sightings near Hawaii: A clue to the wintering grounds? Marine Ecology Progress Series 2: 271-275.

Hersh, S.L., and D.A. Duffield. 1990. Distinction between northwest Atlantic offshore and coastal bottlenose dolphins based on hemoglobin profile and morphometry. Pages 129-139 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego: Academic Press.

Herzing, D.L. 1996. Vocalizations and associated underwater behavior of free-ranging Atlantic spotted dolphins, *Stenella frontalis* and bottlenose dolphins, *Tursiops truncatus*. Aquatic Mammals 22(2):67-79.

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). Pages 289-308 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. San Diego: Academic Press.

Heyning, J.E., and J.G. Mead. 1996. Suction feeding in beaked whales: Morphological and observational evidence. Contributions in Science, Natural History Museum of Los Angeles County 464:1-12.

Heyning, J.E., and W.F. Perrin. 1994. Evidence for two species of common dolphins (genus *Delphinus*) from the eastern North Pacific. Contributions in Science, Natural History Museum of Los Angeles County 442:1-35.

Hiraguchi, T., T.K. Yamada, H. Ishikawa, and H. Hiruda. 2001. Marine mammal stranding data collected by the Sea of Japan cetology. Page 100 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November–3 December 2001. Vancouver, British Columbia.

Hoelzel, A.R., E.M. Dorsey, and S.J. Stern. 1989. The foraging specializations of individual minke whales. Animal Behaviour 38:786-794.

Hoelzel, A.R., C.W. Potter, and P.B. Best. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. Proceedings of the Royal Society of London, Part B 265:1177-1183.

Honma, Y., T. Ushiki, M. Takeda, E. Maito, K. Dewa, and H. Yamanouchi. 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. Japanese Society of Fisheries Science 65(4):547-552.

Horwood, J. 1987. The sei whale: Population biology, ecology, & management. New York: Croom Helm in association with Methuen, Inc.

Horwood, J. 1990. Biology and exploitation of the minke whale. Boca Raton, Florida: CRC Press.

Houck, W.J., and T.A. Jefferson. 1999. Dall's porpoise *Phocoenoides dalli* (True, 1885). Pages 443-472 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Houser, D.S., D.A. Helweg, and P.W.B. Moore. 2001. A bandpass filter-bank model of auditory sensitivity in the humpback whale. Aquatic Mammals 27(2):82-91.

Houston, J. 1990. Status of Hubbs' beaked whale, *Mesoplodon carlhubbsi*, in Canada. Canadian Field-Naturalist 104(1):121-124.

Hoyt, E. 1993. Kujira watching - Whales and dolphins: Alive and being watched Japanese-style. Bath, Avon, UK: Whale and Dolphin Conservation Society.

Huber, H.R., A.C. Rovetta, L.A. Fry, and S. Johnston. 1991. Age-specific natality of northern elephant seals at the South Farallon Islands, California. Journal of Mammalogy 72(3):525-534.

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 distributions of two pelagic cetaceans. Fishery Bulletin 83(3):472-475.

Husar, S. 1978. *Dugong dugon*. Mammalian Species 88:1-7.

Ichikawa, K., N. Arai, T. Akamatsu, T. Shinke, T. Hara, and K. Adulyanukosol. 2003. Acoustical analyses on the calls of dugong. Pages 72-76 in N. Arai, ed. Proceedings on the 4th SEASTAR2000 Workshop. 11-13 December 2003. Bangkok, Thailand.

Ishinazaka, T., and T. Endo. 1999. The reproductive status of Steller sea lions in the Nemuro Strait, Hokkaido, Japan. Biosphere Conservation 2(1):11-19.

IUCN (International Union for Conservation of Nature and Natural Resources). 2004. The 2004 IUCN red list of threatened species. Accessed 3 February 2005. http://www.redlist.org.

Iwasaki, T., Y. Kai, H. Tanakura, and H. Kato. 2001. Satellite tracking of two bottlenose dolphins driven to Taiji, Japan. Page 106 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November–3 December 2001. Vancouver, British Columbia.

Iwashita, M., M. Inque, and Y. Iwasaki. 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 (International Whaling Commission). 1997. Report on the International Whaling Commission Workshop on Climate Change and Cetaceans. Reports of the International Whaling Commission 47:293-319.

IWC (International Whaling Commission). 2001. Report of the Workshop on the Comprehensive Assessment of Right Whales: A worldwide comparison. Journal of Cetacean Research and Management. Right whales: Worldwide status. (Special Issue 2):1-60.

IWC (International Whaling Commission). 2004. Classification of the Order Cetacea (whales, dolphins and porpoises). Journal of Cetacean Research and Management 6(1):v-xii.

Jacobsen, K.O., M. Marx, and N. Øien. 2004. Two-way trans-Atlantic migration of a North Atlantic right whale (*Eubalaena glacialis*). Marine Mammal Science 20(1):161-166.

Jaquet, N., and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. Marine Ecology Progress Series 135:1-9.

Jaquet, N., H. Whitehead, and M. Lewis. 1996. Coherence between 19th century sperm whale distributions and satellite-derived pigments in the tropical Pacific. Marine Ecology Progress Series 145:1-10.

Jaquet, N., S. Dawson, and E. Slooten. 2000. Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: Foraging implications. Canadian Journal of Zoology 78:407-419.

Jefferson, T.A. 1988. *Phocoenoides dalli*. Mammalian Species 319:1-7.
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 behaviour of Dall's porpoise (*Phocoenoides dalli*) in Monterey Bay, California. Aquatic Mammals 17(1):12-19.
Jefferson, T.A. 2002. Preliminary analysis of geographic variation in cranial morphometrics of the finless porpoise (*Neophocaena phocaenoides*). Raffles Bulletin of Zoology Supplement No. 10:3-14.
Jefferson, T.A. 2005. Personal communication via meeting between Dr. Thomas A. Jefferson, National Marine Fisheries Service, La Jolla, California, and Ms. Dagmar Fertl, Geo-Marine, Inc., Plano, Texas, 22-24 June.
Jefferson, T.A., and N.B. Barros. 1997. *Peponocephala electra*. Mammalian Species 553:1-6.
Jefferson, T.A., and S.K. Hung. 2004. *Neophocaena phocaenoides*. Mammalian Species 746:1-12.
Jefferson, T.A., and S. Leatherwood. 1994. *Lagenodelphis hosei.* Mammalian Species 470:1-5.
Jefferson, T.A., and W.W. Newcomer. 1993. *Lissodelphis borealis*. Mammalian Species 425:1-6.
Jefferson, T.A., and A.J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. Mammal Review 27(1):27-50.
Jefferson, T.A., and K. Van Waerebeek. 2002. The taxonomic status of the nominal dolphin species *Delphinus tropicalis* Van Bree, 1971. Marine Mammal Science 18(4):787-818.
Jefferson, T.A., P.J. Stacey, and R.W. Baird. 1991. A review of killer whale interactions with other marine mammals: Predation to co-existence. Mammal Review 21(4):151-180.
Jefferson, T.A., S. Leatherwood, and M.A. Webber. 1993. FAO species identification guide. Marine mammals of the world. Rome: FAO (Food and Agriculture Organization of the United Nations).
Jefferson, T.A., M.W. Newcomer, S. Leatherwood, and K. Van Waerebeek. 1994. Right whale dolphins *Lissodelphis borealis* (Peale, 1848) and *Lissodelphis peronii* (Lacépède, 1804). Pages 335-362 in S.H. Ridgway and S.R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.
Jefferson, T.A., R.L. Pitman, S. Leatherwood, and M.L.L. Dolar. 1997. Developmental and sexual variation in the external appearance of Fraser's dolphins (*Lagenodelphis hosei*). Aquatic Mammals 23(3):145-153.
Jefferson, T.A., K.M. Robertson, and J.Y. Wang. 2002. Growth and reproduction of the finless porpoise in southern China. Raffles Bulletin of Zoology Supplement No. 10:105-113.
Johnson, M., and P. Tyack. 2004. Measuring the behavior and response to sound of beaked whales using recording tags. Prepared by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts for Consortium for Oceanographic Research and Education, Washington, D.C. 11 pp.
Johnson, M., P.T. Madsen, W.M.X. Zimmer, N. Aguilar de Soto, and P.L. Tyack. 2004. Beaked whales echolocate on prey. Proceedings of the Royal Society of London, Part B 271:S383-S386.
Jones, M.L., and S. L. Swartz. 2002. Gray whale *Eschrichtius robustus*. Pages 524-536 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.
Jørgensen, C., C. Lydersen, O. Brix, and K.M. Kovacs. 2001. Diving development in nursing harbour seal pups. Journal of Experimental Biology 204:3993-4004.
JSWA (Japan Small-Type Whaling Association). 2002. Japanese community-based minke whaling. Accessed 28 July 2005. http://homepage2.nifty.com/jstwa/.
Jurasz, C.M., and V.P. Jurasz. 1979. Feeding modes of the humpback whale, *Megaptera novaeangliae*, in southeast Alaska. Scientific Reports of the Whales Research Institute 31:69-83.
Kajimura, H. 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. U.S. Department of Commerce. 49 pp.
Kakuda, T., Y. Tajima, K. Arai, K. Kogi, T. Hishii, and T.K. Yamada. 2002. On the resident "bottlenose dolphins" from Mikura water. Memoirs of the National Science Museum, Tokyo 38(December 25):255-272.
Kamminga, C., T. Kataoka, and F.J. Engelsma. 1986. Investigations on cetacean sonar VII: Underwater sounds of *Neophocaena phocaenoides* of the Japanese coastal population. Aquatic Mammals 12(2):52-60.

Karczmarski, L., B. Wursig, S. Rickards, G. Gailey, C. Vanderlip, and K. Larson. 2001. Spinner dolphins in a remote atoll habitat: Ecological bases of social dynamics. Page 111 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November - 3 December 2001. Vancouver, British Columbia.

Kasai, H., H. Saito, A. Yoshimori, and S. Taguchi. 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.

Kastak, D., and R.J. Schusterman. 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., and R.J. Schusterman. 1999. In-air and underwater hearing sensitivity of a northern elephant seal (*Mirounga angustirostris*). Canadian Journal of Zoology 77:1751-1758.

Kastak, D., R.J. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of the Acoustical Society of America 106(2):1142-1148.

Kastelein, R., P. Bunskoek, M. Hagedoorn, W.W.L. Au, and D. de Haan. 2002. Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrrow-band frequency-modulated signals. Journal of the Acoustical Society of America 112(1):334-344.

Kastelein, R.A., M. Hagedoorn, W.W.L. Au, and D. de Haan. 2003. Audiogram of a striped dolphin (*Stenella coeruleoalba*). Journal of the Acoustical Society of America 113(2):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. 1975. Past occurrence of *Globicephala melaena* in the western North Pacific. Scientific Reports of the Whales Research Institute 27:95-110.

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. 1985. Fishery--dolphin conflict in the Iki Island area of Japan. Pages 253-272 in J.R. Beddington, R.J.H. Beverton and D.M. Lavigne, eds. Marine mammals and fisheries. London: George Allen & Unwin.

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. 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. 1999b. Dugongs in Okinawa. SireNews 31:10-11.

Kasuya, T. 1999c. Finless porpoise *Neophocaena phocaenoides* (G. Cuvier, 1829). Pages 411-442 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Kasuya, T. 2002. Giant beaked whales *Berardius bairdii* and *B. arnuxii*. Pages 519-522 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Kasuya, T. 2005. Personal communication between Dr. Toshio Kasuya, Teikyo University of Science and Technology, Uenohara, Yamanashi Prefecture, Japan, and Dr. Thomas A. Jefferson, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California, 24 July.

Kasuya, T., and R.L. Brownell, Jr. 2001. Conservation status and the future prospects of dugongs in Japanese water**.** Unpublished manuscript. 8 pp.

Kasuya, T., and T. Miyashita 1997. Distribution of Baird's beaked whales off Japan. Reports of the International Whaling Commission 47:963-968.

Kasuya, T., and T. Miyashita. 1988. Distribution of sperm whale stocks in the North Pacific. Scientific Reports of the Whales Research Institute 39:31-75.

Kasuya, T., and N. Miyazaki. 1982. The stock of *Stenella coeruleoalba* off the Pacific coast of Japan. Pages 21-37 in Mammals in the seas, FAO Fisheries Series No. 5, Volume IV. Rome, Italy.

Kasuya, T., and M. Nishiwaki. 1971. First record of *Mesoplodon densirostris* from Formosa. Scientific Reports of the Whales Research Institute 23:129-137.

Kasuya, T., and S. Ohsumi. 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 K. Shirakihara. 2005. Abundance of Japanese finless porpoise populations. Scientific Committee paper SM/WP4. Cambridge, United Kingdom: International Whaling Commission. 2 pp.

Kasuya, T., and S. Tai. 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., T. Tobayama, and S. Matsui. 1984. Review of the live-capture of small cetaceans in Japan. Reports of the International Whaling Commission 34:597-602.

Kasuya, T., T. Miyashita, and F. Kasamatsu. 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., R.L. Brownell, Jr., and K.C. Balcomb III. 1997a. Life history of Baird's beaked whales off the Pacific coast of Japan. Reports of the International Whaling Commission 47:969-979.

Kasuya, T., Y. Izumisawa, Y. Komyo, Y. Ishino, and Y. Maejima. 1997b. Life history parameters of bottlenose dolphins off Japan. IBI Reports 7:71-108.

Kasuya, T., Y. Yamamoto, and T. Iwatsuki. 2002. Abundance decline in the finless porpoise population in the Inland Sea of Japan. Raffles Bulletin of Zoology Supplement No. 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. 2002. Bryde's whales *Balaenoptera edeni* and *B. brydei*. Pages 171-176 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Kato, H., and T. Kasuya. 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 T. Miyashita. 2004. Japan progress report on cetacean research, April 2003 to April 2004. International Whaling Commission Scientific Program Working Document SC/56/ProgRe.Japan. 15 pp.

Kato, H., E. Shinohara, T. Kishiro, and S. Noji. 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.K., B. Baxter, O. Brizier, S.D. Kraus, J. Perkins, and H. Whitehead. 1979. Identification of humpback whales by fluke photographs. Pages 33-44 in H.E. Winn and B.L. Olla, eds. Behavior of marine animals. Volume 3: Cetaceans. New York: Plenum Press.

Kelly, B.P. 1988a. Ribbon seal--*Phoca fasciata*. Pages 95-106 in J.W. Lentfer, ed. Selected marine mammals of Alaska: Species accounts with research and management recommendations. Washington, D.C.: Marine Mammal Commission.

Kelly, B.P. 1988. Bearded seal--*Erignathus barbatus*. Pages 77-94 in J.W. Lentfer, ed. Selected marine mammals of Alaska: Species accounts with research and management recommendations. Washington, D.C.: Marine Mammal Commission.

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., and H.E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. Continental Shelf Research 7:107-114.

Kenney, R.D., P.M. Payne, D.W. Heinemann, and H.E. Winn. 1996. Shifts in northeast shelf cetacean distributions relative to trends in Gulf of Maine/Georges Bank finfish abundance. Pages 169-196 in K. Sherman, N.A. Jaworski, and T.J. Smayda, eds. The northeast shelf ecosystem: Assessment, sustainability, and management. Boston: Blackwell Science.

Kenney, R.D., G.P. Scott, T.J. Thompson, and H.E. Winn. 1997. Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. Journal of Northwest Atlantic Fishery Science 22:155-171.

Kenyon, K.W., and D.W. Rice. 1961. Abundance and distribution of the Steller sea lion. Journal of Mammalogy 42(2):223-234.

Ketten, D.R. 1992. The marine mammal ear: Specializations for aquatic audition and echolocation. Pages 717-750 in D.B. Webster, R.R. Fay and A.N. Popper, eds. The evolutionary biology of hearing. Berlin: 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-TM-NMFS-SWFSC-256. 74 pp.

Kingsley, M.C.S. 1990. Status of the ringed seal, *Phoca hispida*, in Canada. Canadian Field-Naturalist 104:138-145.

Kingsley, M.C.S., and I. Stirling. 1991. Haul-out behaviour of ringed and bearded seals in relation to defence against surface predators. Canadian Journal of Zoology 69:1857-1861.

Kingston, S.E., and P.E. Rosel. 2004. Genetic differentiation among recently diverged delphinid taxa determined using AFLP markers. Journal of Heredity 95(1):1-10.

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. External morphology of Risso's dolphin off the Pacific Coast of Japan. Pages 115-116 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November–3 December 2001. Vancouver, British Columbia.

Kishiro, T., and T. Kasuya. 1993. Review of Japanese drive fisheries and their status. Reports of the International Whaling Commission 43:439-452.

Kiyota, M., N. Baba, and M. Mouri. 1992. Occurrence of an elephant seal in Japan. Marine Mammal Science 8(4):433.

Klatsky, L.J. 2004. Movement and dive behavior of bottlenose dolphins (*Tursiops truncatus*) near the Bermuda Pedestal. M.S. Thesis, San Diego State University.

Knowlton, A.R., J. Sigurjónsson, J.N. Ciano, and S.D. Kraus. 1992. Long distance movements of North Atlantic right whales (*Eubalaena glacialis*). Marine Mammal Science 8(4):397-405.

Kogi, K., T. Hishii, A. Imamura, T. Iwatani, and K.M. Dudzinski. 2004. Demographic parameters of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) around Mikura Island, Japan. Marine Mammal Science 20(3):510-526.

Kooyman, G.L., R.L. Gentry, and D.L. Urquhart. 1976. Northern fur seal diving behavior: A new approach to its study. Science, New Series 193(4251):411-412.

Kopelman, A.H., and S.S. Sadove. 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(2):200-208.

Koski, W.R., R.A. Davis, G.W. Miller, and D.E. Withrow. 1993. Reproduction. Pages 239-274 in J.J. Burns, J.J. Montague, and C.J. Cowles, eds. The bowhead whale (Special Publication 2). Lawrence, Kansas: Society for Marine Mammalogy.

Koski, W.R., J.W. Lawson, D.H. Thomson, and W.J. Richardson. 1998. Point Mugu Sea Range marine mammal technical report. Point Mugu and San Diego, California: Naval Air Warfare Center, Weapons Division and Southwest Division, Naval Facilities Engineering Command. 364 pp.

Kovacs, K.M. 2002. Hooded seal *Cystophora cristata*. Pages 580-582 in W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. San Diego, CA: Academic Press.

Kovacs, K.M., K.M. Konas, and S.E. Welke. 1990. Sex and age aggregation by *Phoca viutlina concolor* at haulout sites during the breeding season in the Passamaquoddy Bay region, New Brunswick. Marine Mammal Science 6:204-214.

Krafft, B.A., C. Lydersen, K.M. Kovacs, I. Gjertz, and T. Haug. 2000. Diving behaviour of lactating bearded seals (*Erignathus barbatus*) in the Svalbard area. Canadian Journal of Zoology 78:1408-1418.

Krafft, B.A., C. Lydersen, I. Gjertz, and K.M. Kovacs. 2002. Diving behaviour of sub-adult harbour seals (*Phoca vitulina*) at Prins Karls Forland, Svalbard. Polar Biology 25:230-234.

Kraus, S.D., P.K. Hamilton, R.D. Kenney, A.R. Knowlton, and C.K. Slay. 2001. Reproductive parameters of the North Atlantic right whale. Journal of Cetacean Research and Management. Right whales: Worldwide status. (Special Issue 2):231-236.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). Pages 183-212 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Krützen, M., J. Mann, M.R. Heithaus, R.C. Connor, L. Bejder, and W.B. Sherwin. 2005. Cultural transmission of tool use in bottlenose dolphins. Proceedings of the National Academy of Sciences 102(25):8939-8943.

Krützen, M., W.B. Sherwin, R.C. Connor, L.M. Barre, T. Van de Casteele, J. Mann, and R. Brooks. 2003. Contrasting relatedness patterns in bottlenose dolphins (*Tursiops* sp.) with different alliance strategies. Proceedings of the Royal Society of London 270:497-502.

Lafortuna, C.L., M. Jahoda, A. Azzellino, F. Saibene, and A. Colombini. 2003. Locomotor behaviours and respiratory pattern of the Mediterranean fin whale (*Balaenoptera physalus*). European Journal of Applied Physiology 90:387-395.

Lammers, M.O. 2004. Occurrence and behavior of Hawaiian spinner dolphins (*Stenella longirostris*) along Oahu's leeward and south shores. Aquatic Mammals 30(2):237-250.

Lammers, M.O., W.W.L. Au, and D.L. Herzing. 2003. The broadband social acoustic signaling behavior of spinner and spotted dolphins. Journal of the Acoustical Society of America 114(3):1629-1639.

Lanyon, J.M. 2003. Distribution and abundance of dugongs in Moreton Bay, Queensland, Australia. Wildlife Research 30:397-409.

Laurinolli, M.H., A.E. Hay, F. Desharnais, and C.T. Taggart. 2003. Localization of North Atlantic right whale sounds in the Bay of Fundy using a sonobuoy array. Marine Mammal Science 19(4):708-723.

Lavery, S., M.L. Dalebout, N. Funahashi, M. Yong-Woon, and C.S. Baker. 2003. Genetic evidence for multiple stocks of minke whales threatened by hunting and bycatch in coastal waters of Japan and Korea. Page 93 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14-19 December. Greensboro, NC.

Leatherwood, S., and R.R. Reeves. 1983. The Sierra Club handbook of whales and dolphins. San Francisco: Sierra Club Books.

Leatherwood, S., and W.A. Walker. 1979. The northern right whale dolphin *Lissodelphis borealis* Peale in the eastern North Pacific. Pages 85-141 in H.E. Winn and B.L. Olla, eds. Behavior of marine animals: Current perspectives in research. Volume 3: Cetaceans. New York: Plenum Press.

Leatherwood, S., D.K. Caldwell, and H.E. Winn. 1976. Whales, dolphins, and porpoises of the western North Atlantic: A guide to their identification. NOAA Technical Report NMFS CIRC-396:1-176.

Leatherwood, S., R.R. Reeves, A.E. Bowles, B.S. Stewart, and K.R. Goodrich. 1984. Distribution, seasonal movements, and abundance of Pacific white-sided dolphins in the eastern North Pacific. Scientific Reports of the Whales Research Institute 35:129-1575.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1988. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters: A guide to their identification. New York: Dover Publications, Inc.

Leatherwood, S., M.L.L. Dolar, C.J. Wood, L.V. Aragones, and C.L. Hill. 1992. Marine mammal species confirmed from Philippine waters. Silliman Journal 36(1):65-86.

Leatherwood, S., T.A. Jefferson, J.C. Norris, W.E. Stevens, L.J. Hansen, and K.D. Mullin. 1993. Occurrence and sounds of Fraser's dolphin (*Lagenodelphis hosei*) in the Gulf of Mexico. Texas Journal of Science 45(4):349-354.

Le Boeuf, B.J. 1974. Male-male competition and reproductive success in elephant seals. American Zoologist 14:163-176.

Le Boeuf, B.J., and D.E. Crocker. 2005. Ocean climate and seal condition. BMC Biology 3:9.

Le Boeuf, B.J., and R.S. Peterson. 1969. Social status and mating activity in elephant seals. Science 163(3862):91-93.

Le Boeuf, B.J., R.J. Whiting, and R.F. Gannt. 1972. Perinatal behavior of northern elephant seal females and their young. Behaviour XLIII:121-156.

Le Boeuf, B.J., D.P. Costa, A.C. Huntley, G.L. Kooyman, and R.W. Davis. 1986. Pattern and depth of dives in northern elephant seals, *Mirounga angustirostris*. Journal of Zoology, London 208:1-7.

Le Boeuf, B.J., D.E. Crocker, D.P. Costa, S.B. Blackwell, P.M. Webb, and D.S. Houser. 2000. Foraging ecology of northern elephant seals. Ecological Monographs 70(3):353-382.

LeDuc, R.G., W.L. Perryman, J.W. Gilpatrick, Jr., J. Hyde, C. Stinchcomb, J.V. Carretta, and R.L. Brownell, Jr. 2001. A note on recent surveys for right whales in the southeastern Bering Sea. Journal of Cetacean Research and Management. Right whales: Worldwide status. (Special Issue 2):287-289.

LeDuc, R.G., D.W. Weller, J. Hyde, A.M. Burdin, P.E. Rosel, R.L. Brownell, Jr., B. Würsig, and A.E. Dizon. 2002. Genetic differences between western and eastern gray whales (*Eschrichtius robustus*). Journal of Cetacean Research and Management 4(1):1-5.

Li, S., K. Wang, D. Wang, and T. Akamatsu. 2005. Echolocation signals of the free-ranging Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientalis*). Journal of the Acoustical Society of America 117(5):3288-3296.

Littaye, A., A. Gannier, S. Laran, and J.P.F. Wilson. 2004. The relationship between summer aggregation of fin whales and satellite-derived environmental conditions in the northwestern Mediterranean Sea. Remote Sensing of Environment 90:44-52.

Ljungblad, D.K., P.O. Thompson, and S.E. Moore. 1982. Underwater sounds recorded from migrating bowhead whales, *Balaena mysticetus*, in 1979. Journal of the Acoustical Society of America 71(2):477-482.

Lodi, L., and B. Hetzel. 1999. Rough-toothed dolphin, *Steno bredanensis*, feeding behaviors in Ilha Grande Bay, Brazil. Biociências 7(1):29-42.

Loughlin, T.R. 1997. Using the phylogeographic method to identify Steller sea lion stocks. Pages 159-171 in A.E. Dizon, S.J. Chivers and W.F. Perrin, eds. Molecular genetics of marine mammals (Special Publication 3). Lawrence, Kansas: Society for Marine Mammalogy.

Loughlin, T.R. 2002. Steller's sea lion *Eumetopias jubatus*. Pages 1181-1185 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, CA: Academic Press.

Loughlin, T.R., and M.A. Perez. 1985. *Mesoplodon stejnegeri*. Mammalian Species 250:1-6.

Loughlin, T.R., C.H. Fiscus, A.M. Johnson, and D.J. Rugh. 1982. Observations of *Mesoplodon stejnegeri* (Ziphiidae) in the central Aleutian Islands, Alaska. Journal of Mammalogy 63(4):697-700.

Loughlin, T.R, D.J. Rugh, and C.H. Fiscus. 1984. Northern sea lion distribution and abundance: 1956-80. Journal of Wildlife Management 48(3):729-740.

Loughlin, T.R., M.A. Perez, and R.L. Merrick. 1987. *Eumetopias jubatus*. Mammalian Species 283:1-7.

Lowry, L.F. 1993. Foods and feeding ecology. Pages 201-238 in J.J. Burns, J.J. Montague, and C.J. Cowles, eds. The bowhead whale (Special Publication 2). Lawrence, Kansas: Society for Marine Mammalogy.

Lowry, L.F., K.J. Frost, and J.J. Burns. 1980. Feeding of bearded seals in the Bering and Chukchi Seas and trophic interactions with Pacific walruses. Arctic 33(2):330-342.

Lowry, L.F., K.J. Frost, R. Davis, D.P. DeMaster, and R.S. Suydam. 1998. Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. Polar Biology 19:221-230.

Lowry, L.F., G. Sheffield, and J.C. George. 2004. Bowhead whale feeding in the Alaskan Beaufort Sea, based on stomach contents analyses. Journal of Cetacean Research and Management 6(3):215-223.

Lucas, Z.N., and D.F. McAlpine. 2002. Extralimital occurrences of ringed seals, *Phoca hispida*, on Sable Island, Nova Scotia. Canadian Field-Naturalist 116:607-610.

Lydersen, C. 1991. Monitoring ringed seal (*Phoca hispida*) activity by means of acoustic telemetry. Canadian Journal of Zoology 69:1178-1182.

Lydersen, C., and K.M. Kovacs. 1999. Behaviour and energetics of ice-breeding, North Atlantic phocid seals during the lactation period. Marine Ecology Progress Series 187:265-281.

Lydersen, C., M.O. Hammill, and K.M. Kovacs. 1994. Diving activity in nursing bearded seal (*Erignathus barbatus*) pups. Canadian Journal of Zoology 72:96-103.

Lynn, S.K., and D.L. Reiss. 1992. Pulse sequence and whistle production by two captive beaked whales, *Mesoplodon* species. Marine Mammal Science 8(3):299-305.

MacGarvin, M., and M. Simmonds. 1996. Whales and climate change. Pages 321-332 in M.P. Simmonds and J.D. Hutchinson, eds. The conservation of whales and dolphins: Science and practice. Chichester, England: John Wiley & Sons Ltd.

MacLeod, C.D. 1998. Intraspecific scarring in odontocete cetaceans: An indicator of male 'quality' in aggressive social interactions? Journal of Zoology, London 244:71-77.

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., and A.F. Zuur. 2005. Habitat utilization by Blainville's beaked whales off Great Abaco, northern Bahamas, in relation to seabed topography. Marine Biology 147:1-11.

MacLeod, C.D., M.B. Santos, and G.J. Pierce. 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, C.D., N. Hauser, and H. Peckham. 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., W.F. Perrin, R. Pitman, J. Barlow, L. Ballance, A. D'Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D.L. Palka, and G.T. Waring. In Press. Known and inferred distributions of beaked whale species (Family Ziphiidae; Order Cetacea). Journal of Cetacean Research and Management.

Madsen, P.T., D.A. Carder, W.W.L. Au, P.E. Nachtigall, B. Møhl, and S.H. Ridgway. 2003. Sound production in neonate sperm whales (L). Journal of the Acoustical Society of America 113(6):2988-2991.

Madsen, P.T., I. Kerr, and R. Payne. 2004. Source parameter estimates of echolocation clicks from wild pygmy killer whales (*Feresa attenuata*) (L). Journal of the Acoustical Society of America 116(4), Part 1:1909-1912.

Madsen, P. T., M. Johnson, N. Aguilar de Soto, W.M.X. Zimmer, and P. Tyack. 2005. Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*). Journal of Experimental Biology 208(2):181-194.

Maldini, D. 2003. Abundance and distribution patterns of Hawaiian odontocetes: Focus on O'ahu. Ph.D. diss., University of Hawai'i, Manoa.

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack. 1986. Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling. Final Report. OCS Study MMS 88-0048. Anchorage, Alaska: Outer Continental Shelf Environmental Assessment Program Research Unit 675. 207 pp.

Mantua, N. 2002. Pacific-Decadal Oscillation (PDO). Pages 592-594 in 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. Chichester, England: John Wiley & Sons, Ltd.

Mantua, N., and S.R. Hare. 2002. The Pacific Decadal Oscillation. Journal of Oceanography 58:35-44.

Marsh, H. 1995. The life history, pattern of breeding, and population dynamics of the dugong. Pages 75-83 in T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee. Technical Report 1. Washington, D.C.: National Biological Service.

Marsh, H. 2002. Dugong: *Dugong dugon.* Pages 344-347 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Marsh, H., H. Penrose, C. Eros, and J. Hugues. 2002. Dugong: Status reports and action plans for countries and territories. Report UNEP/DEWA/RS.02-1. Nairobi, Kenya: United Nations Environment Programme.

Marsh, H., H. Penrose, and C. Eros. 2003. A future for the dugong? Pages 383-399 in N. Gales, M. Hindell and R. Kirkwood, eds. Marine mammals: Fisheries, tourism and management issues. Collingwood VIC, Australia: CSIRO Publishing.

Marshall, C.D., H. Maeda, M. Iwata, M. Furuta, S. Asano, F. Rosas, and R.L. Reep. 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.

Marten, K., and S. Psarakos. 1999. Long-term site fidelity and possible long-term associations of wild spinner dolphins (*Stenella longirostris*) seen off Oahu, Hawaii. Marine Mammal Science 15(4):1329-1336.

Mate, B.R., S.L. Nieukirk, and S.D. Kraus. 1997. Satellite-monitored movements of the northern right whale. Journal of Wildlife Management 61(4):1393-1405.

Mate, B.R., B.A. Lagerquist, and J. Calambokidis. 1999. Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. Marine Mammal Science 15(4):1246-1257.

Matthews, J.N., S. Brown, D. Gillespie, M. Johnson, R. McLanaghan, A. Moscrop, D. Nowacek, R. Leaper, T. Lewis, and P. Tyack. 2001. Vocalisation rates of the North Atlantic right whale (*Eubalaena glacialis*). Journal of Cetacean Research and Management 3(3):271-281.

Mattila, D.K., L.N. Guinee, and C.A. Mayo. 1987. Humpback whale songs on a North Atlantic feeding ground. Journal of Mammalogy 68(4):880-883.

Mazzuca, L.L., S. Atkinson, B. Keating, and E.T. Nitta. 1999. Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998. Aquatic Mammals 25(2):105-114.

McAlpine, D.F. 2002. Pygmy and dwarf sperm whales *Kogia breviceps and K. sima*. Pages 1007-1009 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

McConnell, B.J., and M.A. Fedak. 1996. Movements of southern elephant seals. Canadian Journal of Zoology 74:1485-1496.

McCowan, B., and D. Reiss. 1995. Maternal aggressive contact vocalizations in captive bottlenose dolphins (*Tursiops truncatus*): Wide-band, low frequency signals during mother/aunt-infant interactions. Zoo Biology 14:293-309.

McDonald, M.A., and C.G. Fox. 1999. Passive acoustic methods applied to fin whale population density estimation. Journal of the Acoustical Society of America 105(5):2643-2651.

McDonald, M.A., and S.E. Moore. 2002. Calls recorded from North Pacific right whales (*Eubalaena japonica*) in the eastern Bering Sea. Journal of Cetacean Research and Management 4(3):261-266.

McDonald, M.A., J. Calambokidis, A.M. Teranishi, and J.A. Hildebrand. 2001. The acoustic calls of blue whales off California with gender data. Journal of the Acoustical Society of America 109(4):1728-1735.

McLellan, W.A., H.N. Koopman, S.A. Rommel, A.J. Read, C.W. Potter, J.R. Nicolas, A.J. Westgate, and D.A. Pabst. 2002. Ontogenetic allometry and body composition of harbour porpoises (*Phocoena phocoena,* L.) from the western North Atlantic. Journal of Zoology, London 257:457-471.

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. 1989. Beaked whales of the genus - *Mesoplodon*. Pages 349-430 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. London: Academic Press.

Mead, J.G., and C.W. Potter. 1990. Natural history of bottlenose dolphins along the central Atlantic coast of the United States. Pages 165-195 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego: Academic Press.

Mead, J.G., and C.W. Potter. 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., W.A. Walker, and W.J. Houck. 1982. Biological observations on *Mesoplodon carlhubbsi* (Cetacea: Ziphiidae). Smithsonian Contributions to Zoology 344:1-25.

Medrano-González, L., C.S. Baker, M.R. Robles-Saavedra, J. Murrell, M.J. Vázquez-Cuevas, B.C. Congdon, J.M. Straley, J. Calambokidis, J. Urbán-Ramírez, L. Flórez-González, C. Olavarría-Barrera, A. Aguyao-Lobo, J. Nolasco-Soto, R.A. Juárez-Salas, and K. Villavicencio-LLamosas. 2001. Trans-oceanic population genetic structure of humpback whales in the North and South Pacific. Memoirs of the Queensland Museum 47(2):465-479.

Mellinger, D.K., and C.W. Clark. 2003. Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic. Journal of the Acoustical Society of America 114(2):1108-1119.

Mellinger, D.K., C.D. Carson, and C.W. Clark. 2000. Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico. Marine Mammal Science 16(4):739-756.

Mellinger, D.K., K.M. Stafford, S.E. Moore, L. Munger, and C.G. Fox. 2004. Detection of North Pacific right whale (*Eubalaena japonica*) calls in the Gulf of Alaska. Marine Mammal Science 20(4):872-879.

Mendes, S., W. Turrell, T. Lütkebohle, and P. Thompson. 2002. Influence of the tidal cycle and a tidal intrusion front on the spatio-temporal distribution of coastal bottlenose dolphins. Marine Ecology Progress Series 239:221-229.

Merrick, R. L., and T. R. Loughlin. 1997. Foraging behavior of adult female and young-of-the-year Steller sea lions in Alaskan waters. Canadian Journal of Zoology 75:776-786.

Merrick, R.L., M.K. Chumbley, and G.V. Byrd. 1997. Diet diversity of Steller sea ions (*Eumetopias jubatus*) and their population decline in Alaska: A potential relationship. Canadian Journal of Fisheries and Aquatic Sciences 75:776-786.

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., S.L. Swartz, A. Martínez, C.M. Burks, and W.A. Watkins. 2003. First records of the pantropical spotted dolphin (*Stenella attenuata*) for the Puerto Rican Bank, with a review of the species in the Caribbean. Caribbean Journal of Science 39(3):381-392.

Miller, P.J.O., M.P. Johnson, and P.L. Tyack. 2004. Sperm whale behaviour indicates the use of echolocation click buzzes 'creaks' in prey capture. Proceedings of the Royal Society of London, Part B 271:2239-2247.

Mitchell, E. 1975. Report of the meeting on smaller cetaceans, Montreal, April 1-11, 1974. Subcommittee on small cetaceans, Scientific Committee, International Whaling Commission. Journal of Fisheries Research Board of Canada 32(7):889-983.

Mitchell, E.D., Jr. 1991. Winter records of the minke whale (*Balaenoptera acutorostrata acutorostrata* Lacépède 1804) in the southern North Atlantic. Reports of the International Whaling Commission 41:455-457.

Mitchell, E., and M. Kozicki. 1975. Supplementary information on minke whale (*Balaenoptera acutorostrata*) from Newfoundland fishery. Journal of the Fisheries Research Board of Canada 32(7):985-994.

Miyashita, T. 1986. Abundance of some globicephalid cetaceans in the adjacent waters of Japan. International Whaling Commission Scientific Program working document IWC/SC/38/SM17. 18 pp.

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(III):435-450.

Miyashita, T., and H. Hatanaka. 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 T. Kasuya. 1988. Distribution and abundance of Dall's porposises off Japan. Scientific Reports of the Whales Research Institute 39:121-150.

Miyashita, T., T. Kasuya, and K. Mori. 1990. An examination of the feasibility of using photo-identification techniques for a short-finned pilot whale stock off Japan. Reports of the International Whaling Commission (Special Issue 12):425-428.

Miyashita, T., H. Kato, and T. Kasuya, eds. 1995. Worldwide map of cetacean distribution based on Japanese sighting data (Volume 1).140 pp. Shimizu, Shizuoka, Japan: National Research Institute of Far Seas Fisheries.

Miyashita, T., T. Kishiro, N. Higashi, F. Sato, K. Mori, and H. Kato. 1996. Winter distribution of cetaceans in the western North Pacific inferred from sighting cruises 1993-1995. Reports of the International Whaling Commission 46:437-441.

Miyazaki, N. 1983. Catch statistics of small cetaceans taken in Japanese waters. Reports of the International Whaling Commission 33:621-631.

Miyazaki, N., and M. Amano. 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., and W.F. Perrin. 1994. Rough-toothed dolphin—*Steno bredanensis* (Lesson, 1828). Pages 1-21 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Miyazaki, N., and K. Nakayama. 1989. Records of cetaceans in the waters of the Amami Islands. Memoirs of the National Science Museum, Tokyo 22:235-249.

Miyazaki, N., and C. Shikano. 1989. Two forms of *Lagenorhynchus obliquidens* in the Japanese waters. Abstracts, Theriological Congress, Rome.

Miyazaki, N., and S. Wada 1978a. Observation of Cetacea during whale marking cruise in the western tropical Pacific, 1976. Scientific Reports of the Whales Research Institute 30:179-195.

Miyazaki, N., and S. Wada. 1978b. Fraser's dolphin, *Lagenodelphis hosei* in the western North Pacific. Scientific Reports of the Whales Research Institute 30:231-244.

Miyazaki, N., T. Kasuya, and M. Nishiwaki. 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., M. Amano, and Y. Fujise. 1987. Growth and skull morphology of the harbour porpoises in the Japanese waters. Memoirs of the National Science Museum, Tokyo 20:137-146.

Miyazaki, N., T. Kuramochi, and M. Amano. 1991. Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) off northern Hokkaido. Memoirs of the National Science Museum, Tokyo 24:131-139.

Miyazaki, N., Y. Fujise, and K. Iwata. 1998. Biological analysis of a mass stranding of melon-headed whales (*Peponocephala electra*) at Aoshima, Japan. Bulletin of the National Science Museum, Tokyo, Series A 24(1):31-60.

Mizroch, S.A., D.W. Rice, D. Zwiefelhofer, J. Waite, and W.L. Perryman. 2005. Distribution and movements of fin whales in the North Pacific Ocean. Draft. 71 pp.

Mizuno, A.W., M. Suzuki, and N. Ohtaishi. 2001. Distribution of the spotted seal *Phoca largha* along the coast of Hokkaido, Japan. Mammal Study 26(2):109-118.

Mizuno, A.W., A. Wada, T. Kshinazaka, K. Hattori, Y. Watanabe, and N. Ohtaishi. 2002. Distribution and abundance of spotted seals *Phoca largha* and ribbon seals *Phoca fasciata* in the southern Sea of Okhotsk. Ecological Research 17:79-96.

MMC (Marine Mammal Commission). 2005. Annual report to Congress 2004. Bethesda, Maryland: Marine Mammal Commission.

Mobley, J.R., Jr., M. Smultea, T. Norris, and D. Weller. 1996. Fin whale sighting north of Kaua'i, Hawai'i. Pacific Science 50(2):230-233.

Møhl, B., M. Wahlberg, P.T. Madsen, A. Heerfordt, and A. Lund. 2003. The monopulsed nature of sperm whale clicks. Journal of the Acoustical Society of America 114(2):1143-1154.

Moore, P.W.B., and R.J. Schusterman. 1987. Audiometric assessment of northern fur seals, *Callorhinus ursinus*. Marine Mammal Science 3(1):31-53.

Moore, S.E., and J.T. Clarke. 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., and D.K. Ljungblad. 1984. Gray whales in the Beaufort, Chukchi, and Bering Seas: Distribution and sound production. Pages 543-559 in M.L. Jones, S.L. Swartz and S. Leatherwood, eds. The gray whale *Eschrichtius robustus*. San Diego, California: Academic Press, Inc.

Moore, S.E., and R.R. Reeves. 1993. Distribution and movement. Pages 313-386 in J.J. Burns, J.J. Montague, and C.J. Cowles, eds. The bowhead whale (Special Publication 2). Lawrence, Kansas: Society for Marine Mammalogy.

Moore, S.E., J.M. Waite, L.L. Mazzuca, and R.C. Hobbs. 2000. Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. Journal of Cetacean Research and Management 2(3):227-234.

Moore, S.E., W.A. Watkins, M.A. Daher, J.R. Davies, and M.E. Dahlheim. 2002. Blue whale habitat associations in the northwest Pacific: Analysis of remotely-sensed data using a Geographic Information System. Oceanography 15(3):20-25.

Morejohn, G.V. 1979. The natural history of Dall's porpoise in the North Pacific Ocean. Pages 45-83 in H.E. Winn and B.L. Olla, eds. Behavior of marine animals: Current perspectives in research. Volume 3: Cetaceans. New York: Plenum Press.

Mori, K. 1999. Whale and dolphin watching and associated research programs in the Ogasawara Islands, Japan. Wild Dolphin Swim Program Workshop: A workshop held in conjunction with the 13th Biennial Conference on the Biology of Marine Mammals. 28 November. Maui, Hawaii. Society of Marine Mammalogy.

Mori, K., F. Sato, M. Yamaguchi, H. Suganuma, and S. Ueyanagi. 1998. Distribution, migration and local movements of humpback whale (*Megaptera novaeangliae*) in the adjacent waters of the Ogasawara (Bonin) Islands, Japan. Journal of the School of Marine Science and Technology Tokai University 45:197-213.

Mori, K., H. Abe, M. Suzuki, and T. Kubodera. 1999. School structure, distribution and food habits of sperm whales near the Ogasawara Islands, Japan. Page 130 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November - 3 December, 1999. Wailea, HI.

Mori, J., T. Kubodera, and N. Baba. 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.

Morisaka, T., M. Shinohara, F. Nakahara, and T. Akamatsu. 2005a. Effects of ambient noise on the whistles of Indo-Pacific bottlenose dolphin populations. Journal of Mammalogy 86(3):541-546.

Morisaka, T., M. Shinohara, F. Nakahara, and T. Akamatsu. 2005b. Geographic variation in the whistles among three Indo-Pacific bottlenose dolphin *Tursiops aduncus* populations in Japan. Fisheries Science 71**:**568-576.

Morton, A. 2000. Occurrence, photo-identification and prey of Pacific white-sided dolphins (*Lagenorhyncus obliquidens*) in the Broughton Archipelago, Canada 1994-1998. Marine Mammal Science 16(1):80-93.

Moulton, V.D., E.H. Miller, and H. Ochoa-Acuna. 2000. Haulout behaviour of captive harp seals (*Pagophilus groenlandicus*): Incidence, seasonality, and relationships to weather. Applied Animal Behaviour Science 65:367-378.

Mullin, K.D., T.A. Jefferson, L.J. Hansen, and W. Hoggard. 1994. First sightings of melon-headed whales (*Peponocephala electra*) in the Gulf of Mexico. Marine Mammal Science 10(3):342-348.

Muñoz-Hincapié, M.F., D.M. Mora-Pinto, D.M. Palacios, E.R. Secchi, and A.A. Mignucci-Giannoni. 1998. First osteological record of the dwarf sperm whale in Colombia, with notes on the zoogeography of *Kogia* in South America**.** Revista Academia Colombiana de Ciencias 22(84):433-444

Murphy, M.A. 1995. Occurrence and group characteristics of minke whales, *Balaenoptera acutorostrata*, in Massachusetts Bay and Cape Cod Bay. Fishery Bulletin 93:577-585.

Nachtigall, P.E., W.W.L. Au, J.L. Pawloski, and P.W.B. Moore. 1995. Risso's dolphin (*Grampus griseus*) hearing thresholds in Kaneohe Bay, Hawaii. Pages 49-53 in R.A. Kastelein, J.A. Thomas, and P.E. Nachtigall, eds. Sensory systems of aquatic mammals. Woerden, The Netherlands: De Spil Publishers.

Nachtigall, P.E., D.W. Lemonds, and H.L. Roitblat. 2000. Psychoacoustic studies of dolphin and whale hearing. Pages 330-363 in W.W.L. Au, A.N. Popper, and R.R. Fay, eds. Hearing by whales and dolphins. New York: Springer-Verlag.

Nachtigall, P.E., J.L. Pawloski, and W.W.L. Au. 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.

Nachtigall, P.E., A.Y. Supin, J. Pawloski, and W.W.L. Au. 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.

Nakajima, M., and M. Nishiwaki. 1965. The first occurrence of a porpoise (*Electra electra*) in Japan. Scientific Reports of the Whales Research Institute 19:91-104.

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. 1979. A record of the bearded seal wandering with special reference to the wandering speed. Scientific Reports of the Whales Research Institute 31:121-123.

Naito, Y., and S. Konno. 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 M. Nishiwaki. 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.

Nakahara, F., S. Uchida, N. Higashi, A. Takemura, and M. Amano. 2003. A comparison of the vocalizations of two forms of short-finned pilot whales (*Globicephala macrorhynchus*) off the Pacific coast of Japan. Page 117 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December 2003. Greensboro, North Carolina.

Nakamura, H., G. Lin, and T. Yamagata. 1997. Decadal climate variability in the North Pacific during the recent decades. Bulletin of the American Meteorological Society 78(10):2215-2225.

Natoli, A., V.M. Peddemors, and A.R. Hoelzel. 2004. Population structure and speciation in the genus *Tursiops* based on microsatellite and mitochondrial DNA analyses. Journal of Evolutionary Biology 17:363-375.

Nekoba-Dutertre, N., M. Poole, and B. Bilgre. 1999. Rough-tooth dolphins (*Steno bredanensis*) in French Polynesia. Page 133 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Maui.

Nelson, D., and J. Lien. 1996. The status of the long-finned pilot whale, *Globicephala melas*, in Canada. Canadian Field-Naturalist 110(3):511-524.

Nemoto, T., and A. Kawamura. 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.

Nerini, M. 1984. A review of gray whale feeding ecology. Pages 423-450 in M.L. Jones, S.L. Swartz, and S. Leatherwood, eds. The gray whale, *Eschrichtius robustus*. San Diego, California: Academic Press.

Nishiwaki, M. 1959. Humpback whales in Ryukyuan waters. Scientific Reports of the Whales Research Institute 14:49-86.

Nishiwaki, M. 1966. Distribution and migration of the larger cetaceans in the North Pacific shown by Japanese whaling results. Pages 171-191 in K.S. Norris, ed. Whales, dolphins, and porpoises. Berkeley: University of California Press.

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. Pages 80-81 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. 18-19 August 1972. University of Guelph, Ontario, Canada.

Nishiwaki, M., and C. Handa. 1958. Killer whales caught in the coastal waters off Japan for recent 10 years. Scientific Reports of the Whales Research Institute13:85-96.

Nishiwaki, M., and T. Kamiya. 1959. *Mesoplodon stejnegeri* from the coast of Japan. Scientific Reports of the Whales Research Institute 14:35-48.

Nishiwaki, M., and T. Kasuya. 1970. A Greenland right whale caught at Osaka Bay. Scientific Reports of the Whales Research Institute 22:45-62.

Nishiwaki, M., and F. Nagasaki. 1960. Seals of the Japanese coastal waters. Mammalia 24(3):459-467.

Nishiwaki, M.K., and K.S. Norris. 1966. A new genus, *Peponocephala*, for the odontocete cetacean species *Electra electra*. Scientific Reports of the Whales Research Institute 20:95-100.

Nishiwaki, M., and N. Oguro. 1972. Catch of the Cuvier's beaked whales off Japan in recent years. Scientific Reports of the Whales Research Institute 24:35-41.

Nishiwaki, M., T. Kasuya, K. Kureha, and N. Oguro. 1972. Further comments on *Mesoplodon ginkgodens*. Scientific Reports of the Whales Research Institute 24:43-56.

Nishiwaki, M., T. Kasuya, N. Miyazaki, T. Tobayama, and T. Kataoka. 1979. Present distribution of the dugong in the world. Scientific Reports of the Whales Research Institute 31:133-141.

Nitta, E.T., and J.R. Henderson. 1993. A review of interactions between Hawaii's fisheries and protected species. Marine Fisheries Review 55(2):83-92.

NMFS (National Marine Fisheries Service). 1993. Final conservation plan for the northern fur seal (*Callorhinus ursinus*). The National Marine Mammal Laboratory/Alaska Fisheries Science Center, Seattle, Washington, and the Office of Protected Resources/National Marine Fisheries Service, Silver Spring, Maryland 80 pp.

NMFS (National Marine Fisheries Service). 1997. Threatened fish and wildlife: Change in listing status of Steller sea lions under the Endangered Species Act. Federal Register 62: 24345-24355.

NMFS (National Marine Fisheries Service). 1998a. Draft recovery plan for the fin whale, *Balaenoptera physalus* and sei whale, *Balaenoptera borealis*. Silver Spring, Maryland: National Marine Fisheries Service. Prepared by R.R. Reeves, G.K. Silber, and P.M. Payne. 65 pp.

NMFS (National Marine Fisheries Service). 1998b. Recovery plan for the blue whale (*Balaenoptera musculus*). Silver Spring, Maryland: National Marine Fisheries Service. Prepared by R.R. Reeves, P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber. 39 pp.

NMFS (National Marine Fisheries Service). 2002. Endangered and threatened species: Determination on a petition to revise critical habitat for northern right whales in the Pacific. Federal Register 67(34):7660-7665.

NMFS (National Marine Fisheries Service). 2005. Endangered and threatened species; Revision of critical habitat for the northern right whale in the Pacific Ocean. Federal Register 70(211):66332-66346.

Norris, J.C., and S. Leatherwood. 1981. Hearing in the bowhead whale, *Balaena mysticetus*, as estimated by cochlear morphology. Pages 745-787 in T.F. Albert, ed. Tissue structural studies and other investigations on the biology of endangered whales in the Beaufort Sea. Volume II. Final report for contract No. AA851-CTO-22. Prepared for Bureau of Land Management, Alaska OCS Office, Anchorage, Alaska by Department of Veterinary Science, University of Maryland, College Park, Maryland.

Norris, K.S., and T.P. Dohl. 1980. Behavior of the Hawai'ian spinner dolphin, *Stenella longirostris*. Fishery Bulletin 77(4):821-849.

Norris, K.S., and J.H. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. University of California Publications in Zoology 63(4):291-402.

Norris, K.S., R.M. Goodman, B. Villa-Ramirez, and L. Hobbs. 1977. Behavior of California gray whale, *Eschrichtius robustus*, in southern Baja California, Mexico. Fishery Bulletin 75(1):159-172.

Norris, K.S., B. Würsig, R.S. Wells, and M. Würsig, eds. 1994. The Hawaiian spinner dolphin. Berkeley: University of California Press.

Northrop, J., W.C. Cummings, and M.F. Morrison. 1971. Underwater 20-Hz signals recorded near Midway Island. Journal of the Acoustical Society of America 49(6): 1909-1910.

Notarbartolo di Sciara, G. 1982. Bryde's whales (*Balaenoptera edeni* Anderson, 1878) off eastern Venezuela (Cetacea, Balaenopteridae). Technical Report 83-153. San Diego: Hubbs-Sea World Research Institute. 29 pp.

Notarbartolo-di-Sciara, G., M. Zanardelli, M. Jahoda, S. Panigada, and S. Airoldi. 2003. The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. Mammal Review 33(2):105-150.

Nowacek, D.P., M.P. Johnson, and P.L. Tyack. 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. Proceedings of the Royal Society of London, Part B 271:227-231.

NRC (National Research Council). 2003. Decline of the Steller sea ion in Alaskan waters. Washington, D.C.: National Academies Press.

Odell, D.K., and K.M. McClune. 1999. False killer whale *Pseudorca crassidens* (Owen, 1846). Pages 213-243 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

O'Hara, T.M., J.C. George, R.J. Tarpley, K. Burek, and R.S. Suydam. 2002. Sexual maturation in male bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort Seas stock. Journal of Cetacean Research and Management 4(2):143-148.

Ohizumi, H., and T. Kishiro. 2003. Stomach contents of a Cuvier's beaked whale (*Ziphius cavirostris*) stranded on the central Pacific coast of Japan. Aquatic Mammals 29(1):99-103.

Ohizumi, H., M. Yoshioka, K. Mori, and N. Miyazaki. 1998. Stomach contents of common dolphins (*Delphinus delphis*) in the pelagic western North Pacific. Marine Mammal Science 14(4):835-844.

Ohizumi, H., T. Kuramochi, M. Amano, and N. Miyazaki. 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., T. Matsuishi, and H. Kishino. 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.

Ohizumi, H., T. Isoda, T. Kishiro, and H. Kato. 2003a. 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., T. Isoda, and H. Kato. 2003b. Feeding habits of southern form short-finned pilot whales (*Globicephala macrorynchus*) in the western North Pacific off central Japan. Page 122 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December 2003. Greensboro, NC.

Ohsumi, S. 1972. Catch of marine mammals, mainly small cetaceans, by local fisheries along the coast of Japan. Bulletin of the Far Seas Fisheries Research Laboratory 7:137-166.

Ohsumi, S. 1975. Review of Japanese small-type whaling. Journal of the Fisheries Research Board of Canada 32:1111-1121.

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. 1978. Bryde's whales in the North Pacific in 1976. Reports of the International Whaling Commission 28:277-280.

Ohsumi, S. 1983. Population assessment of Baird's beaked whales in the waters adjacent to Japan. Reports of the International Whaling Commission 33:633-641.

Ohsumi, S., and Y. Masaki. 1975. Japanese whale marking in the North Pacific, 1963-1972. Bulletin of the Far Seas Fisheries Research Laboratory 12:171-219.

Ohtaishi, N., and M. Yoneda. 1981. A thirty four years old male Kuril seal from Shiretoko Pen., Hokkaido. Scientific Reports of the Whales Research Institute 33:131-135.

Okamura, H., K. Matsuoka, T. Hakamada, M. Okazaki, and T. Miyashita. 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.

Oleson, E.M., J. Barlow, J. Gordon, S. Rankin, and J.A. Hildebrand. 2003. Low frequency calls of Bryde's whales. Marine Mammal Science 19(2):407-419.

Olson, P.A., and S.B. Reilly. 2002. Pilot whales *Globicephala melas* and *G. macrorhynchus*. Pages 898-903 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Omura, H. 1962. Further information on Bryde's whale from the coast of Japan. Scientific Reports of the Whales Research Institute 16:7-18.

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.

Omura, H. 1984. History of gray whales in Japan. Pages 57-76 in M.L. Jones, S.L. Swartz and S. Leatherwood, eds. The gray whale *Eschrichtius robustus*. San Diego, California: Academic Press, Inc.

Omura, H. 1986. History of right whale catches in the waters around Japan. Reports of the International Whaling Commission (Special Issue 10):35-41.

Omura, H., and T. Kawakami. 1956. Japanese whale marking in the North Pacific. Norsk Hvalfangst-Tidende 45(10):555-563.

Omura, H., and S. Ohsumi. 1964. A review of Japanese whale marking in the North Pacific to the end of 1962, with some information on marking in the Antarctic. Norsk Hvalfangst-Tidende 4:90-112.

Omura, H., and S. Ohsumi. 1974. Research on whale biology of Japan with special reference to the North Pacific stocks. Pages 196-208 in W.E. Schevill, ed. The whale problem: A status report. Cambridge, MA: Harvard University Press.

Omura, H., and Y. Takahashi. 1981. A pygmy sperm whale stranded at Tokaimura, Ibaragi, Japan. Scientific Reports of the Whales Research Institute 33:119-124.

Omura, H., S. Ohsumi, T. Nemoto, K. Nasu, and T. Kasuya. 1969. Black right whales in the North Pacific. Scientific Reports of the Whales Research Institute 21:1-78.

ONR (Office of Naval Research). 2001. Littoral Warfare Advanced Development (LWAD), LWAD 01-2 experiment, Post-test report: Environmental Conservation. Draft. Technical note MAI LWAD 01-2. 9 pp.

ONR (Office of Naval Research). 2004. Littoral Warfare Advanced Development (LWAD), LWAD 03-4 experiment, Post-test report: Environmental Conservation. Draft. Technical note MAI LWAD 03-4. 6 pp.

Östman, J.S.O. 1994. Social organization and social behavior of Hawai'ian spinner dolphins (*Stenella longirostris*). Ph.D. diss., University of California at Santa Cruz.

Östman-Lind, J., A.D. Driscoll-Lind, and S.H. Rickards. 2004. Delphinid abundance, distribution and habitat use off the western coast of the island of Hawai'i. Administrative Report LJ-04-02C. La Jolla, California: NMFS-SWFSC. Report prepared under Contract No. AB133F-02-CN-0123 28 pp.

Otani, S., Y. Naito, A. Kawamura, M. Kawasaki, S. Nishiwaki, and A. Kato. 1998. Diving behavior and performance of harbor porpoises, *Phocoena phocoena*, in Funka Bay, Hokkaido, Japan. Marine Mammal Science 14(2):209-220.

Pabst, D.A., S.A. Rommel, and W.A. McLellan. 1999. The functional morphology of marine mammals. Pages 15-72 in J.E. Reynolds III and S.A. Rommel, eds. Biology of marine mammals. Washington, D.C.: Smithsonian Institution.

Pack, A.A., D.R. Salden, M. Ferrari, D.A. Glockner-Ferrari, L.M. Herman, H.A. Stubbs, and J.M. Straley. 1998. Male humpback whale dies in competitive group. Marine Mammal Science 14(4):861-873.

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.

Palacios, D.M. 1999. Blue whale (*Balaenoptera musculus*) occurrence off the Galápagos Islands, 1978-1995. Journal of Cetacean Research and Management 1(1):41-51.

Palacios, D.M., and B.R. Mate. 1996. Attack by false killer whales (*Pseudorca crassidens*) on sperm whales (*Physeter macrocephalus*) in the Galápagos Islands. Marine Mammal Science 12(4):582-587.

Panigada, S., M. Zanardelli, S. Canese, and M. Jahoda. 1999. Deep diving performances of Mediterranean fin whales. Page 144 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Maui.

Panin, K.I., and G.K. Panina. 1968. Fur seal ecology and migration to the Sea of Japan during winter and spring. Pages 66-76 in V.A. Arsen'ev and K.I. Panin, eds. Pinnipeds of the North Pacific. Moscow. (In Russian; English translation by Israel Program for Scientific Translations, 1971).

Parks, S.E., and P.L. Tyack. 2005. Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups. Journal of Acoustical Society of America 117(5):3297-3306.

Parks, S.E., D.R. Ketten, J. Trehey O'Malley, and J. Arruda. 2004. Hearing in the North Atlantic right whale: Anatomical predictions. Journal of the Acoustical Society of America 115(5):2442.

Parks, S.E., P.K. Hamilton, S.D. Kraus, and P.L. Tyack. 2005. The gunshot sound produced by male North Atlantic right whales (*Eubalaena glacialis*) and its potential function in reproductive advertisement. Marine Mammal Science 21(3):458-475.

Payne, K., P. Tyack, and R. Payne. 1983. Progressive changes in the songs of humpback whales (*Megaptera novaeangliae*): A detailed analysis of two seasons in Hawaii. Pages 9-57 in R. Payne, ed. Communication and behavior of whales. Volume AAAS Selected Symposia Series 76. Boulder, Colorado: Westview Press.

Payne, P.M., and D.W. Heinemann. 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., and L.A. Selzer. 1989. The distribution, abundance and selected prey of the harbor seal, *Phoca vitulina concolor*, in southern New England. Marine Mammal Science 5(2):173-192.

Payne, P.M., J.R. Nicolas, L. O'Brien, and K.D. Powers. 1986. The distribution of the humpback whale, *Megaptera novaeangliae*, on Georges Bank and in the Gulf of Maine in relation to densities of the sand eel, *Ammodytes americanus*. Fishery Bulletin 84:271-277.

Payne, P.M., D.N. Wiley, S.B. Young, S. Pittman, P.J. Clapham, and J.W. Jossi. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. Fishery Bulletin 88:687-696.

Payne, R.S., and S. McVay. 1971. Songs of humpback whales. Science 173(3997)**:**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.

Peilie, W. 1986. Distribution, ecology and resource conservation of the spotted seal in the Huanghai and Bohai Seas. ACTA Oceanologica Sinica 5(1):126-133.

Perrin, W.F. 1998. *Stenella longirostris*. Mammalian Species 599**:**1-7.

Perrin, W.F., and J.W. Gilpatrick, Jr. 1994. Spinner dolphin—*Stenella longirostris* (Gray, 1828). Pages 99-128 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., and R.L. Brownell, Jr. 2002. Minke whales *Balaenoptera acutorostrata* and *B. bonaerensis*. Pages 750-754 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Perrin, W.F., and A.A. Hohn. 1994. Pantropical spotted dolphin—*Stenella attenuata*. Pages 71-98 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., C.E. Wilson, and F.I. Archer. 1994a. Striped dolphin—*Stenella coeruleoalba* (Meyen, 1833). Pages 129-159 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., S. Leatherwood, and A. Collet. 1994b. Fraser's dolphin—*Lagenodelphis hosei* (Fraser, 1956). Pages 225-240 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Perrin, W.F., M.L.L. Dolar, and D. Robineau. 1999. Spinner dolphins (*Stenella longirostris*) of the western Pacific and southeast Asia: Pelagic and shallow-water forms. Marine Mammal Science 15(4):1029-1053.

Perry, C., and A.L. Thornton. 2000. Towards extinction: The exploitation of small cetaceans in Japan. London, England: EIA (Environmental Investigation Agency). 28 pp.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 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. 2002. Melon-headed whale *Peponocephala electra*. Pages 733-735 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Perryman, W.L., and T.C. Foster. 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. NMFS Administrative Report LJ-80-05. 9 pp.

Perryman, W.L., D.W.K. Au, S. Leatherwood, and T.A. Jefferson. 1994. Melon-headed whale—*Peponocephala electra* (Gray, 1846). Pages 363-386 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego, California: Academic Press.

Philips, J.D., P.E. Nachtigall, W.W.L. Au, J.L. Pawloski, and H.L. Roitblat. 2003. Echolocation in the Risso's dolphin, *Grampus griseus*. Journal of the Acoustical Society of America 113(1):605-616.

Pitcher, K.W., and D.G. Calkins. 1981. Reproductive biology of Steller sea lions in the Gulf of Alaska. Journal of Mammalogy 62(3):599-605.

Pitman, R.L. 2002. Mesoplodont whales *Mesoplodon* spp. Pages 738-742 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Pitman, R.L., and C. Stinchcomb. 2002. Rough-toothed dolphins (*Steno bredanensis*) as predators of mahimahi (*Coryphaena hippurus*). Pacific Science 56(4):447-450.

Pitman, R.L., D.M. Palacios, P.L.R. Brennan, B.J. Brennan, K.C. Balcomb III, and T. Miyashita. 1999. Sightings and possible identity of a bottlenose whale in the tropical Indo-Pacific: *Indopacetus pacificus*? Marine Mammal Science 15(2):531-549.

Pivorunas, A. 1979. The feeding mechanisms of baleen whales. American Scientist 67:432-440.

Plön, S. 2004. The status and natural history of pygmy (*Kogia breviceps*) and dwarf (*K. sima*) sperm whales off southern Africa. Ph D in Zoology, Rhodes University, Grahamstown, South Africa.

Plön, S., and R. Bernard. 1999. The fast lane revisited: Life history strategies of *Kogia* from southern Africa. Page 149 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Maui.

Plön, S.E.E., R.W. Harris, P.M. Illgner, and V.G.C. Cockcroft. 1998. Analysis of pygmy (*Kogia breviceps*) and dwarf (*Kogia simus*) sperm whale strandings along the South African coastline using a geographic information system. Page 108 in Abstracts, The World Marine Mammal Science Conference. 20-24 January 1998. Monte Carlo, Monaco.

Polacheck, T. 1987. Relative abundance, distribution and inter-specific relationship of cetacean schools in the eastern tropical Pacific. Marine Mammal Science 3(1):54-77.

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. diss., University of California, Santa Cruz.

Popov, V.V., and V.O. Klishin. 1998. EEG study of hearing in the common dolphin, *Delphinus delphis*. Aquatic Mammals 24(1):13-20.

Popov, V.V., A.Y. Supin, D. Wang, K. Wang, J. Xiao, and S. Li. 2005. Evoked-potential audiogram of the Yangtze finless porpoise *Neophocaena phocaenoides asiaeorientalis* (L). Journal of the Acoustical Society of America 117(5):2728-2731.

Poulter, T.C. 1968. Underwater vocalization and behavior of pinnipeds. Pages 69-84 in R.J. Harrison, R.C. Hubbard, R.S. Peterson, C.E. Rice, and R.J. Schusterman, eds. The behavior and physiology of pinnipeds. New York: Appleton-Century-Crofts.

Preen, A. 1995a. Impacts of dugong foraging on seagrass habitats: Observational and experimental evidence for cultivation grazing (*Dugong dugon*). Marine Ecology Progress Series 124:201-213.

Preen, A. 1995b. Diet of dugongs: Are they omnivores? Journal of Mammalogy 76(1):163-171.

Prescott, R. 1982. Harbor seals: Mysterious lords of the winter beach. Cape Cod Life 3(4):Pgs. 24-29.

Pryor, K., and I.K. Shallenberger. 1991. Social structure in spotted dolphins (*Stenella attenuata*) in the tuna purse seine fishery in the eastern tropical Pacific. Pages 161-196 in K. Pryor and K.S. Norris, eds. Dolphin societies: Discoveries and puzzles. Berkeley: University of California Press.

Psarakos, S., D.L. Herzing, and K. Marten. 2003. Mixed-species associations between pantropical spotted dolphins (*Stenella attenuata*) and Hawaiian spinner dolphins (*Stenella longirostris*) off Oahu, Hawaii. Aquatic Mammals 29(3):390-395.

Quakenbush, L.T. 1988. Spotted seal--*Phoca largha*. Pages 107-124 in J.W. Lentfer, ed. Selected marine mammals of Alaska: Species accounts with research and management recommendations. Washington, D.C.: Marine Mammal Commission.

Rankin, S., and J. Barlow. 2005. Source of the North Pacific "boing" sound attributed to minke whales. Journal of the Acoustical Society of America 118(5):3346-3351.

Ray, C., W.A. Watkins, and J.J. Burns. 1969. The underwater song of *Erignathus* (bearded seal). Zoologica 54(2):79-86.

Read, A.J. 1990. Age at sexual maturity and pregnancy rates of harbour porpoises *Phocoena phocoena* from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 47:561-564.

Read, A.J. 1999. Harbour porpoise *Phocoena phocoena* (Linnaeus, 1758). Pages 323-355 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Read, A.J., and A.A. Hohn. 1995. Life in the fast lane: The life history of harbor porpoises from the Gulf of Maine. Marine Mammal Science 11(4):423-440.

Read, A.J., and A.J. Westgate. 1997. Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. Marine Biology 130:315-322.

Reeves, R.R., and R.D. Kenney. 2003. Baleen whales: Right whales and allies. Pages 425-463 in G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, eds. Wild mammals of North America: Biology, management, and conservation. Second edition. Baltimore: Johns Hopkins University Press**.**

Reeves, R.R., B.S. Stewart, and S. Leatherwood. 1992. The Sierra Club handbook of seals and sirenians. San Francisco: Sierra Club Books.

Reeves, R.R., S. Leatherwood, G.S. Stone, and L.G. Eldredge. 1999. Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). Apia, Samoa: SPREP.

Reeves, R.R., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. National Audubon Society guide to marine mammals of the world. New York: Alfred A. Knopf, Inc.

Reeves, R.R., B.D. Smith, E.A. Crespo, and G. Notarbartolo di Sciara, (compilers). 2003. 2002-2010 conservation action plan for the world's cetaceans: Dolphins, whales and porpoises. Gland, Switzerland: IUCN. ix + 139 pp.

Reeves, R.R., W.F. Perrin, B.L. Taylor, C.S. Baker, and S.L. Mesnick, 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. NOAA-TM-NMFS-SWFSC-363:1-94.

Rehberg, M.J., K.L. Raum-Suryan, K.W. Pitcher, and T.S. Gelatt. 2001. Development of juvenile Steller sea lion (*Eumetopias jubatus*) diving behavior in Alaska. Page 177 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November–3 December 2001. Vancouver, British Columbia.

Reijnders, P., S. Brasseur, J. van der Toorn, P. van der Wolf, I. Boyd, J. Harwood, D. Lavigne, and L. Lowry. 1993. Seals, fur seals, sea lions, and walrus. Status survey and conservation action plan. Gland, Switzerland: IUCN/SSC Shark Specialist Group. pp. 5-64.

Reilly, S. 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., and V.G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. Marine Mammal Science 6(4):265-277.

Rendell, L., and H. Whitehead. 2004. Do sperm whales share coda vocalizations? Insights into coda usage from acoustic size measurement. Animal Behaviour 67:865-874.

Rice, D.W. 1989. Sperm whale—*Physeter macrocephalus* (Linnaeus, 1758). Pages 177-234 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales. San Diego: Academic Press.

Rice, D.W. 1998. Marine mammals of the world: Systematics and distribution. Society for Marine Mammalogy Special Publication 4:1-231.

Rice, D.W., and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). American Society of Mammalogists Special Publication 3:1-142.

Rice, D.W., A.A. Wolman, and H.W. Braham. 1984. The gray whale *Eschrichtius robustus*. Marine Fisheries Review 46(4):7-14.

Richardson, W.J. 1995. Marine mammal hearing. Pages 205-240 in W.J. Richardson, C.R. Greene, Jr., C.I. Malme, and D.H. Thomson, eds. Marine mammals and noise. San Diego: Academic Press.

Richardson, W.J., C.R. Greene, C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. San Diego, California: Academic Press.

Ridgway, S.H. 2000. The auditory central nervous system. Pages 273-293 in W.W.L. Au, A.N. Popper, and R.R. Fay, eds. Hearing by whales and dolphins. New York: Springer-Verlag.

Ridgway, S.H., and D.A. Carder. 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., B.L. Scronce, and J. Kanwisher. 1969. Respiration and deep diving in the bottlenose porpoise. Science 166:1651-1654.

Ridgway, S.H., D.A. Carder, R.R. Smith, T. Kamolnick, C.E. Schlundt, and W.R. Elsberry. 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: Naval Sea Systems Command. 24 pp.

Ridoux, V., A.J. Hall, G. Steingrimsson, and G. Olaffson. 1998. An inadvertent homing experiment with a young ringed seal, *Phoca hispida*. Marine Mammal Science 14(4):883-888.

Riedman, M. 1990. The pinnipeds: Seals, sea lions, and walruses. Berkeley: University of California Press.

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., and B. Brederlau. 1999. Behavioural observations of dense beaked whales (*Mesoplodon densirostris*) off La Gomera, Canary Islands (1995-1997). Aquatic Mammals 25(2):55-61.

Rivers, J.A. 1997. Blue whale, *Balaenoptera musculus*, vocalizations from the waters off central California. Marine Mammal Science 13(2):186-195.

Robertson, K.M., and S.J. Chivers. 1997. Prey occurrence in pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. Fishery Bulletin 95:334-348.

Robson, B. W., ed. 2002. Fur seal investigations, 2000-2001. NOAA Technical Memorandum NMFS-AFSC 134:1-80.

Roden, C.L., and K.D. Mullin. 2000. Sightings of cetaceans in the northern Caribbean Sea and adjacent waters, winter 1995. Caribbean Journal of Science 36(3-4):280-288.

Roest, A.I. 1964. A ribbon seal from California. Journal of Mammalogy 45(3):416-420.

Ronald, K., and B.L. Gots. 2003. Seals: Phocidae, Otariidae, and Odobenidae. Pages 789-854 in G.A. Feldhamer, B.C. Thompson and J.A. Chapman, eds. Wild mammals of North America: Biology, management, and conservation, 2d ed. Baltimore, Maryland: Johns Hopkins University Press.

Rosenbaum, H.C., R.L. Brownell, M.W. Brown, C. Schaeff, V. Portway, B.N. White, S. Malik, L.A. Pastene, N.J. Patenaude, C.S. Baker, M. Goto, P.B. Best, P.J. Clapham, P. Hamilton, M. Moore, R. Payne, V. Rowntree, C.T. Tynan, J.L. Bannister, and R. DeSalle. 2000. World-wide genetic differentiation of *Eubalaena*: Questioning the number of right whale species. Molecular Ecology 9(11):1793-1802.

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. 1984. The smaller cetaceans of the south east coast of southern Africa. Annals of the Cape Provincial Museums (Natural History) 15, Part 2:173-410.

Ross, G.J.B., and S. Leatherwood. 1994. Pygmy killer whale—*Feresa attenuata* Gray, 1874. Pages 387-404 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 5: The first book of dolphins. San Diego: Academic Press.

Rudolph, P., C. Smeenk, and S. Leatherwood. 1997. Preliminary checklist of Cetacea in the Indonesian Archipelago and adjacent waters. Zoologische Verhandelingen 312:1-48.

Rugh, D.J., and M.A. Fraker. 1981. Gray whale (*Eschrichtius robustus*) sightings in eastern Beaufort Sea. Arctic 34(2):186-187.

Rugh, D.J., and K.E.W. Shelden 2002. Bowhead whale *Balaena mysticetus*. Pages 129-131 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Rugh, D., D. DeMaster, A. Rooney, J. Breiwick, K. Shelden, and S. Moore. 2003. A review of bowhead whale (*Balaena mysticetus*) stock identity. Journal of Cetacean Research and Management 5(3):267-279.

Salden, D.R. 1989. An observation of apparent feeding by a sub-adult humpback whale off Maui, Hawaii. Page 58 in Abstracts, Eighth Biennial Conference on the Biology of Marine Mammals. 7-11 December 1989. Pacific Grove, California.

Salden, D.R., and J. Mickelsen. 1999. Rare sighting of a North Pacific right whale (*Eubalaena glacialis*) in Hawai'i. Pacific Science 53(4):341-345.

Salden, D.R., L.M. Herman, M. Yamaguchi, and F. Sato. 1999. Multiple visits of individual humpback whales (*Megaptera novaeangliae*) between the Hawaiian and Japanese winter grounds. Canadian Journal of Zoology 77:504-508.

Santos, M.B., G.J. Pierce, J. Herman, A. López, A. Guerra, E. Mente, and M.R. Clarke. 2001. Feeding ecology of Cuvier's beaked whale (*Ziphius cavirostris*): A review with new information on the diet of this species. Journal of the Marine Biological Association of the United Kingdom 81:687-694.

Sanvito, S., and F. Galimberti. 2003. Source level of male vocalisations in the genus *Mirounga*: Repeatability and correlates. Bioacoustics 14:47-59.

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. Reports of the International Whaling Commission (Special Issue 10):43-63.

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 41:467-489.

Schevill, W.E., W.A. Watkins, and C. Ray. 1963. Underwater sounds of pinnipeds. Science 141(3575):50-53.

Schilling, M.R., I. Seipt, M.T. Weinrich, S.E. Frohock, A.E. Kuhlberg, and P.J. Clapham. 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., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 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.

Schneider, D.C., and P.M. Payne. 1983. Factors affecting haul-out of harbor seals at a site in southeastern Massachusetts. Journal of Mammalogy 64(3):518-520.

Schotten, M., W.W.L. Au, M.O. Lammers, and R. Aubauer. 2004. Echolocation recordings and localization of wild spinner dolphins (*Stenella longirostris*) and pantropical spotted dolphins (*S. attenuata*) using a four-hydrophone array. Pages 393-400 in J.A. Thomas, C.F. Moss and M. Vater, eds. Echolocation in bats and dolphins. Chicago, Illinois: University of Chicago Press.

Schusterman, R.J. 1978. Vocal communication in pinnipeds. Pages 247-308 in H. Markowitz and V.J. Stevens, eds. Behavior of captive wild animals. Chicago, Illinois: Nelson-Hall.

Schusterman, R.J., R.F. Bailliet, and S. St. John. 1970. Vocal displays under water by the gray seal, the harbor seal, and the stellar [sic] sea lion. Psychonomic Science 18(5):303-305.

Schusterman, R.J., B. Southall, D. Kastak, C. Reichmuth, and D. Levenson. 2000. Why pinnipeds don't echolocate. Journal of the Acoustical Society of America 107(4):2256-2264.

Schwartz, M., A. Hohn, H. Bernard, S. Chivers, and K. Peltier. 1992. Stomach contents of beach cast cetaceans collected along the San Diego County coast of California, 1972-1991. Administrative Report. LJ-92-18. La Jolla, California: NMFS-SWFSC. 33 pp.

Scott, M.D., and K.L. Cattanach. 1998. Diel patterns in aggregations of pelagic dolphins and tuna in the eastern Pacific. Marine Mammal Science 14(3):401-428.

Scott, M. D., and S.J. Chivers. 1990. Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. Pages 387-402 in S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. San Diego, California: Academic Press.

Scott, M.D., A.A. Hohn, A.J. Westgate, J.R. Nicolas, B.R. Whitaker, and W.B. Campbell. 2001. A note on the release and tracking of a rehabilitated pygmy sperm whale (*Kogia breviceps*). Journal of Cetacean Research and Management 3(1):87-94.

Scott, T.M., and S.S. Sadove. 1997. Sperm whale, *Physeter macrocephalus*, sightings in the shallow shelf waters off Long Island, New York. Marine Mammal Science 13(2):317-321.

Shane, S.H. 1990. Comparison of bottlenose dolphin behavior in Texas and Florida, with a critique of methods for studying dolphin behavior. Pages 541-558 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego: 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 93:13-29.

Shane, S.H. 1995. Behavior patterns of pilot whales and Risso's dolphins off Santa Catalina Island, California. Aquatic Mammals 21(3):195-197.

Shane, S.H., R.S. Wells, and B. Würsig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. Marine Mammal Science 2(1):34-63.

Shaughnessy, P.D., and F.H. Fay. 1977. A review of the taxonomy and nomenclature of North Pacific harbour seals. Journal of Zoology, London 182:385-419.

Shelden, K.E.W., S.E. Moore, J.M. Waite, P.R. Wade, and D.J. Rugh. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. Mammal Review 35(2):129-155.

Shipley, C., B.S. Stewart, and J. Bass. 1992. Seismic communication in northern elephant seals. Pages 553-562 in J.A. Thomas, R.A. Kastelein, and A.Y. Supin, eds. Marine mammal sensory systems. New York: Plenum Press.

Shirakihara, K. 2005. Abundance and distribution of finless porpoises in Japanese waters. International Whaling Commission (IWC) Scientific program working document SC/57/SM11. 20 pp.

Shirakihara, M., K. Shirakihara, J. Tomonaga, and M. Takatsuki. 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., H. Yoshida, and K. Shirakihara. 2003. Indo-Pacific bottlenose dolphins *Tursiops aduncus* in Amakusa, western Kyushu, Japan. Fisheries Science 69:654-656.

Silber, G.K. 1986. The relationship of social vocalizations to surface behavior and aggression in the Hawaiian humpback whale (*Megaptera novaeangliae*). Canadian Journal of Zoology 64:2075-2080.

Silva-Jr., J.M., L.J. Pandolfo, and I. Sazima. 2004. Vomiting behavior of the spinner dolphin (*Stenella longirostris*) and squid meals. Aquatic Mammals 30(2):271-274.

Simão, S.M., S.C. Moreira. 2005. Vocalizations of a female humpback whale in Arraial do Cabo (RJ, Brazil). Marine Mammal Science 21(1):150-153.

Simpkins, M.A., L.M. Hiruki-Raring, G. Sheffield, J.M. Grebmeier, and J.L. Bengston. 2003. Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska in March 2001. Polar Biology 26:577-586.

Sleptsov, M.M. 1961. Distribution of cetaceans in the Sea of Japan. Trudy Instituta Morfologii Zhivotnykh 34:93-110.

Slijper, E.J., W.L. van Utrecht, and C. Naaktgeboren. 1964. Remarks on the distribution and migration of whales, based on observations from Netherlands ships. Bijdragen Tot de Dierkunde 34:3-93.

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(Suppl.):483-486.

Smith, T.G., and I. Stirling. 1975. The breeding habit of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Canadian Journal of Zoology 53:1297-1305.

Smith, R.C., P. Dustan, D. Au, K.S. Baker, and E.A. Dunlap. 1986. Distribution of cetaceans and sea-surface chlorophyll concentrations in the California Current. Marine Biology 91:385-402.

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.

Southall, B. 2005. Personal communication via email between Dr. Brandon Southall, National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Maryland, and Ms. Dagmar Fertl, Geo-Marine, Inc., Plano, Texas, 6 May, 26 July.

Southall, B.L., R.J. Schusterman, and D. Kastak. 2000. Masking in three pinnipeds: Underwater, low-frequency critical ratios. Journal of the Acoustical Society of America 108(3):1322-1326.

Spong, P. 2000. New orca sighting makes news. Accessed 1 August 2005. http://www.cmeps.org/articles/index.html.

Springer, A.M, J.F. Piatt, V.P. Shuntov, G.B. Van Vliet, V.L. Vladimirov, A.E. Kuzin, and A.S. Perlov. 1999. Marine birds and mammals of the Pacific Subarctic Gyres. Progress in Oceanography 43:443-487.

Stacey, P.J., and R.W. Baird. 1991. Status of the false killer whale, *Pseudorca crassidens*, in Canada. Canadian Field-Naturalist 105(2):189-197.

Stacey, P.J., S. Leatherwood, and R.W. Baird. 1994. *Pseudorca crassidens*. Mammalian Species 456:1-5.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 2001. Geographic and seasonal variation of blue whale calls in the North Pacific. Journal of Cetacean Research and Management 3(1):65-76.

Stanley, H.F., S. Casey, J.M. Carnahan, S. Goodman, J. Harwood, and R.K. Wayne. 1996. Worldwide patterns of mitochondrial DNA differentiation in the harbor seal (*Phoca vitulina*). Molecular Biology and Evolution 13(2):368-382.

Stern, J.S. 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.

Stern, J.S. 2002. Migration and movement patterns. Pages 742-748 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Stevick, P.T., B.J. McConnell, and P.S. Hammond. 2002. Patterns of movement. Pages 185-216 in A.R. Hoelzel, ed. Marine mammal biology: An evolutionary approach. Oxford: Blackwell Science.

Stewart, B.S. 1997. Ontogeny of differential migration and sexual segregation in northern elephant seals. Journal of Mammalogy 78(4):1101-1116.

Stewart, B.S., and R.L. DeLong. 1994. Postbreeding foraging migrations of northern elephant seals. Pages 290-309 in B.J. Le Boeuf and R.M. Laws, eds. Elephant seals: Population ecology, behavior, and physiology. Berkeley: University of California Press.

Stewart, B.S., and R.L. DeLong. 1995. Double migrations of the northern elephant seal, *Mirounga angustirostris*. Journal of Mammalogy 76(1):196-205

Stewart, B.S., and H.R. Huber. 1993. *Mirounga angustirostris*. Mammalian Species 449:1-10.

Stewart, B.S., and S. Leatherwood. 1985. Minke whale *Balaenoptera acutorostrata* Lacepede, 1804. Pages 91-136 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. San Diego: Academic Press.

Stewart, B.S., and P.K. Yochem. 1984. Seasonal abundance of pinnipeds at San Nicolas Island, California, 1980-1982. Bulletin of the Southern California Academy of Sciences 83(3):121-132.

Stewart, B.S., and P.K. Yochem. 1991. Northern elephant seals on the southern California Channel Islands and El Nino. Pages 234-243 in F. Trillmich and K. A. Ono, eds. Pinnipeds and El Niño: Responses to environmental stress. Berlin: Springer-Verlag.

Stewart, B.S., P.K. Yochem, H.R. Huber, R.L. DeLong, R.J. Jameson, W.J. Sydeman, S.G. Allen, and B.J. Le Boeuf. 1994. History and present status of the northern elephant seal population. Pages 29-48 in B.J. Le Boeuf and R.M. Laws, eds. Elephant seals: Population ecology, behavior, and physiology. Berkeley: University of California Press.

Stirling, I. 1973. Vocalization in the ringed seal (*Phoca hispida*). Journal of the Fisheries Research Board of Canada 30(10):1592-1594.

Stirling, I., W. Calvert, and H. Cleator. 1983. Underwater vocalizations as a tool for studying the distribution and relative abundance of wintering pinnipeds in the high Arctic. Arctic 36(3):262-274.

Stone, G.S., S.K. Katona, A. Mainwaring, J.M. Allen, and H.D. Corbett. 1992. Respiration and surfacing rates of fin whales (*Balaenoptera physalus*) observed from a lighthouse tower. Reports of the International Whaling Commission 42:739-745.

Sund, P. 1975. Evidence of feeding during migration and of an early birth of the California gray whale (*Eschrichtius robustus*). Journal of Mammalogy 56(1):265-266.

Swartz, S.L. 1986. Gray whale migratory, social and breeding behavior. Reports of the International Whaling Commission (Special Issue 8):207-229.

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.

Szczepaniak, I.D., M.A. Webber, and T.A. Jefferson. 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., D.E. Bain, K. Kiehl, S. Pennington, S. Wong, and K.R. Henry. 1999. Killer whale (*Orcinus orca*) hearing: Auditory brainstem response and behavioral audiograms. Journal of the Acoustical Society of America 106(2):1134-1141.

Tamura, T., and U. Fujise. 2002. Geographical and seasonal changes of the prey species of minke whale in the northwestern Pacific. ICES Journal of Marine Science 59:516-528.

Tanaka, S. 1987. Satellite radio tracking of bottlenose dolphins *Tursiops truncatus*. Nippon Suisan Gakkaishi 53(8):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.

Teilmann, J., E.W. Born, and M. Acquarone. 1999. Behaviour of ringed seals tagged with satellite transmitters in the North Water polynya during fast-ice formation. Canadian Journal of Zoology 77:1934-1946.

Temte, J.L., M.A. Bigg, and O. Wiig. 1991. Clines revisited: The timing of pupping in the harbour seal (*Phoca vitulina*). Journal of Zoology, London 224:617-632.

Terasawa, F., T. Yamagami, M. Kitamura, and A. Fujimoto. 1997. A pygmy killer whale (*Feresa attenuata*) stranded at Sagami Bay, Japan. Aquatic Mammals 23(1):69-72.

Terhune, J.M. 1999. Pitch separation as a possible jamming-avoidance mechanism in underwater calls of bearded seals (*Erignathus barbatus*). Canadian Journal of Zoology 77:1025-1034.

Terhune, J.M., and K. Ronald. 1976. The upper frequency limit of ringed seal hearing. Canadian Journal of Zoology 54:1226-1229.

Terhune, J., and S. Turnbull. 1995. Variation in the psychometric functions and hearing thresholds of a harbour seal. Pages 81-93 in R.A. Kastelein, J.A. Thomas, and P.E. Nachtigall, eds. Sensory systems of aquatic mammals. 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.

Tershy, B.R., and D. Breese. 1991. Sightings and feeding of gray whales in the northern Gulf of California. Journal of Mammalogy 72(4):830-831.

Tershy, B.R., J. Urbán-Ramírez, D. Breese, L. Rojas-Bracho, and L.T. Findley. 1993. Are fin whales resident to the Gulf of California? Revista de Investigación Científica 1:69-72.

Thode, A., D.K. Mellinger, S. Stienessen, A. Martinez, and K. Mullin. 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.

Thomas, J., N. Chun, W. Au, and K. Pugh. 1988. Underwater audiogram of a false killer whale (*Pseudorca crassidens*). Journal of the Acoustical Society of America 84(3):936-940.

Thomas, J.A., J.L. Pawloski, and W.W.L. Au. 1990b. Masked hearing abilities in a false killer whale (*Pseudorca crassidens*). Pages 395-404 in J. Thomas and R. Kastelein, eds. Sensory abilities of cetaceans. New York: Plenum Press.

Thompson, P.O., and W.A. Friedl. 1982. A long term study of low frequency sounds from several species of whales off Oahu, Hawaii. Cetology 45:1-19.

Thompson, P.M., D. Miller, R. Cooper, and P.S. Hammond. 1994. Changes in the distribution and activity of female harbour seals during the breeding season: Implications for their lactation strategy and mating patterns. Journal of Animal Ecology 63(1):24-30.

Thomson, D.H., and W.J. Richardson. 1995. Marine mammal sounds. Pages 159-204 in W.J. Richardson, C.R. Greene, Jr., C.I. Malme, and D.H. Thomson, eds. Marine mammals and noise. San Diego: Academic Press.

Tillman, M.F. 1978. Modified DeLury estimates of the North Pacific Bryde's whale stock. Reports of the International Whaling Commission 28:315-317.

Tomich, P.Q. 1986. Mammals in Hawai'i: A synopsis and notational bibliography, Second Edition. Honolulu, Hawaii: Bishop Museum Press.

Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica 19(1):1-50.

Tremel, D.P., J.A. Thomas, K.T. Ramirez, G.S. Dye, W.A. Bachman, A.N. Orban, and K.K. Grimm. 1998. Underwater hearing sensitivity of a Pacific white-sided dolphin, *Lagenorhynchus obliquidens*. Aquatic Mammals 24(2):63-69.

Trianni, M.S., and C.C. Kessler. 2002. Incidence and strandings of the spinner dolphin, *Stenella longirostris*, in Saipan Lagoon. Micronesica 34(2):249-260.

Trites, A.W., P.A. Livingston, S. Mackinson, M.C. Vasconcellos, A.M. Springer, and D. Pauly. In press. Ecosystem change and the decline of marine mammals in the eastern Bering Sea: Testing the ecosystem shift and commercial whaling hypotheses. Fisheries Centre Research Reports 1999 7:1-100.

Turl, C.W. 1993. Low-frequency sound detection by a bottlenose dolphin. Journal of the Acoustical Society of America 94(5):3006-3008.

Tyack, P. 1986. Population biology, social behavior and communication in whales and dolphins. Trends in Ecology and Evolution 1(6):144-150.

Tyack, P., and H. Whitehead. 1983. Male competition in large groups of wintering humpback whales. Behaviour 83:132-153.

Tynan, C.T., D.P. DeMaster, and W.T. Peterson. 2001. Endangered right whales on the southeastern Bering Sea shelf. Science 294:1894.

Uchida, S. 1982. Research on cetaceans in the Ryukyu Archipelago. Okinawa, Japan: Okinawa Keeping Center. TransPerfect Translations. 43 pp.

Uchida, S. 1985. Research on cetaceans in the Ryukyu Archipelago: II. Okinawa, Japan: Management Foundation of the Ocean Expo Memorial Park. TransPerfect Translations. 36 pp.

Uchida, S. 1997. In search of humpbacks (A 1991-1995 survey of cetaceans in Japanese waters). Pages 18-33 in S. Uchida, ed. Kings of the sea: Humpback whales: A 1991-1995 survey of cetaceans in Japanese waters. Tokai, Japan: Tokai Foundation.

Urian, K.W., D.A. Duffield, A.J. Read, R.S. Wells, and E.D. Shell. 1996. Seasonality of reproduction in bottlenose dolphins, *Tursiops truncatus*. Journal of Mammalogy 77(2):394-403.

Urick, R.J. 1983. Principles of underwater sound. 3rd edition. Los Altos, California: Peninsula Publishing.

USFWS (U.S. Fish and Wildlife Service). 2003. 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.

van Bree, P.J.H. 1996. Extralimital records of the ringed seal, *Phoca hispida* Schreber, 1775, on the west-European continental shelf. Bonner Zooligische Beitrope 46(1-4):377-383.

Vanderlaan, A.S.M., A.E. Hay, and C.T. Taggart. 2003. Characterization of North Atlantic right-whale (*Eubalaena glacialis*) sounds in the Bay of Fundy. IEEE Journal of Oceanic Engineering 28(2):164-173.

Van Parijs, S.M., P.J. Corkeron, J. Harvey, S.A. Hayes, D.K. Mellinger, P.A. Rouget, P.M. Thompson, M. Wahlberg, and K.M. Kovacs. 2003. Patterns in the vocalizations of male harbor seals. Journal of the Acoustical Society of America 113(6):3403-3410.

Van Waerebeek, K., and B. Würsig. 2002. Pacific white-sided dolphin and dusky dolphin, *Lagenorhynchus obliquidens* and *L. obscurus*. Pages 859-861 in W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Van Waerebeek, K., J.C. Reyes, A.J. Read, and J.S. McKinnon. 1990. Preliminary observations of bottlenose dolphins from the Pacific coast of South America. Pages 143-154 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego, California: Academic Press.

Van Waerebeek, K., F. Félix, B. Haase, D.M. Palacios, D.M. Mora-Pinto, and M. Muňoz-Hincapié. 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.

Verboom, W.C., and R.A. Kastelein. 1995. Acoustic signals by harbour porpoises (*Phocoena phocoena*). Pages 1-39 in P.E. Nachtigall, J. Lien, W.W.L. Au and A.J. Read, eds. Harbour porpoises: Laboratory studies to reduce bycatch. Woerden, the Netherlands: De Spil Publishers.

Vester, H.I., L.P. Folkow, and A.S. Blix. 2001. Underwater sound production from captive hooded and harp seals during live fish hunting. Page 224 in Abstracts, Fourteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 2001. Vancouver, British Columbia.

Visser, I.N., and F.J. Bonoccorso. 2003. New observations and a review of killer whale (*Orcinus orca*) sightings in Papua New Guinea waters. Aquatic Mammals 29(1):150-172.

Von Saunder, A., and J. Barlow. 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-264:1-49.

Wada, K. 1998. Steller sea lions: Present status of studies of migratory ecology, and conflict between fisheries and conservation in Japan. Biosphere Conservation 1(1):1-6.

Wada, K., S. Hayama, T. Nakaoka, and H. Uno. 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. 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. 1983. Genetic structure and taxonomic status of minke whales in the coastal waters of Japan. Reports of the International Whaling Commission 33:361-363.

Wade, L.S., and G.L. Friedrichsen. 1979. Recent sightings of the blue whale, *Balaenoptera musculus*, in the northeastern tropical Pacific. Fishery Bulletin 76(4):915-919.

Wade, P.R, and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. Reports of the International Whaling Commission 43:477-493.

Waite, J.M., M.E. Dahlheim, R.C. Hobbs, S.A. Mizroch, O. von Ziegesar-Matkin, J.M. Straley, L.M. Herman, and J.K. Jacobsen. 1999. Evidence of a feeding aggregation of humpback whales (*Megaptera novaeangliae*) around Kodiak Island, Alaska. Marine Mammal Science 15(1):210-220.

Walker, W.A. 1981. Geographical variation in morphology and biology of bottlenose dolphins (*Tursiops*) in the eastern North Pacific. NMFS-SWFC Administrative Report. LJ-81-03C.

Walker, W.A., and M.B. Hanson. 1999. Biological observations on Stejneger's beaked whale, *Mesoplodon stejnegeri*, from strandings on Adak Island, Alaska. Marine Mammal Science 15(4):314-334.

Walker, W.A., J.G. Mead, R.L. Brownell, Jr. 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(4):909-919.

Wang, D. 2005. Personal communication via email between Dr. Wang Ding, Institute of Hydrobiology, Chinese Academy of Sciences, Whuhan Hubei, China, and Dr. Thomas A. Jefferson, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California, 18 August.

Wang, J.Y., and S.-C. Yang. 2004. Unusual cetacean stranding events in Chinese waters in early 2004 and the gross examination of a ginkgo-toothed beaked whale, *Mesoplodon ginkgodens*. International Whaling Commission (IWC) Scientific program working document SC/56/E38. 7 pp.

Wang, J.Y., L.-S. Chou, and B.N. White. 1999. Mitochondrial DNA analysis of sympatric morphotypes of bottlenose dolphins (genus: *Tursiops*) in Chinese waters. Molecular Ecology 8:1603-1612.

Wang, M.-.C., W.A. Walker, K.-T. Shao, and L.S. Chou. 2002. Comparative analysis of the diets of pygmy sperm whales and dwarf sperm whales in Taiwanese waters. Acta Zoologica Taiwanica 13(2):53-62.

Wang, M.-.C., W.A. Walker, K.-T. Shao, and L.-S. Chou. 2003. Feeding habits of the pantropical spotted dolphin, *Stenella attenuata*, off the eastern coast of Taiwan. Zoological Studies 42(2):368-378.

Waring, G.T., and J.T. Finn. 1995. Cetacean trophic interactions off the northeast USA inferred from spatial and temporal co-distribution patterns. Unpublished meeting document, ICES C.M. 1995/N:7. Copenhagen: International Council for the Exploration of the Sea. 1-44.

Waring, G.T., P. Gerrior, P.M. Payne, B.L. Parry, and J.R. Nicolas. 1990. Incidental take of marine mammals in foreign fishery activities off the northeast United States, 1977-88. Fishery Bulletin 88(2):347-360.

Waring, G.T., C.P. Fairfield, C.M. Ruhsam, and M. Sano. 1993. Sperm whales associated with Gulf Stream features off the northeastern USA shelf. Fishery Oceanography 2(2):101-105.

Waring, G.T., T. Hamazaki, D. Sheehan, G. Wood, and S. Baker. 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., D. Belden, M. Vecchione, and R. Gibbons. 2003. Mid-water prey in beaked whale and sperm whale deep-water habitat south of Georges Bank. Page 172 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December 2003. Greensboro, NC, USA.

Wartzok, D., and D.R. Ketten. 1999. Marine mammal sensory systems. Pages 117-175 in J.E. Reynolds, III and S.A. Rommel, eds. Biology of marine mammals. Washington, D.C.: Smithsonian Institution Press.

Watanabe, Y., M. Onuma, T. Kariya, T. Ishinazaka, T. Isono, and N. Ohtaishi. 2003. The genetic structure of Steller sea lion which have migrated to Hokkaido. Page 172 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14-19 December. Greensboro, NC.

Watkins, W.A., and G.C. Ray. 1977. Underwater sounds from ribbon seal, *Phoca* (*Histriophoca*) *fasciata*. Fishery Bulletin 75(2):450-453.

Watkins, W.A., and W.E. Schevill. 1976. Right whale feeding and baleen rattle. Journal of Mammalogy 57:58-66.

Watkins, W.A., and W.E. Schevill. 1977. Sperm whale codas. Journal of the Acoustical Society of America 62(6):1485-1490.

Watkins, W.A., and W.E. Schevill. 1979. Aerial observation of feeding behavior in four baleen whales: *Eubalaena glacialis*, *Balaenoptera borealis*, *Megaptera novaeangliae*, and *Balaenoptera physalus*. Journal of Mammalogy 60(1):155-163.

Watkins, W.A., P. Tyack, K.E. Moore, and J.E. Bird. 1987. The 20-Hz signals of finback whales (*Balaenoptera physalus*). Journal of the Acoustical Society of America 82(6):1901-1912.

Watkins, W.A., M.A. Daher, K.M. Fristrup, and T.J. Howald. 1993. Sperm whales tagged with transponders and tracked underwater by sonar. Marine Mammal Science 9(1):55-67.

Watkins, W.A., M.A. Daher, A. Samuels, and D.P. Gannon. 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., M.A. Daher, N.A. DiMarzio, A. Samuels, D. Wartzok, K.M. Fristrup, P.W. Howey, and R.R. Maiefski. 2002. Sperm whale dives tracked by radio tag telemetry. Marine Mammal Science 18(1):55-68.

Wedekin, L.L., A. Freitas, M.H. Engel, and I. Sazima. 2004. Rough-toothed dolphins (*Steno bredanensis*) catch diskfishes while interacting with humpback whales (*Megaptera novaeangliae*) off Abrolhos Bank breeding ground, southwest Atlantic. Aquatic Mammals 30(2):327-329.

Wei, Z., D. Wang; X. Kuang, K. Wang, X. Wang, J. Xiao, Q. Zhao, and X. Zhang. 2002. Observations on behavior and ecology of the Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientalis*) group at Tian-E-Zhou Oxbow of the Yangtze River. Raffles Bulletin of Zoology, Supplement 10:97-103.

Weilgart, L.S., and H. Whitehead. 1997. Group-specific dialects and geographical variation in coda repertoire in South Pacific sperm whales. Behavioral Ecology and Sociobiology 40:277-285.

Weinrich, M. 1995. Humpback whale competitive groups observed on a high-latitude feeding ground. Marine Mammal Science 11(2):251-254.

Weinrich, M.T., M.R. Schilling, and C.R Belt. 1992. Evidence for acquisition of a novel feeding behavior: Lobtail feeding in humpback whales, *Megaptera novaeangliae*. Animal Behaviour 44:1059-1072.

Weller, D.W., B. Würsig, H. Whitehead, J.C. Norris, S.K. Lynn, R.W. Davis, N. Clauss, and P. Brown. 1996. Observations of an interaction between sperm whales and short-finned pilot whales in the Gulf of Mexico. Marine Mammal Science 12(4):588-594.

Weller, D.W., B. Wursig, A.L. Bradford, A.M. Burdin, S.A. Blokhin, H. Minakuchi, and R.L. Brownell, Jr. 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., S.H. Reeve, A.M. Burdin, B. Wursig, and R.L. Brownell, Jr. 2002a. 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., A.M. Burdin, B. Würsig, B.L. Taylor, and R.L. Brownell, Jr. 2002b. The western gray whale: A review of past exploitation, current status and potential threats. Journal of Cetacean Research and Management 4(1):7-12.

Wellington, G.M., and S. Anderson. 1978. Surface feeding by a juvenile gray whale, *Eschrichtius robustus*. Fishery Bulletin 76(1):290-293.

Wells, R.S., and M.D. Scott. 1999. Bottlenose dolphin – *Tursiops truncatus* (Montagu, 1821). Pages 137-182 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego: Academic Press.

Wells, R.S., A.B. Irvine, and M.D. Scott. 1980. The social ecology of inshore odontocetes. Pages 263-318 in L. M. Herman, eds. Cetacean behavior: Mechanisms and functions. New York: John Wiley.

Wells, R.S., M.D. Scott, and A.B. Irvine. 1987. The social structure of free-ranging bottlenose dolphins. Pages 247-305 in H.H. Genoways, ed. Current mammalogy. Volume 1. New York: Plenum Press.

Wells, R.S., L.J. Hansen, A. Baldridge, T.P. Dohl, D.L. Kelly, and R.H. Defran. 1990. Northward extension of the range of bottlenose dolphins along the California coast. Pages 421-431 in S. Leatherwood and R.R. Reeves, eds. The bottlenose dolphin. San Diego: Academic Press.

Weslawski, J.M., M. Ryg, T.G. Smith, and N.A. Oritsland. 1994. Diet of ringed seals (*Phoca hispida*) in a fjord of west Svalbard. Arctic 47(2):109-114.

Westgate, A.J., and A.J. Read. 1998. Applications of new technology to the conservation of porpoises. Marine Technology Society Journal 32:70-81.

Westgate, A.J., A.J. Read, P. Berggren, H.N. Koopman, and D.E. Gaskin. 1995. Diving behaviour of harbour porpoises, *Phocoena phocoena*. Canadian Journal of Fisheries and Aquatic Sciences 52:1064-1073.

Whitehead, H. 2003. Sperm whales: Social evolution in the ocean. Chicago: University of Chicago Press.

Whitehead, H., and L. Weilgart. 1991. Patterns of visually observable behaviour and vocalizations in groups of female sperm whales. Behaviour 118:276-296.

Whitehead, H., and L. Weilgart. 2000. The sperm whale: Social females and roving males. Pages 154-172 in J. Mann, R.C. Connor, P.L. Tyack, and H. Whitehead, eds. Cetacean societies: Field studies of dolphins and whales. Chicago: University of Chicago Press.

Whitehead, H., S. Brennan, and D. Grover. 1992. Distribution and behaviour of male sperm whales on the Scotian Shelf, Canada. Canadian Journal of Zoology 70:912-918.

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. 2002. Rocky reefs provide foraging habitat for dugongs in the Darwin region of northern Australia. Australian Mammalogy 24:147-150.

Wiggins, S.M., M.A. McDonald, L.M. Munger, S.E. Moore, and J.A. Hildebrand. 2004. Waveguide propagation allows range estimates for North Pacific right whales in the Bering Sea. Canadian Acoustics 32(2):146-154.

Willis, P.M., and R.W. Baird. 1998a. Status of the dwarf sperm whale, *Kogia simus*, with special reference to Canada. Canadian Field-Naturalist 112(1):114-125.

Willis, P.M., and R.W. Baird. 1998b. Sightings and strandings of beaked whales on the west coast of Canada. Aquatic Mammals 24(1):21-25.

Wilson, S.C. 1978. Social organization and behavior of harbor seals, *Phoca vitulina concolor*, in Maine. Final report to the U.S. Marine Mammal Commission. Washington, D.C.: Smithsonian Institution.

Winn, H.E., and P.J. Perkins. 1976. Distribution and sounds of the minke whale, with a review of mysticete sounds. Cetology 19:1-12.

Winn, H.E., J.D. Goodyear, R.D. Kenney, and R.O. Petricig. 1995. Dive patterns of tagged right whales in the Great South Channel. Continental Shelf Research 15:593-611.

Wolski, L.F., R.C. Anderson, A.E. Bowles, and P.K. Yochem. 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.

Won, C., and B. Yoo. 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.

Woodley, T.H., and D.M. Lavigne. 1991. Incidental capture of pinnipeds in commercial fishing gear. Technical Report No. 91-01. International Marine Mammal Association Inc. 52 pp.

Wormuth, J.H., P.H. Ressler, R.B. Cady, and E.J. Harris. 2000. Zooplankton and micronekton in cyclones and anticyclones in the northeast Gulf of Mexico. Gulf of Mexico Science 18(1):23-34.

Würsig, B., and C. Clark. 1993. Behavior. Pages 157-199 in J.J. Burns, J.J. Montague, and C.J. Cowles, eds. The bowhead whale (Special Publication 2). Lawrence, Kansas: Society for Marine Mammalogy.

Würsig, B., and T.A. Jefferson. 1990. Methods of photo-identification for small cetaceans. Reports of the International Whaling Commission (Special Issue 12):43-52.

Würsig, B., and M. Würsig. 1977. The photographic determination of group size, composition, and stability of coastal porpoises (*Tursiops truncatus*). Science 198:755-756.

Würsig, B., S.K. Lynn, T.A. Jefferson, and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. Aquatic Mammals 24(1):41-50.

Würsig, B., T.A. Jefferson, and D.J. Schmidly. 2000. The marine mammals of the Gulf of Mexico. College Station: Texas A&M University Press.

Würsig, B., R.R. Reeves, and J.G. Ortega-Ortiz. 2002. Global climate change and marine mammals. Pages 589-608 in P.G.H. Evans and J.A. Raga, eds. Marine mammals: Biology and conservation. New York: Kluwer Academic/Plenum Publishers.

Wynne, K. 1992. Guide to marine mammals of Alaska. Fairbanks: Alaska Sea Grant College Program, Univerisity of Alaska.

Wynne, K., and M. Schwartz. 1999. Guide to marine mammals & turtles of the U.S. Atlantic and Gulf of Mexico. Narragansett: Rhode Island Sea Grant.

Yamada, M. 1954. Some remarks on the pygmy sperm whale, *Kogia*. Scientific Reports of the Whales Research Institute 9:37-58.

Yamada, T. 2001. Beaked whales of the seas around Japan. Page 31 in Summary of the Workshop on the Biology and Conservation of Beaked Whales, 28 November 2001, Vancouver, British Columbia.

Yamada, T.K. 2002. On an unidentified beaked whale found stranded in Kagoshima: 25 December 2002. Accessed 10 May 2005. http://svrsh1.kahaku.go.jp/sendai/indexE.html.

Yamada, T.K., and A. Yamada. 1999. *Mesoplodon stejnegeri* of the seas around Japan. Page 205 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, HI.

Yamada, T.K., A. Amaha Óztúrk, A. Morota, H. Ito, and K. Sakiyama. 1998. A washed-up humpback whale skull and its implications on the migratory route. Memoirs of the National Science Museum Tokyo 30:139-146.

Yamaguchi, M., and A.M. Burdin. 2003. The first photographic match of a humpback whale (*Megaptera novaeangliae*) between Japan and Russia; evidence for the feeding destination of the western North Pacific population? Page 181 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14-19 December, 2003. Greensboro, NC, USA.

Yamaguchi, M., J.M. Acebes, and Y. Miyamura. 2002. 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. Page 36 in Abstracts, SEAMAM II: Second International Conference on the Marine Mammals of Southeast Asia, 22-23 July 2002, Dumaguete, Philippines.

Yamamoto, S., H. Ito, and M. Komaba. 2001. 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. Page 32 in Summary of the Workshop on the Biology and Conservation of Beaked Whales, 28 November 2001, Vancouver, British Columbia.

Yamamuro, M., K. Aketa, and S. Uchida. 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.

Yochem, P.K., and S. Leatherwood. 1985. Blue whale *Balaenoptera musculus* (Linnaeus, 1758). Pages 193-240 in S.H. Ridgway and R. Harrison, eds. Handbook of marine mammals. Volume 3: The sirenians and baleen whales. San Diego: Academic Press.

Yoshida, H. 2002. Population structure of finless porpoises (Neophocaena phocaenoides) in coastal waters of Japan. Raffles Bulletin of Zoology, Supplement 10**:**35-42.

Yoshida, H., and H. Kato. 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, M., and R.B. Trono. 2004. Dugong conservation network in Asia and Pacific. Pages 1-9 in Knowledgeable Marketplace Reports, The Third IUCN World Conservation Congress. 17-25 November 2004. Bangkok, Thailand.

Yoshioka, M., M. Kanda, I. Takahashi, M. Kashiwagi, and K. Mori. 1999. Photo-identification study of sperm whales in the Kumano Sea off the Pacific Coast of central Japan. Page 207 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November - 3 December, 1999. Wailea, HI.

Young, D.D., and V.G. Cockcroft. 1994. Diet of common dolphins (*Delphinus delphis*) off the south-east coast of southern Africa: Opportunism or specialization? Journal of Zoology, London 234:41-53.

Yu, H-y., H-K. Mok, R-C. Wei, and L-S., Chou. 2003. Vocalizations of a rehabilitated rough-toothed dolphin, *Steno bredanensis*. Page 183 in Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals. 14–19 December. Greensboro, North Carolina, USA.

Zamon, J.E. 2001. Seal predation on salmon and forage fish schools as a function of tidal currents in the San Juan Islands, Washington, USA. Fisheries Oceanography 10(4):353-366.

Zerbini, A.N., E.R. Secchi, S. Siciliano, and P.C. Simões-Lopez. 1997. A review of the occurrence and distribution of whales of the genus *Balaenoptera* along the Brazilian coast. Reports of the International Whaling Commission 47:407-417.

Zhou, K. 1991. Marine mammal studies in China. IBI Reports 2:11-33.

Zhou, K., Q. Weijuan, and L. Yuemin. 1982. *Pseudorca crassidens* (Owen) from the coastal waters of China. Investigations on Cetacea 13:263-269.

Zimmer, W.M.X., P.L. Tyack, M.P. Johnson, and P.T. Madsen. 2005a. Three-dimensional beam pattern of regular sperm whale clicks confirms bent-horn hypothesis. Journal of the Acoustical Society of America 117(3):Part 1:1473-1485.

Zimmer, W.M.X., M.P. Johnson, P.T. Madsen, and P.L. Tyack. 2005b. Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). Journal of the Acoustical Society of America 117(6):3919-3927.

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3.2 SEA TURTLES

3.2.1 Introduction

Sea turtles are long-lived reptiles that can be found throughout the world's tropical, subtropical, and temperate seas (CCC and STSL 2003). There are seven living species of sea turtles from two distinct families, the Cheloniidae (hard-shelled sea turtles; six species) and the Dermochelyidae (leatherback sea turtle; one species). These two families are distinguished from one another on the basis of their carapace (upper shell) and other morphological features. Sea turtles are an important marine resource in that they provide nutritional, economic, and existence (non-use) value to humans (Witherington and Frazer 2003). Over the last few centuries, sea turtle populations have declined dramatically due to anthropogenic activities such as coastal development, oil exploration, commercial fishing, marine-based recreation, pollution, and over-harvesting (NRC 1990; Eckert 1995). As a result, all seven species are currently listed as either threatened or endangered under the ESA. Each of these seven species is also currently listed as either endangered or critically endangered on the 2004 IUCN Red List of Threatened Species (IUCN 2004).

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

Although they are specialized for life at sea, sea turtles begin their lives on land. Aside from this brief terrestrial period, which lasts approximately three months as eggs and an additional few minutes to a few hours as hatchlings scrambling to the surf, sea turtles are rarely encountered out of the water. Sexually mature females return to land in order to nest, while certain species in the Hawaiian Islands, Australia, and the Galapagos Islands haul out on land in order to bask (Carr 1995; Spotila et al. 1997). Sea turtles bask to thermoregulate, elude predators, avoid harmful mating encounters, and possibly to accelerate the development of their eggs, accelerate their metabolism, and destroy epiphytic growth on their carapaces (Whittow and Balazs 1982; Spotila et al. 1997). On occasion, sea turtles can unintentionally end up on land if they are dead, sick, injured, or cold-stunned. These events, also known as strandings, can be caused by either biotic (e.g., predation and disease) or abiotic (e.g., water temperature) factors.

Female sea turtles nest in tropical, subtropical, and warm-temperate latitudes, often in the same region or on the same beach where they hatched (Miller 1997). Upon selecting a suitable nesting beach, most sea turtles tend to re-nest in close proximity during subsequent nesting attempts. The leatherback turtle is a notable divergence from this pattern. This species nests primarily on high-energy beaches with little reef or rock offshore. On these types of beaches stochastic erosion reduces the probability of nest survival. To compensate, leatherbacks scatter their nests over larger geographic areas and lay on average two times as many clutches as other species (Eckert 1987).

At times, sea turtles may fail to nest after emerging from the ocean. These non-nesting emergences, known as false crawls, can occur if sea turtles are obstructed from laying their eggs (by debris, rocks, or roots), are distracted by surrounding conditions on the nesting beach (e.g., noise, lighting, or human presence), or are uncomfortable with the consistency or moisture of the sand on the nesting beach. Individuals that are successful at nesting usually lay several clutches of eggs during a nesting season,

with each clutch containing between 50 and 200 eggs depending upon the species (Witzell 1983; Dodd 1988; Hirth 1997). Most sea turtles, with the possible exception of Kemp's ridley turtles (*Lepidochelys kempii*), do not nest in consecutive years; instead, they will often skip two or three years before returning to the nesting grounds (Márquez-M. 1990; Ehrhart 1995). Nesting success is vital to the long-term existence of sea turtles since it is estimated only one out of every one thousand hatchlings survives long enough to reproduce (Frazer 1986).

During the nesting season, daytime temperatures can be lethal on tropical, subtropical, and warm-temperate beaches. As a result, adult sea turtles most often nest and hatchlings most often emerge from their nest at night (Miller 1997). After emerging from the nest, sea turtle hatchlings use visual cues (e.g., light intensity or wavelengths) to orient themselves towards the sea (Lohmann et al. 1997). Hatchlings have a strong tendency to crawl in the direction of the brightest light, which on most beaches is towards the ocean/sky horizon (Ernst et al. 1994). However, some hatchlings never make it into the water. On the beach, sea turtle hatchlings are easy prey for seabirds during the day and scavenging crabs and mammals at night (Ehrhart 1995; Miller 1997). Hatchlings can also be disoriented if artificial beachfront lighting appears brighter than the seaward horizon (Witherington and Bjorndal 1991).

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

Once in the later juvenile developmental habitat, most sea turtles change from surface to benthic feeding and begin to feed upon larger items such as crustaceans, mollusks, sponges, coelenterates, fishes, and seagrasses (Bjorndal 1997). An exception is the leatherback turtle, which will feed on pelagic soft-bodied invertebrates at both the surface and at depth (S. Eckert et al. 1989). Sea turtles do not have teeth, but their jaws have modified "beaks" suited to their particular diet (Mortimer 1995). A sea turtle's diet varies according to its feeding habitat and its preferred prey. Upon moving from the later juvenile developmental habitat to the adult foraging habitat, sea turtles may demonstrate further changes in prey preference, dietary composition, and feeding behavior (Bjorndal 1997; Musick and Limpus 1997).

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

Although sea turtles are nearsighted out of water, their vision underwater is very good. Their sense of smell is also very keen and sea turtles are believed to use olfaction in conjunction with sight during foraging (Ernst et al. 1994). Sea turtle hearing sensitivity is not well studied. Reception of sound through bone conduction, with the skull and shell acting as receiving structures, is hypothesized to occur in some sea turtle species (Lenhardt et al. 1983). A few preliminary investigations using adult green, loggerhead,

and Kemp's ridley turtles suggest that these sea turtles are most sensitive to low-frequency sounds (Ridgway et al. 1969; Lenhardt et al. 1983; Bartol et al. 1999).

The range of maximum sensitivity for sea turtles is 100 to 800 Hz, with an upper limit of about 2,000 Hz (Lenhardt 1994). Hearing below 80 Hz is less sensitive but still potentially usable to the animal (Lenhardt 1994). Green turtles are most sensitive to sounds between 200 and 700 Hz, with peak sensitivity at 300 to 400 Hz. They possess an overall hearing range of approximately 100 to 1,000 Hz (Ridgway et al. 1969). Bartol et al. (1999) reported that juvenile loggerhead turtles hear sounds between 250 and 1,000 Hz. Finally, sensitivity even within the optimal hearing range is apparently low—threshold detection levels in water are relatively high at 160 to 200 dB re 1 μPa-m (Lenhardt 1994).

For more information on the biology, life history, and conservation of sea turtles, the following websites can be consulted: seaturtle.org (http://www.seaturtle.org), the Caribbean Conservation Corporation (CCC) (http://www.cccturtle.org), and the Archie Carr Center for Sea Turtle Research (http://accstr.ufl.edu/index.html). Other important resources include NMFS and USFWS authored sea turtle recovery plans (http://www.nmfs.noaa.gov/pr/recovery/#turtles), NMFS compiled Proceedings of the Annual Symposia on Sea Turtle Biology and Conservation (http://www.nmfs.noaa.gov/pr/species/turtles/symposia.htm), Bjorndal (1995), Lutz and Musick (1997), Bolten and Witherington (2003), Lutz et al. (2003), and Gulko and Eckert (2004).

3.2.2 Sea Turtles of the Japan and Okinawa Complexes OPAREA

Five of the seven living species of sea turtles are known to occur in the western North Pacific Ocean and the Japan and Okinawa Complexes OPAREA: the green, hawksbill, loggerhead, olive ridley, and leatherback turtles (**Table 3-2**). Green, loggerhead, and olive ridley turtles are listed as threatened under the ESA while hawksbill and leatherback turtles are listed as endangered. On the 2004 IUCN Red List, the green, loggerhead, and olive ridley turtles are currently listed as endangered while the hawksbill and leatherback turtles are listed as critically endangered (IUCN 2004). Critical habitats have not yet been designated for any of these species in the Pacific Ocean. Of these species, the green, hawksbill, and loggerhead turtles regularly occur in the waters off Japan and Okinawa, whereas the olive ridley and leatherback turtles are seldom reported (Uchida and Nishiwaki 1995).

Table 3-2. Sea turtle species with known occurrence in the Japan and Okinawa Complexes OPAREA. Taxonomy follows Pritchard (1997).

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

[1] A species' occurrence in the OPAREA can be described as one of the following: Regular—occurs as a regular or normal part of the fauna in the OPAREA, regardless of how abundant or common it is; Rare—occurs in the OPAREA sporadically; or Extralimital—does not normally occur in the OPAREA and occurrences there are considered beyond the species' normal range.

[2] Although both species as a whole are listed under the ESA as threatened, the Eastern Pacific nesting stock of the green turtle and the Mexican Pacific nesting stock of the olive ridley turtle are listed as endangered. Since the nesting areas for greens and olive ridley turtles encountered at sea often cannot be determined, a conservative approach to management requires the assumption that some greens and olive ridleys found in the OPAREA may be endangered.

Most of what is known about the biology of sea turtles in Japan (which includes the four main islands as well as the Ryukyu and Ogasawara archipelagos) comes from studies undertaken at their nesting beaches (Kamezaki and Matsui 1997). These studies include nesting surveys (e.g., nest counts and

identifications), nest monitoring and protection efforts, tagging programs (e.g., mark-recapture and satellite-tracking studies), and biological sampling projects (Matsunaga and Nakano 2003). Studies at Hiwasa Beach and Kamouda Beach (on the northeast coast of Shikoku) have been conducted since the 1950s, providing the longest time series of sea turtle nesting data in the world (Kamezaki et al. 2003). Research initiatives at Japanese nesting beaches are undertaken by a wide variety of stakeholder groups including government agencies, research institutes, universities, and non-governmental organizations.

The occurrence patterns of sea turtles in the Japan and Okinawa Complexes OPAREA and vicinity are presented for the winter-spring (December through May) and summer-fall (June through November) in the maps in **Appendix B**. For some of the species, occurrence patterns in the OPAREA apply year round. The process used to create the map figures is described in Section 1.4.2.4. On the map figures, various types of shading and terminology designate the occurrence of sea turtles in the Japan and Okinawa Complexes OPAREA. “Expected occurrence” (area shaded in purple) is defined as the area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and documented occurrence records. “Concentrated occurrence” (area shaded in light green) is the subarea of a species' expected occurrence where there is the highest likelihood of encountering that species; the designation is based primarily on areas of concentrated sighting/nesting records and preferred habitat. “Low/unknown occurrence” (light blue area) is where the likelihood of encountering a species is rare or not known. “Occurrence not expected” (white, unmarked area) is the area within the protected species data extent where a species encounter is not expected to occur.

Only the loggerhead and green turtles are regularly found in western North Pacific Ocean waters off the four main islands of Japan, with loggerheads occurring in much higher numbers due to their greater preference for temperate foraging habitats and nesting beaches (Uchida 1994). The loggerhead is the only sea turtle species that nests on the Japanese mainland (Uchida and Nishiwaki 1995; Kamezaki et al. 2003). Loggerhead and green turtles primarily inhabit continental shelf waters that are located south of the point where the Kuroshio Current deflects east off the Pacific coast of Honshū (between 35°N and 36°N). These species are also more commonly found along the Pacific coast of mainland Japan (the east and south coasts) than they are in the Sea of Japan (the west coast). This is likely due to the close proximity of the Kuroshio Current to the shorelines of East and South Japan. The Kuroshio Current is the dominant oceanographic feature in the western North Pacific Ocean and is capable of carrying sea turtles of all ages into these areas (Kamezaki and Matsui 1997). Although loggerhead and green turtles are common residents of the coastal bays and estuaries of East and South Japan, they are rarely found in the waters of the Inland Sea between Honshū, Shikoku, and Kyūshū (Matsuzawa personal communication).

Located in subtropical waters, the Ryukyu Islands (which include the Osumi, Amami, Okinawa, and Yaeyama island groups) accommodate a more diverse assemblage of nesting sea turtles than adjacent areas in East Asia since both temperate (loggerhead turtles) and tropical (green and hawksbill turtles) species nest in this archipelago (Kikukawa et al. 1999). The loggerhead turtle is the predominant nesting species throughout this archipelago as well (Kamezaki 1986, 1989; Kikukawa et al. 1999). Between 1995 and 1996, 61 sea turtle clutches were recorded on Okinawa and the 12 tiny islands adjacent to it, of which 47 belonged to loggerheads (Kikukawa et al. 1999). Green, hawksbill, and loggerhead turtles not only nest on the beaches of the Okinawa island group, they are also frequently encountered in the coastal waters surrounding these islands (Iwao 2004).

Based upon the above information, the occurrence patterns of all sea turtle species in the Japan and Okinawa Complexes OPAREA are dictated by the most prevalent species: the loggerhead turtle. Only around the Ogasawara Islands, located several hundred kilometers east of Okinawa, are the occurrence patterns of all sea turtles dictated by another species: the green turtle. During winter-spring, sea turtles are expected to occur throughout much of the OPAREA, including all of the West Japan and Okinawa study areas (**Figure B-1**). Only within the northern portion of the East Japan study area is the occurrence of all sea turtles low or unknown during winter-spring. These are waters that lie north of where the Kuroshio Current deflects east off Honshū. In summer-fall, sea turtles are expected to occur in all three study areas, with areas of concentrated occurrence encompassing continental shelf waters off the east and south coasts of Japan (up to the point of the Kuroshio Current deflection) as well as shelf waters surrounding the Izu, Osumi, Amami, and Okinawa island groups (**Figure B-1**). The insular shelf waters

surrounding the Ogasawara Islands are also an area of concentrated sea turtle occurrence, due to the island chain's importance as a green turtle rookery, although these islands are located a good distance outside the OPAREA. Sea turtle occurrence is low or unknown in the Inland Sea throughout the year; however, this water body is also located outside of the OPAREA boundaries.

Each sea turtle species known to occur in the Japan and Okinawa Complexes OPAREA is listed below with its description, status, habitat preferences, distribution (including location and seasonal occurrence in the Japan and Okinawa Complexes OPAREA), behavior, and life history. Species appearance within the text follows the taxonomic order as presented in **Table 3-2**.

- Green Turtle (*Chelonia mydas*)

  Description—The green turtle, known as "aoumigame" in Japanese, is the largest hard-shelled sea turtle. Adult green turtles commonly exceed 100 cm in carapace length and 100 kg in weight. Adult carapaces range in color from solid black to gray, yellow, green, and brown in muted to conspicuous patterns. Hatchlings are distinctively black on the dorsal surface (NMFS and USFWS 1998a, 1998b).

  The genus *Chelonia* includes a single species, *Chelonia mydas*, with two distinct subpopulations in the Pacific, the East Pacific green turtle (or black turtle) and the green turtle. The East Pacific green turtle is conspicuously smaller, typically darker in color, and has a narrower, more strongly vaulted carapace than the green turtle (NMFS and USFWS 1998a, 1998b). According to genetic analyses, the East Pacific green turtle is not a unique lineage relative to other green turtle populations throughout the world (Bowen and Karl 1997). As a result, the genus *Chelonia* is considered monotypic in this report and any mention of "green turtle" will be in reference to the species, *Chelonia mydas*. In several areas of the Pacific Ocean (including San Diego Bay, the Hawaiian Islands, southeast Asia, northern Australia, and possibly off Baja California, Mexico), resident populations of *Chelonia mydas* have shown physical or genetic characteristics of multiple breeding populations (Dutton and McDonald 1990; Nichols et al. 2000a; HDLNR 2002; Moritz et al. 2002).

  Status—Green turtles are classified as threatened under the ESA throughout their Pacific range, except for the population that nests in the eastern Pacific Ocean, which is classified as endangered. On the 2004 IUCN Red List, the green turtle is listed as endangered worldwide (IUCN 2004). The primary threats to green turtles in the Pacific Ocean include entanglement in debris, boat collisions, increased coastal development on nesting beaches, and illegal harvesting of turtles and eggs (NMFS and USFWS 1998a, 1998b). Aside from the growing population of green turtles in the waters surrounding the Hawaiian Islands, this species is believed to be in serious decline throughout the Pacific Ocean (NMFS and USFWS 1998a; Balazs and Chaloupka 2004). Horikoshi et al. (1994) stated that the population of green turtles nesting at Japan's Ogasawara Islands has already declined due to past commercial exploitation, although recent nesting data from 2001 and 2002 indicate that the nesting population may now be increasing (Matsuzawa personal communication). Since Japan is home to the northernmost nesting sites for green turtles in the entire Pacific, the green turtle population residing there is estimated to be small (Uchida 1994).

  Habitat Preferences—In the Pacific Ocean, the early juvenile nursery habitat of the green turtle is unknown. After hatchlings leave the nesting beach, they apparently move into convergence zones or driftlines in the open ocean where they spend an undetermined amount of time in the pelagic environment (Balazs 2004). In recent years, small numbers of early juveniles have been captured by commercial drift net vessels fishing in international waters to the north and west of the Hawaiian Islands (NMFS and USFWS 1998a). Nichols et al. (2001) has also documented early juveniles basking near or on top of kelp mats off Baja California. Once green turtles reach a certain carapace length, which can be anywhere from 20 to 45 cm (depending upon the population), they migrate to shallow nearshore areas where they spend the majority of their lives as late juveniles and adults (Balazs 1980; Bjorndal and Bolten 1988; Ernst et al. 1994; NMFS and USFWS 1998a, 1998b).

  The optimal habitats for late juveniles and adults (i.e., benthic life stages) are warm, quiet, and shallow (3 to 10 m deep) waters that possess an abundance of submerged aquatic vegetation

(seagrasses and/or algae) and are located in close proximity to nearshore reefs or rocky areas used for resting (Ernst et al. 1994). Green turtles can feed as deep as their primary food source will grow. Around the Hawaiian Islands, green turtles often forage in coastal waters less than 10 m deep, but have been known to forage and also rest at depths of 20 to 50 m (Balazs 1980; Brill et al. 1995). Feeding grounds in Japan are located in shallow waters along the Pacific coast of the archipelago from 26°N to 38°N, and may extend west into the East China Sea and waters near Taiwan (Suganuma 1989; Tachikawa et al. 1994). Late juvenile and adult green turtles are frequently captured in coastal gillnet and setnet fisheries off the east coast of Taiwan, where rocky shores provide a suitable feeding ground (Cheng and Chen 1997).

Distribution—Green turtles are distributed worldwide in tropical and subtropical seas and prefer water temperatures above 20°C (NMFS and USFWS 1998a, 1998b). The most important nesting and feeding grounds lie within the tropics (Pritchard 1997). In the western Pacific Ocean, green turtles range from central Japan and Korea to the southern coast of Australia and are most abundant off Southeast Asia and northern Australia (Eckert 1993). In Japan, green turtle sightings most often occur around the main island of Honshū (to as far north as 38°N) with fewer records in the southern Ryukyu Islands (Suganuma 1989; Eckert 1993; Tachikawa et al. 1994; Uchida and Nishiwaki 1995). Adult green turtles also concentrate around the Ogasawara Islands during the nesting season (Suganuma 1989; Suganuma et al. 1996). In the eastern Pacific Ocean, green turtles have been sighted in waters as far north as Alaska and as far south as Chile (Chandler 1991; Hodge and Wing 2000), with the largest populations occurring off southern Mexico and Central America (Clifton et al. 1995; Cornelius 1995). In the insular Pacific Ocean, green turtles are found around the Hawaiian Islands and throughout the coastal areas of Micronesia (Pritchard 1977; NMFS and USFWS 1998a).

As they grow, juvenile green turtles are known to move through a series of developmental feeding habitats, which are often separated by thousands of kilometers (Hirth 1997). Mixed-stock analyses on juvenile foraging populations have revealed that developmental feeding habitats likely contain green turtles from multiple stocks. Green turtles captured on foraging grounds off Baja California and in San Diego Bay have shown physical and genetic characteristics of both Mexican Pacific and Hawaiian breeding populations (Dutton and McDonald 1990; Nichols et al. 2000a); however, little is known regarding the stock compositions of juvenile foraging populations in the western Pacific Ocean. Moritz et al. (2002) observed that green turtle feeding assemblages in the western Pacific Ocean include turtles from multiple breeding populations; however, their study focused primarily on adult turtles.

Adult green turtles are known to undertake extensive migrations, the longest of which are between their foraging habitats and nesting beaches. Long-distance reproductive migrations have been noted for green turtles nesting at a number of locations in the Pacific Ocean including the Northwestern Hawaiian Islands (NWHI), the Ogasawara Islands, Taiwan, China, Hong Kong, American Samoa, and Guam (Balazs 1976, 1980, 1983; Tachikawa et al. 1994; Cheng 2000; Song et al. 2002; Chan 2003; Craig et al. 2004; Gutierrez 2004). Green turtles that breed in the Ogasawara Islands make regular reproductive migrations from their foraging grounds along the Pacific coast of Japan (e.g., the Izu Islands, mainland Japan, and the Ryukyu Islands) and may even come from areas as far west as the East China Sea or the coast of Taiwan. This has been evidenced by mark-recapture studies on headstarted early juveniles, subadults, and nesting and foraging adults (Suganuma 1989). The reproductive migrations of green turtles between Japan and the Ogasawara Islands are very similar to those of green turtles in the Hawaiian archipelago (Uchida 1994). Every few years, green turtles in the Hawaiian Islands migrate from their primary foraging grounds in the Main Hawaiian Islands (MHI) to nesting beaches in the NWHI (Balazs 1976, 1983; Balazs et al. 1994; Balazs and Ellis 2000). Adult green turtles residing in Japanese waters may also travel long distances to the west in order to nest. Reproductive migrations have been documented between nesting beaches in China and Taiwan and foraging grounds off mainland Japan and the Ryukyu Islands (Cheng 2000; Song et al. 2002).

Green turtles nest throughout the Pacific Ocean, with active nesting colonies in the eastern, central, and western regions. Major nesting colonies in the eastern Pacific are located in Mexico and the Galapagos Islands, while high-density nesting sites in the western Pacific are found primarily in northeastern Australia along the Great Barrier Reef (Eckert 1993). Green turtle nesting populations in

the central Pacific are relatively small (NMFS and USFWS 1998a). In Japan, green turtle nesting is usually restricted to the Ogasawara Islands and beaches in the Ryukyu Islands located south of 30.5°N (Uchida 1994; **Figure 3-3**). These island groups represent the northern limit for green turtle rookeries in the western Pacific Ocean. The Ogasawara Islands are the most productive green turtle nesting areas in Japan and the population that nests there is believed to be on the rise (Matsuzawa personal communication). Currently, green turtles nest in the Mukojima, Chichijima, and Hahajima groups of this island chain (Suganuma et al. 1996). The green turtle nesting population at Okinawa, and throughout the Ryukyu Islands, is relatively small (Kikukawa et al. 1999). The northernmost nesting records for green turtles in Japan are from the Izu Islands (in 2004) and southern Kyūshū (in 1999) (Matsuzawa personal communication).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Green turtles are the second most common sea turtle species found in the OPAREA and vicinity (Uchida and Nishiwaki 1995). Within the East Japan, West Japan, and Okinawa study areas, green turtle occurrence patterns are the same year round (**Figure B-2**). Only around the Ogasawara Islands do they change on a seasonal basis. This species is expected to occur in continental shelf waters off eastern and southern Japan and in coastal waters surrounding the Izu Islands. However, its occurrence is low or unknown in the Inland Sea, the Sea of Japan, and the East China Sea due to a lack of occurrence records in those areas (Matsuzawa personal communication). Green turtles are also expected to occur in shelf waters surrounding all of the Ryukyu Islands except the Daito Islands, as there is no information available on green turtles in that island group. Areas of expected occurrence are based upon the distribution of known sighting, stranding, and nesting records as well as results from tagging studies, which indicate that green turtles often travel along the coasts of the Izu Islands, mainland Japan, and the Ryukyu Islands during their reproductive migrations to and from the Ogasawara Islands (Tachikawa et al. 1994; Uchida 1994; Uchida and Nishiwaki 1995).

  Around the Ogasawara Islands (i.e., landward of the insular shelf break), green turtle occurrence is expected in winter-spring and concentrated in summer-fall (**Figure B-2**). The period of peak nesting and hatching occurs from June through November, the months encompassed by the summer-fall season (Suganuma et al. 1996). Since the Ogasawara Islands are one of the most important green turtle rookeries in the western North Pacific, green turtles are expected to occur there year round. Less intense nesting activity occurs during the spring. Mating is also prevalent in the spring, although it is not as intensely studied as nesting. Nearly all green turtle studies at the Ogasawara Islands have involved nesting females and hatchlings (Suganuma 1985, 1989).

  Green turtles are not expected to occur north of the Kuroshio Current deflection off the coast of Honshū, as they are a predominantly tropical species (**Figure B-2**). Post-hatchlings and early juveniles may become entrained in the current, but they likely do not venture north of it while passing through the deep, oceanic waters of the western North Pacific. Due to the lack of information available regarding the habitats utilized by these early life stages, all oceanic waters south of the Kuroshio Current deflection are designated as areas of low or unknown occurrence.

Behavior and Life History—Adult green turtles are primarily herbivorous; they most often feed on seagrasses (e.g., turtle grass, manatee grass, shoal grass, and eelgrass) and macroalgae (Burke et al. 1992; Ernst et al. 1994; Bjorndal 1997). Occasionally, adults will also eat animal matter such as jellyfish, salps, sponges, and other reef-associated fauna (Bjorndal 1997). Observations of foraging adult green turtles suggest that when benthic age classes feed, they generally lie down on the sea bottom and then crawl or swim to nearby sites when food is no longer within reach (Hochscheid et al. 1999). Juvenile green turtles are omnivorous, feeding on a variety of algae, invertebrates, and small fish (Ernst et al. 1994). In the Hawaiian Islands, it is not unusual for juvenile green turtles to bite on fishing hooks baited with squid, shrimp, and fish flesh (Balazs 1980). In the western Pacific Ocean, the diet of benthic-stage green turtles is determined by the habitat in which they are living (Mortimer 1995). In coastal areas with a diverse array of available of food items, benthic-stage green turtles will often feed selectively on preferred species of seagrass or algae (André et al. 2005).

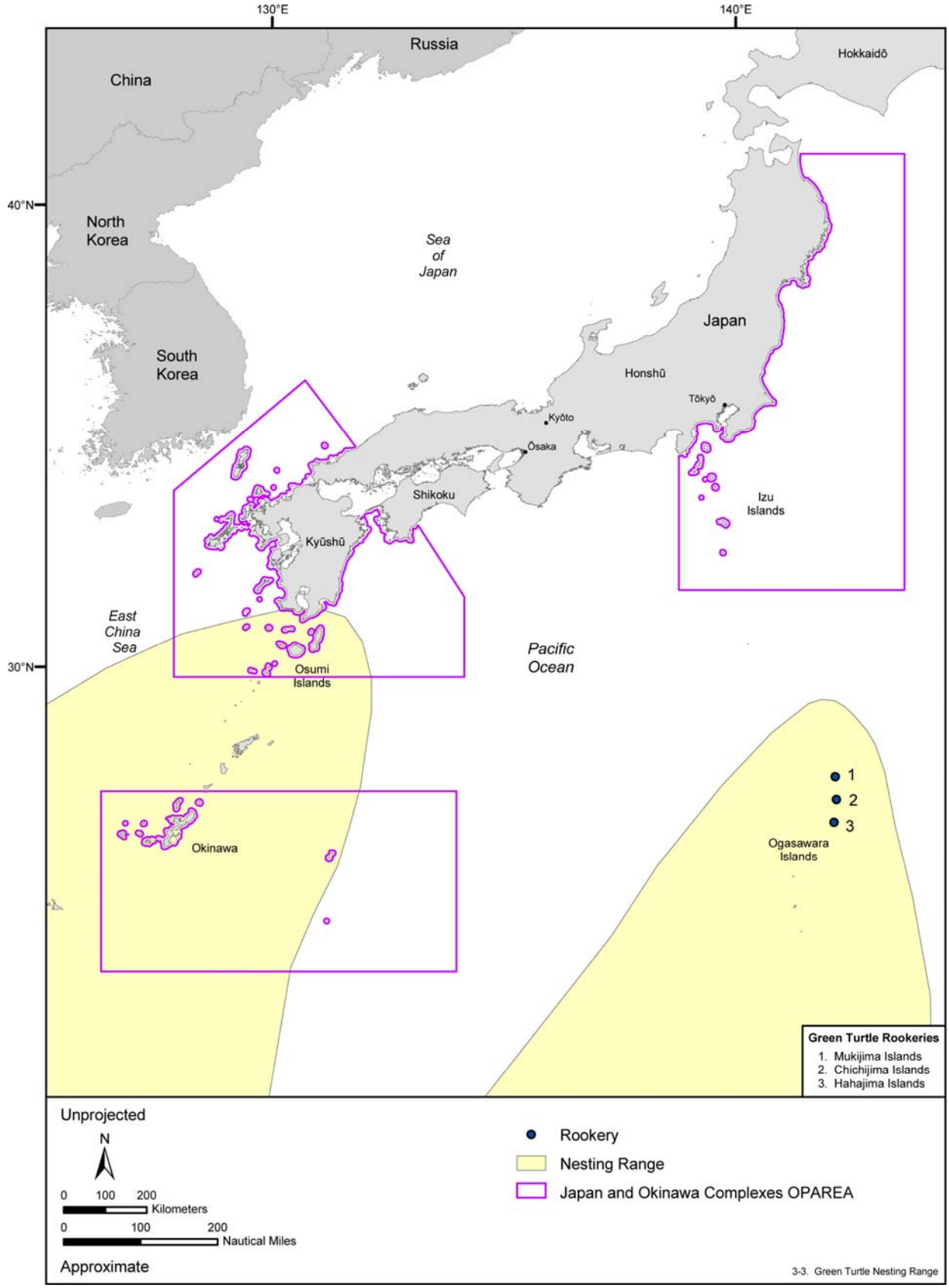

Figure 3-3. Nesting range and important rookeries of the green turtle in the Japan and Okinawa Complexes OPAREA and vicinity. Source map (scanned): STAJ (2005a). Source information: Suganuma et al. (1996).

Green turtles take between 27 and 50 years to reach sexual maturity, the longest age to maturity for any sea turtle species (Frazer and Ehrhart 1985). During the breeding season, green turtle courtship and copulation occur in waters proximal to the nesting beach (Owens 1980; NMFS and USFWS 1998a). In the Ogasawara Islands, mating occurs from March through May and nesting follows from May through early September, with a peak in nesting activity between June and July (Suganuma et al. 1996). In the Ryukyu Islands, the green turtle nesting season runs from May through August (Abe et al. 1997; Kikukawa et al. 1999). Remigration intervals (the number of years between successive nesting seasons) for green turtles nesting at the Ogasawara Islands range from two to nine years with a mode of four years (Tachikawa et al. 1994). From 1991 through 1994, green turtles laid an average of four clutches per nesting season at the Ogasawara Islands; the average clutch size for these nests was slightly over 100 eggs (Suganuma et al. 1996).

Green turtles typically make dives shallower than 30 m (Hochscheid et al. 1999; Hays et al. 2000). In 1997, a maximum dive depth of 164.5 m was recorded for a post-nesting female from the Ogasawara Islands (Matsuzawa personal communication). Studies on green turtle diving patterns around Japan are just beginning, although a number of studies have already been conducted on juveniles in the Hawaiian Islands and Australia. The maximum dive time recorded for a juvenile green turtle around the Hawaiian Islands is 66 min, with routine dives ranging from 9 to 23 min (Brill et al. 1995). At Heron Island, Australia, juvenile green turtles are known to alter their diving behavior seasonally. During winter, juveniles spend significantly more time in shallow water (<1 m), dive for longer periods of time (twice as long), and remain at the surface for longer periods of time (three times as long) than they do during summer (Southwood et al. 2003).

- Hawksbill Turtle (*Eretmochelys imbricata*)

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

Status—Hawksbill turtles are classified as endangered under the ESA and are second only to the Kemp’s ridley turtle in terms of global endangerment (Bass 1994; NMFS and USFWS 1998c). On the 2004 IUCN Red List, hawksbills are listed as critically endangered worldwide (IUCN 2004). Only five regional populations worldwide remain with more than 1,000 females nesting annually (Seychelles, the Mexican Atlantic, Indonesia, and two in Australia; Meylan and Donnelly 1999). A lack of regular quantitative surveys for hawksbill turtles in the Pacific Ocean and the discrete nature of this species’ nesting have made it extremely difficult for scientists to assess the distribution and population status of hawksbills in the region (NMFS and USFWS 1998c; Seminoff et al. 2003). The status of the hawksbill is clearly of a higher concern for the Pacific due to the serious depletion of the species caused by habitat destruction and international harvest of turtles and eggs (NMFS and USWFS 1998c). In the Java Sea region off Indonesia, serious declines in hawksbill turtle nesting activity (by about 72%) have been observed over the past 20 years (Suganuma et al. 1999). Not much is known regarding the abundance of hawksbills in Japanese waters, although the population is believed to be very small (Eckert 1993; Ishikawa and Osawa 2002).

Habitat Preferences—The oceanic whereabouts of early juvenile hawksbills in the Pacific Ocean are unknown, although it is likely that they would occur in offshore waters associated with major current systems (NMFS and USFWS 1998c; Seminoff et al. 2003). The Kuroshio Current and its extensions may serve as the early juvenile nursery habitat for hawksbills in the western North Pacific Ocean. In the Atlantic Ocean and Caribbean Sea, where hawksbills have been studied more intensely, early juveniles are known to inhabit oceanic waters where they are sometimes associated with driftlines and floating patches of *Sargassum* (Witzell 1983; Parker 1995; Meylan and Donnelly 1999).

In the Pacific Ocean, hawksbill turtles are believed to migrate to benthic foraging grounds when they reach 30 to 35 cm in carapace length (Hirth et al. 1992; Seminoff et al. 2003). Late juvenile and adult hawksbills forage around coral reefs, mangroves, and other hardbottom habitats in open bays and coastal zones throughout the tropical Pacific (Eckert 1993). Shallow seagrass beds may also serve as important developmental habitats for late juveniles (Bjorndal and Bolten 1988; Diez et al. 2003). In neritic habitats, the resting areas for late juveniles and adults are generally located in deeper waters (i.e., on sandy bottoms at the base of a reef flat) than their foraging areas (Houghton et al. 2003).

Distribution—Hawksbill turtles are circumtropical in distribution, generally occurring from 30°N to 30°S within the Atlantic, Pacific, and Indian Ocean basins (NMFS and USFWS 1998c). In the western Pacific Ocean, hawksbills have been recorded from as far north as the Sea of Japan to as far south as New Zealand and Tasmania (Witzell 1983). Although located in the northernmost part of its distribution, little is known about the distribution of hawksbills around Japan (Eckert 1993; Ishikawa and Osawa 2002). Hawksbills are believed to be most prevalent in the coastal waters surrounding the southern Ryukyu Islands (Uchida 1994), although infrequent sightings have been recorded along both the east and west coasts of mainland Japan as far north as 38°N (Uchida and Nishiwaki 1995). These occurrence records are likely attributable to the entrainment of hawksbills in the Kuroshio and Tsushima Currents, which would carry them north from their more southerly centers of distribution (Kamezaki and Matsui 1997).

Hawksbills were originally thought to be a non-migratory species because of the close proximity of their nesting beaches to their coral reef feeding habitats and the high rates of local recapture. Hawksbills are now known to travel long distances over the course of their lives (Meylan 1999). Tag return, genetic, and satellite telemetry studies have indicated that hawksbill turtles utilize multiple developmental habitats as they age. However, within a given life stage, such as the later juvenile stage, some hawksbills may remain at a specific developmental habitat for a long period of time (Meylan 1999). In February 1985, a benthic-stage juvenile was captured from the coastal waters surrounding an islet in the southern Ryukyu Islands. A year and a half later, the same individual was recaptured in a lagoon only 9 km away from its original capture site (Kamezaki 1987).

Hawksbill nesting in the North Pacific Ocean is widespread and occurs at scattered locations in very small numbers (Eckert 1993). The Japanese islands only provide minor nesting sites for hawksbills in the western North Pacific (Uchida 1994). As a result, hawksbill nesting in Japan is rare and is usually confined to the nation's southern islands, namely the Yaeyama and Okinawa groups of the Ryukyu archipelago (Eckert 1993; Kikukawa et al. 1999; **Figure 3-4**). The northernmost nesting records in Japan are known from the Tokara archipelago and the Amami Islands (Uchida 1994; Matsuzawa personal communication). The largest rookeries for hawksbill turtles in the western Pacific Ocean are located much further south along the coasts of Indonesia, Malaysia, and Australia (Meylan and Donnelly 1999; Suganuma et al. 1999).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Based upon their worldwide distribution, their preference for nearshore habitats, and their known nesting range, hawksbill turtles are expected to occur year round in shelf waters surrounding all islands of the Ryukyu archipelago that are located south of 30°N (**Figure B-3**). However, this excludes the shelf waters of the Daito Islands, as there is no information available about the occurrence of hawksbill turtles in that area. In all other waters of the OPAREA, hawksbill occurrence is low, unknown, or not expected. Since the hawksbill is a highly tropical species, it is not expected to occur in waters north of where the Kuroshio Current deflects off the coast of Honshū. South of the Kuroshio deflection, hawksbills may potentially occur off the Japanese mainland as evidenced by a few sightings and strandings of juvenile turtles off southern Honshū, Shikoku, and Kyūshū (Uchida and Nishiwaki 1995). Occurrence is not concentrated in any of the coastal areas surrounding the northern and central Ryukyu Islands (i.e., the Osumi, Amami, and Okinawa islands) since nesting activity in these areas is low (Kikukawa et al. 1999). The species is more highly abundant in coastal areas much closer to the Equator (e.g., Malaysia and Indonesia).

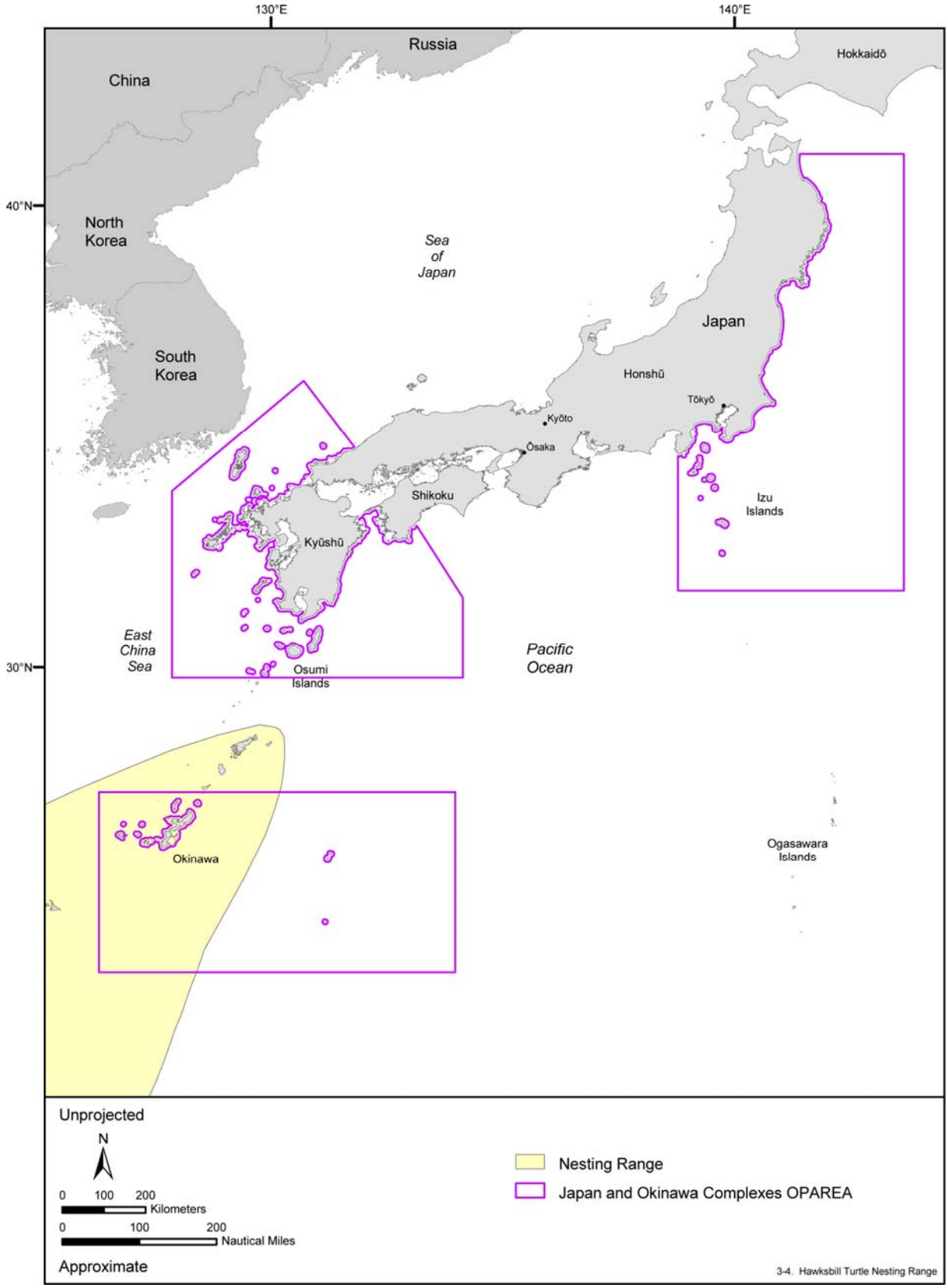

Figure 3-4. Nesting range of the hawksbill turtle in the Japan and Okinawa Complexes OPAREA and vicinity. Source map (scanned): STAJ (2005a). Source information: Matsuzawa personal communication.

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

Hawksbill turtles often nest in multiple, small, scattered colonies with mating activities believed to take place in the shallow waters adjacent to the nesting beach. The nesting season for hawksbills in the western Pacific is not known, although nesting probably occurs at a low level year round (Eckert 1993). Very few data are available for hawksbills that nest in Japan. Much of what is known about hawksbill nesting has been learned from studies at rookeries in the Caribbean Sea, Indian Ocean, and more tropical areas of the western Pacific Ocean. At tropical latitudes, nesting most often occurs at night on beaches with sufficient vegetative cover. Females nest between 2 and 5 times per season and inter-nesting intervals last around 14 to 16 days. The typical remigration interval is two to three years. Clutch sizes in the Pacific Ocean are relatively large at 110 to 150 eggs and incubation times range from 50 to 61 days (NMFS and USFWS 1998c).

Hawksbills may have the longest routine dive times of all sea turtles. Starbird et al. (1999) reported that dive times for inter-nesting females at Buck Island, St. Croix, U.S. Virgin Islands (USVI) averaged 56.1 min with a maximum of 73.5 min. Average dives during the day ranged from 34 to 65 min, while those at night were between 42 and 74 min. Data from time-depth recorder studies in Puerto Rico indicate that foraging dives of juvenile hawksbills range from 8.6 to 14.0 min and have a mean depth of 4.7 m, while resting dives range from 30.4 to 37.1 min and have a mean depth of 6.8 m (van Dam and Diez 1996). This study, in combination with a more recent habitat utilization study in the Seychelles, indicates that juvenile hawksbills display alternating patterns of short, shallow foraging dives followed by deeper, longer resting dives (van Dam and Diez 1996; Houghton et al. 2003).

- Loggerhead Turtle (*Caretta caretta*)

Description—The loggerhead turtle, known in Japan as "akaumigame," is a large hard-shelled sea turtle that is named for its proportionately large head and powerful jaws. The average carapace length of an adult female is between 90 and 95 cm and the average weight is 100 to 150 kg (Dodd 1988; NMFS and USFWS 1998d). Between 1969 and 1979, females nesting at Gamouda Beach (located on Shikoku) averaged 89 cm in carapace length and 97 kg in weight (Uchida and Nishiwaki 1995). From 1992 to 2001, females nesting at Minabe Senri Beach (located on Honshū) ranged between 74 and 96 cm in carapace length (Hatase et al. 2004). Adult loggerheads usually possess a reddish-brown carapace with scutes that are bordered with yellow (NMFS and USFWS 1998d). Genetic analyses have indicated that loggerheads nesting in Japan are genetically distinct from other nesting populations throughout the world (Hatase et al. 2002a).

Status—Loggerhead turtles are classified as threatened under the ESA and are listed as endangered on the 2004 IUCN Red List (IUCN 2004). Recent data suggest that loggerhead nesting populations in Japan are in considerable decline (Sato et al. 1997; Kikukawa et al. 1999; Suganuma 2002; Kamezaki et al. 2003; STAJ 2005b). Field studies in eastern Australia are also indicating significant declines in Pacific loggerhead nesting activity (Limpus and Limpus 2003). A few thousand to hundreds of thousands of loggerheads likely comprise the juvenile foraging population off Baja California (Pitman 1990), yet it is probable that there are fewer than 1,000 females nesting annually in Japan (Kamezaki et al. 2003). Long-term counts of loggerheads in all parts of southern Japan have shown that the number of loggerheads breeding there has decreased by more than half since 1990 (Sato et al. 1997; Hatase et al. 2002b; STAJ 2005b).

Incidental bycatch in commercial fisheries is currently a tremendous source of loggerhead mortality. Lewison et al. (2004) noted that an estimated 30,000 to 75,000 loggerhead turtles were taken as pelagic longline bycatch in the Pacific Ocean in 2000. Rapid declines in nesting females at all major

Pacific rookeries suggest that longline and drift net bycatch may be leading to increased levels of loggerhead mortality throughout the Pacific Ocean (Kamezaki et al. 2003; Limpus and Limpus 2003).

Habitat Preferences—The loggerhead turtle occurs worldwide in habitats ranging from coastal estuaries, bays, and lagoons to waters far beyond the continental shelf (Dodd 1988). Early juveniles are primarily oceanic, occurring in pelagic convergence zones where they are transported throughout the ocean by dominant currents (Carr 1987). A common pattern in the developmental migration of this species in the North Pacific Ocean is to reside on the eastern side (e.g., just offshore of Baja California) for a number of years and then migrate back to coastal waters on the western side (e.g., off Japan and China; Nichols 2005). Late juvenile and adult loggerheads are generally found in coastal, neritic habitats (<200 m deep) where they forage on benthic organisms that tend to occur around reefs and other hardbottom areas (Dodd 1988). The shallow waters of the East China Sea are known to be a major wintering area for adult loggerheads in the western North Pacific (Iwamoto et al. 1985; Matsuzawa personal communication). However, offshore of Japan, adults can also be found in oceanic waters (≥1,000 m in depth) (Hatase et al. 2002c). Stable isotope and satellite telemetry studies have suggested that there are size-related differences in the use of feeding habitats by adult female loggerheads around Japan, and that there may also be size-related differences in the use of the same habitats by adult males (Hatase et al. 2002c, 2002d; Hatase and Sakamoto 2004).

Satellite-tracking studies on loggerheads captured in the Hawaiian longline fishery indicate that individuals traveling west in oceanic waters of the North Pacific move north and south on a seasonal basis. These individuals move primarily through the region bounded by 28°N and 40°N and occupy SSTs between 15° and 25°C. The Transition Zone Chlorophyll Front (TZCF) and the Kuroshio Extension Current appear to be important foraging and migration habitats for juvenile loggerhead turtles in the central North Pacific (Polovina et al. 2004). Polovina et al. (2000) noticed that juvenile loggerheads often follow the 17° and 20°C isotherms north of the Hawaiian Islands. Off Japan, oceanic waters south of the Kuroshio Current may represent alternate wintering grounds for late juvenile and adult loggerheads that do not migrate to more tropical waters in the East China Sea (Hatase et al. 2002d).

Distribution—The loggerhead turtle is a circumglobal species inhabiting the temperate, subtropical, and tropical waters of the Atlantic, Pacific, and Indian Oceans (Ernst et al. 1994). Polovina et al. (2000) inferred that the distribution of loggerheads is continuous across the Pacific Ocean, although Eckert (1993) and the NMFS and USFWS (1998d) indicated that they are less common in the central Pacific than they are in the eastern and western Pacific. In the western Pacific Ocean, the northernmost records are from Russia while the southernmost are from Tasmania and New Zealand (Dodd 1988). Large adult foraging populations occur in several areas of the western Pacific, including the East and South China Seas, the coastal waters off southern Japan, the Great Barrier Reef, and the shallow bays and estuaries of northeastern Australia (Iwamoto et al. 1985; Nishimura and Nakahigashi 1990; Uchida 1994; Limpus 1995; Hatase et al. 2002c; Nichols 2005). In the eastern Pacific Ocean, loggerheads are documented to occur as far north as Alaska and as far south as Chile (Bane 1992; Donoso-P. et al. 2000). The largest juvenile foraging population in the North Pacific Ocean is found off the west coast of Baja California in a band starting about 30 km offshore and extending out at least another 30 km (NMFS and USFWS 1998d; Nichols et al. 2000b; Nichols 2003).

Genetic analyses indicate that nearly all of the loggerheads found in the North Pacific Ocean are born on nesting beaches in Japan (Bowen et al. 1995; Resendiz et al. 1998). Loggerheads born on Japanese nesting beaches appear to utilize the entire North Pacific Ocean during the course of development, much like loggerheads born on southeast U.S. beaches use the North Atlantic Ocean (Bolten et al. 1998). There is substantial evidence that individuals from the Japanese stock make two separate transoceanic crossings. The first crossing (west to east) is made immediately after hatching from the nesting beach, while the second (east to west) is made upon reaching either the late juvenile or adult life stage. After hatchling, loggerheads born on Japanese beaches swim with the NPSG system in order to reach developmental habitats in the eastern North Pacific (off southern California and Mexico; Polovina et al. 2000). Unlike the case in the eastern Atlantic, however, where nesting

grounds exist (e.g., in the Mediterranean Sea along the coast of Greece), all juvenile loggerheads found in the eastern Pacific must eventually return to the western Pacific in order to reproduce.

Nichols et al. (2000c) have concluded that loggerhead turtles are highly capable of trans-Pacific migration and that the band of water between 25°N and 30°N, also known as the Subtropical Frontal Zone, may be an important migratory corridor for loggerheads returning to the western Pacific. In 1996 and 1997, over the course of 368 days, a captive-reared loggerhead turtle named "Adelita" migrated over 11,000 km across the Pacific Ocean from a juvenile feeding area off Santa Rosalita, Baja California to an adult foraging area at Sendai Bay, Japan (**Figure 3-5**). From 1998 to 2000, several other transoceanic migrations of captive-reared loggerhead turtles were monitored through the use of satellite telemetry, this time from waters off San Diego, California to Japan (Parker et al. 2004; Eckert personal communication).

Loggerhead nesting grounds are located in warm, temperate, and subtropical regions, with some scattered nesting in the tropics. The world's largest nesting colonies are found at Masirah Island, Oman (bordering the Arabian Sea) and along the Atlantic coast of Florida. Nesting in the Pacific Ocean basin is restricted to the western region (primarily Japan and Australia). Loggerhead nesting beaches in Japan are widely distributed from 24°N to 37°N, a latitudinal range very similar to that of the western North Atlantic nesting population (Kamezaki et al. 2003). The most important Japanese rookeries are located on the Pacific coast of mainland Japan (excluding the island of Hokkaido) and in the northern Ryukyu Islands, with lower level nesting occurring along the Sea of Japan (Kamezaki 1989; Uchida and Nishiwaki 1995; **Figure 3-6**). The Yaeyama group of the Ryukyu archipelago may be the southernmost extent of loggerhead nesting in the North Pacific Ocean, as there are no nesting records for this species in Taiwan or the Philippines (Kamezaki et al. 2003).

Major nesting beaches in mainland Japan include Miyazaki Beach (Kyūshū), Hiwasa Beach (Shikoku), Minabe Senri Beach (Honshū), and Omaezaki Beach (Honshū); submajor nesting beaches include Nagasakibana Beach (Kyūshū), Shibushi Beach (Kyūshū), Nichinan Beach (Kyūshū), Nobeoka Beach (Kyūshū), Kamouda Beach (Shikoku), and Minabe Iwashiro Beach (Honshū) (Kamezaki et al. 2003; **Figure 3-6**). The most important nesting beaches in the Ryukyu Islands are found on Yakushima Island (located in the Osumi Islands). Inakahama Beach and Maehama Beach, located on the island's northwest coast, account for approximately 30% of all loggerhead nesting in Japan (Kamezaki 1989). At Okinawa, loggerhead nesting occurs primarily along the island's northern half (Kikukawa et al. 1996, 1999). However, over the past decade, nesting activity has been most intensely monitored at Itoman Beach in the developed southern half (Kamezaki et al. 2003).

- Information Specific to the Japan and Okinawa Complexes OPAREA—In Japanese waters, loggerhead turtles are widely distributed from Honshū to the southern Ryukyu Islands and from the continental shelf into deep, oceanic waters of the western North Pacific (Uchida and Nishiwaki 1995; Hatase et al. 2002b, 2002c, 2002d). Due to their wide range in habitat preferences, which vary from one life stage to the next, loggerhead occurrence is expected throughout the much of the OPAREA year round (**Figure B-4**). Only during winter-spring in waters north of where the Kuroshio Current deflects east off the coast of Honshū is loggerhead occurrence low or unknown. Off the northeast coast of Honshū, the cold water Oyashio Current dominates the region's oceanography. To prevent themselves from stranding due to cold-stunning, loggerhead turtles will often avoid this cold water current during the coldest months of the year. However, when these temperate waters warm up in the summer-fall, loggerheads likely expand their range north to take advantage of northward-moving prey, much as they do off the northeastern coast of the U.S. (Shoop and Kenney 1992; Morreale and Standora 1998).

  In the summer-fall, loggerhead turtle occurrence is expected throughout all three of the study areas that comprise the OPAREA, and is concentrated in continental shelf waters off mainland Japan south of the Kuroshio Current deflection (**Figure B-4**). Loggerhead occurrence is also concentrated in insular shelf waters surrounding all islands in the Izu, Osumi, Amami, and Okinawa groups. This is due to the known seasonal migration of large numbers of loggerheads

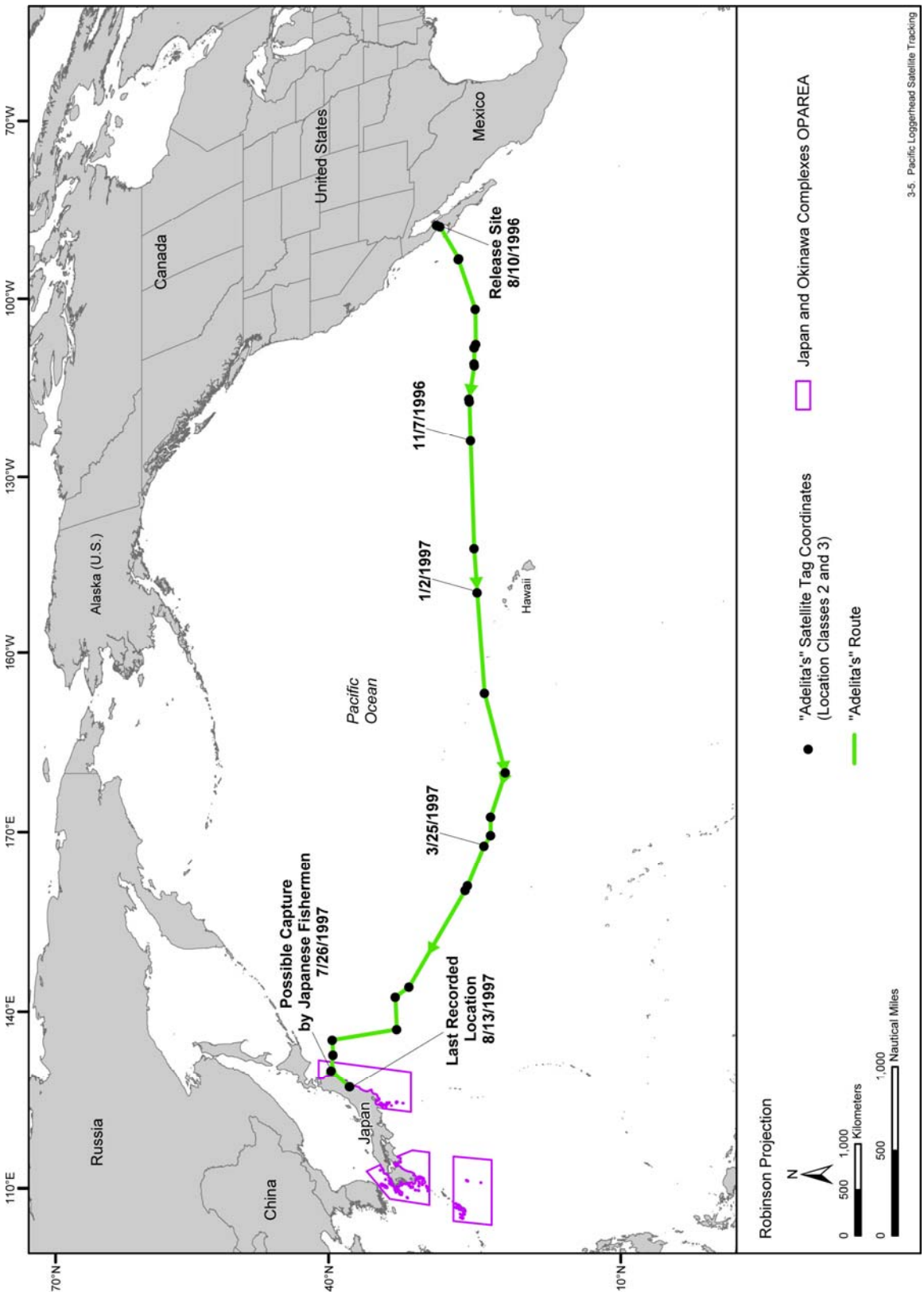

Figure 3-5. The transpacific migration of loggerhead turtle "Adelita" from Baja California, Mexico to Sendai Bay, Japan between August 1996 and August 1997. Satellite-tag coordinates with location classes of 2 (accurate to within 350 m) and 3 (accurate to within 150 m) are presented. Source data: Nichols et al. (2000c).

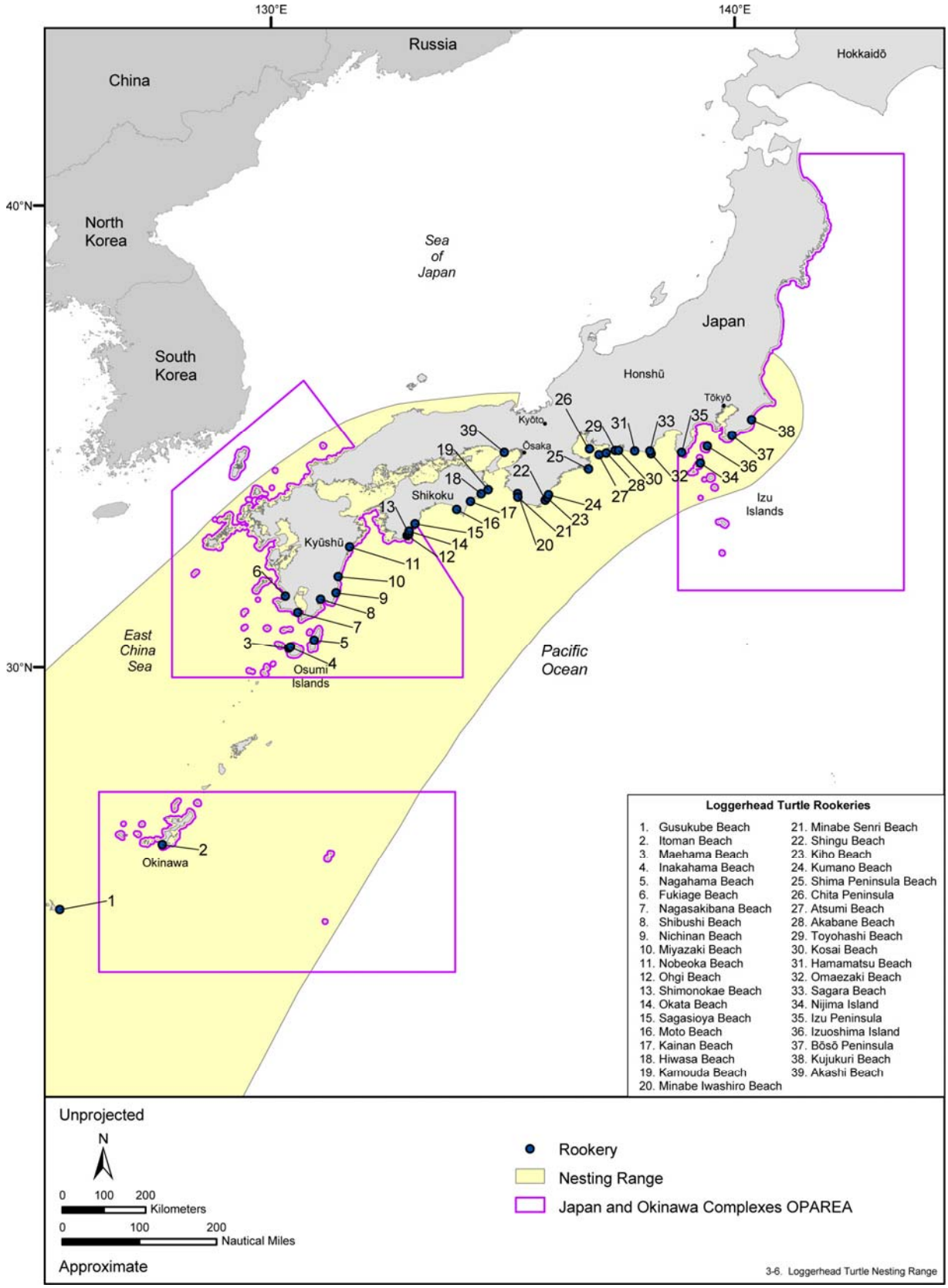

Figure 3-6. Nesting range and important rookeries of the loggerhead turtle in the Japan and Okinawa Complexes OPAREA and vicinity. Source maps (scanned): Kamezaki et al. (2003) and STAJ (2005a).

into the coastal waters of the Japanese archipelago in order to nest or feed (Iwamoto et al. 1985). Loggerheads nest throughout the Ryukyu Islands and along the East Japan mainland to as far north as 37°N (Kamezaki et al. 2003). As a result, a large number of adult and hatchling turtles can be expected to occur off these nesting beaches during the summer-fall. The only area of low or unknown occurrence for loggerheads around Japan during summer-fall is the Inland Sea, which is located inshore of the West Japan study area.

Behavior and Life History—The diet of a loggerhead turtle changes with age and size. Studies in the Atlantic Ocean have indicated that post-hatchlings consume a wide variety of food items including algae, zooplankton, jellyfish, larval shrimp and crabs, insects, and gastropods (Richardson and McGillivary 1991; Witherington 1994). There have been no studies on the foraging behavior of post-hatchlings in the Pacific Ocean. Juvenile loggerheads are also omnivorous, foraging on pelagic crabs, mollusks, jellyfish, and vegetation captured at or near the surface (Dodd 1988; Parker et al. 2005). Off Baja California, the distribution of juvenile loggerheads coincides with that of a large population of pelagic red crabs (NMFS and USFWS 1998d). This indicates that juvenile loggerheads in the eastern Pacific are probably feeding on dense concentrations of this highly abundant crustacean. Studies on loggerheads in the central Pacific Ocean have also provided evidence of surface feeding behavior (Parker et al. 2005). Adult loggerheads are generally carnivorous, often choosing to forage on benthic invertebrates (mollusks, crustaceans, and coelenterates) in nearshore waters. Loggerheads that forage in the East China Sea regularly exhibit this type of diet (Hatase et al. 2002c). However, in deep waters of the western North Pacific off the east coast of Japan, adult loggerheads feed on nutrient-poor items such as jellyfish, salps, and other gelatinous animals (Dodd 1988; Hatase et al. 2002c).

During the breeding season, loggerheads congregate in waters offshore of their nesting beaches. Courtship behavior is often seen in rocky areas that are 20 to 30 m deep (Uchida and Nishiwaki 1995). Loggerhead nesting in the North Pacific Ocean occurs between April and August, when nearshore water temperatures rise above 20°C (Uchida and Nishiwaki 1995; Abe et al. 1997; NMFS and USFWS 1998d). Females from the Japanese nesting stock generally nest at least three times per season at about two-week intervals (Iwamoto et al. 1985; Eckert 1993). Mean inter-nesting intervals of 14 and 15 days have been reported at Miyazaki Beach (Kyūshū) and Inakahama Beach (Yakushima Island), respectively (Iwamoto et al. 1985; Nishimura 1994). It is believed that water temperatures dictate the length of inter-nesting intervals, with lower water temperatures causing longer inter-nesting intervals (Sato et al. 1998). Remote sensing studies suggest that nesting loggerheads swim offshore into the Kuroshio Current during the first few days of their inter-nesting interval, presumably to find warmer water temperatures more suitable for egg development (NMFS and USFWS 1998d; Sato et al. 1998). During inter-nesting intervals, adult loggerheads may rest on the seabed, feed near the surface in deep waters, or spend long periods resting in mid-water (Sakamoto et al. 1990; Minamikawa et al. 2000; Houghton et al. 2002). Loggerhead clutches contain between 60 and 150 eggs and take anywhere from 45 to 82 days to incubate, depending on the time of year. On Japanese nesting beaches, there is a negative correlation between sand temperature and incubation periods, with higher sand temperatures leading to shorter incubation periods and vice versa (Matsuzawa et al. 2002). Adult females nest at multiple year intervals, with the majority nesting every two to three years (Iwamoto et al. 1985).

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

- Olive Ridley Turtle (*Lepidochelys olivacea*)

Description—The olive ridley turtle, known as “himeumigame” in Japanese, is a small, hard-shelled sea turtle named for its olive-green colored shell. Adults often measure between 60 and 70 cm in

carapace length and rarely weigh over 50 kg. The carapace of an olive ridley turtle is wide and almost circular in shape. The olive ridley differs from the Kemp's ridley, the other member of the genus *Lepidochelys*, in that it possesses a smaller head, a narrower carapace, and several more lateral carapace scutes (NMFS and USFWS 1998e).

Status—Olive ridley turtles are classified as threatened under the ESA, although the Mexican Pacific coast nesting population is currently listed as endangered. The 2004 IUCN Red List identifies the olive ridley as endangered worldwide (IUCN 2004). Since its ESA listing in 1978, there has been a general decline in the abundance of this species throughout the Pacific Ocean. Until the advent of commercial exploitation, the olive ridley was highly abundant in the eastern tropical Pacific, probably outnumbering all other sea turtle species combined in the area (NMFS and USFWS 1998e). Clifton et al. (1995) estimated that a minimum of 10 million olive ridleys were present in ocean waters off the Pacific coast of Mexico prior to 1950. Even though there are no current estimates of worldwide abundance, the olive ridley is still considered the world's most abundant sea turtle. However, the species is relatively scarce throughout the western Pacific Ocean (NMFS and USFWS 1998e).

Habitat Preferences—There is little information available on the nursery habitats utilized by early juvenile olive ridleys in the Pacific Ocean. However, scientists with the NMFS-SWFSC have observed concentrations of early juveniles in oceanic waters where flotsam and debris were visible at the surface. It is possible that young age classes occupy convergence zones in offshore waters, where they are able to find food and shelter among aggregated floating objects (NMFS and USFWS 1998e).

Late juvenile and adult olive ridleys also typically inhabit offshore waters, foraging either at the surface or at depth. They usually feed down to depths of 150 m, although one individual was observed feeding on crustaceans at a depth of 290 m. This deep-diving individual was originally thought to be a green turtle (Landis 1965), although it was later verified by Eckert et al. (1986) that it was in fact an olive ridley. Polovina et al. (2004) noted that late juvenile olive ridleys in the North Pacific Ocean are found primarily between 8°N and 31°N in waters between 23° and 28°C.

Distribution—The olive ridley turtle is a pantropical species, occurring worldwide in tropical and warm temperate waters. It is by far the most common and widespread sea turtle in the Pacific Ocean. Individuals in the eastern Pacific regularly occur in waters as far north as California and as far south as Ecuador, although the species' main foraging area is located between Mexico and Colombia (Pitman 1990; NMFS and USFWS 1998e). In offshore areas far from North and South America, olive ridley turtles become increasingly uncommon, both at sea and around oceanic islands (Balazs 1995). However, small numbers of olive ridleys are known to forage in the central North Pacific Ocean. This is evidenced by occasional captures of this species in the Hawaiian longline fishery (Dutton et al. 2000; Polovina et al. 2003, 2004).

Olive ridleys are rare visitors to the waters off Japan (Uchida 1994; Uchida and Nishiwaki 1995), but are regular inhabitants of several areas to the south (e.g., waters off India, China, Malaysia, and Papua New Guinea; Eckert 1993). Available information suggests that olive ridleys may traverse through oceanic waters offshore of the Japanese archipelago during foraging and developmental migrations, although the Kuroshio Current likely serves as the northern limit of this species' distribution in the western Pacific (Kamezaki and Matsui 1997). Winter strandings of olive ridleys along the west coast of mainland Japan also indicate an occasional presence of the species in the Sea of Japan and the likely entrainment of those individuals in the Tsushima Current (Honma and Yoshie 1975; Matsuzawa personal communication).

Bordering the Indian Ocean, the shores of Orissa, India are home to the world's largest nesting aggregation of olive ridley turtles (Shanker et al. 2003). The world's second largest nesting population of olive ridleys occurs in the eastern Pacific Ocean along the west coasts of Mexico and Central America (NMFS and USFWS 1998e). The largest rookeries in this region are found in southern Mexico (La Escobilla) and northern Costa Rica (Playas Nancite and Ostional), with some individuals nesting as far north as Baja California (Fritts et al. 1982; López-Castro et al. 2000). Olive ridley nesting also takes place in the western Pacific Ocean along the shores of Malaysia and Thailand, but

in smaller numbers (Eckert 1993). Due to their preference for beaches located along continental margins, female olive ridleys are not expected to nest in the central Pacific Ocean (Balazs 1995).

Incidental captures of olive ridleys in the Hawaiian longline fishery demonstrate that individuals from western Pacific nesting populations often forage in the central North Pacific Ocean (Dutton et al. 1999). Olive ridleys of western Pacific origin have been observed in association with major ocean currents of the central North Pacific, specifically the southern edge of the Kuroshio Extension Current, the Northern Equatorial Current, and the Equatorial Counter Current. These habitats, which are also frequented by Pacific loggerhead turtles, are probably not used as frequently by olive ridleys of eastern Pacific origin. Instead, olive ridleys from eastern Pacific nesting populations seem to inhabit waters in the center of the NPSG system, which are characterized by warmer temperatures, weaker currents, greater vertical stratification, and a deeper thermocline (Polovina et al. 2003, 2004). About one-third of all olive ridleys found in the central North Pacific are derived from western Pacific or Indian Ocean nesting populations (HDLNR 2002).

- Information Specific to the Japan and Okinawa Complexes OPAREA—The occurrence of the olive ridley turtle is low or unknown throughout the year in all waters of the OPAREA that are seaward of the continental shelf break and south of the Kuroshio Current deflection off the coast of Honshū (**Figure B-5**). Olive ridleys are primarily a tropical and oceanic species and are, therefore, not expected to occur on the continental shelf off eastern and southern Japan, on the insular shelves surrounding the Ryukyu and Ogasawara Islands, nor in any waters of the western North Pacific Ocean north of the Kuroshio Current deflection. Strandings of olive ridleys on the west coast of Japan indicate a low or unknown occurrence of this species in the Sea of Japan (Honma and Yoshie 1975; Matsuzawa personal communication). It is likely that the Kuroshio and Tsushima Currents carried these individuals north from their more southerly centers of distribution (Eckert 1993; Kamezaki and Matsui 1997). As a result, the waters of the East China Sea are also designated as an area of low/unknown occurrence.

Behavior and Life History—The olive ridley turtle is considered omnivorous, eating a variety of benthic and pelagic prey items including fish, crabs, shrimp, snails, oysters, sea urchins, jellyfish, salps, fish eggs, and vegetation (NMFS and USFWS 1998e). However, crustaceans and fish serve as their primary food source. Olive ridleys that interact with the Hawaiian longline fishery are known to feed predominantly on tunicates (salps and pyrosomas), which are found well below the water surface (Polovina et al. 2004).

At sea, olive ridleys readily associate with floating objects such as logs, plastic debris, and even dead whales (Arenas and Hall 1992; Pitman 1992). Scientists believe that olive ridley turtles associate with flotsam since it provides them with shelter from predators and an abundance of prey items (NMFS and USFWS 1998e). Olive ridleys in the eastern Pacific Ocean are also known to bask at the surface, where they are often accompanied by seabirds that will roost upon their exposed carapaces and feed on fish that aggregate beneath them (Pitman 1993). Surface basking allows an olive ridley turtle to conserve energy, avoid predators, and raise its body temperature (Gulko and Eckert 2004).

There is currently no estimate of the age at which olive ridleys begin to reproduce; however, nesting adults usually range between 50 and 75 cm in carapace length (NMFS and USFWS 1998e). Unlike all other species of sea turtle except the Kemp's ridley, the olive ridley is known for nesting en masse. This type of nesting activity is known as an *arribada* (Spanish for "arrival"). During an *arribada*, hundreds to tens of thousands of breeding olive ridleys congregate in the waters in front of the nesting beach and then, signaled by some unknown cue, emerge from the sea in unison. Nesting occurs throughout the year, peaking from August to December in the eastern Pacific, from February to July in Malaysia, and from October to February in Thailand. Females usually nest every 1 to 2 years. A typical female produces two clutches per nesting season, with each clutch averaging 105 eggs. Lone individuals nest at 15 to 17 day intervals while mass nesters arrive to the nesting beach at 28 day intervals. Incubation time from deposition to emergence is approximately 55 days (Eckert 1993; NMFS and USFWS 1998e).

Relatively few studies have investigated the diving behavior of olive ridley turtles. In the eastern tropical Pacific Ocean, olive ridleys make more frequent submergences and spend more time at the surface during the day than at night (Beavers and Cassano 1996; Parker et al. 2003). As a result, nighttime dives are longer in duration (reaching a maximum of 95.5 min). Olive ridleys have been observed at depths of 290 m, although only about 10% of their time is spent at depths greater than 100 m (S. Eckert et al. 1986; Polovina et al. 2003). It appears that the eastern tropical Pacific's permanent thermocline, located at depths between 20 and 100 m, is an important foraging area for adult olive ridleys, as at least 25% of their total dive time is spent there (Parker et al. 2003).

- Leatherback Turtle (*Dermochelys coriacea*)

Description—The leatherback turtle, known in Japan as "osagame," is the largest living sea turtle. These turtles are placed in the family Dermochelyidae, a separate family from all other sea turtles, in part because of their unique carapace structure. A leatherback's carapace lacks the outer layer of horny scutes (bony external plates or scales) possessed by all other sea turtles; instead, it is composed of a flexible layer of dermal bones underlying tough, oily connective tissue and smooth skin. The body of a leatherback is barrel-shaped and tapered to the rear, with seven longitudinal dorsal ridges, and is almost completely black with variable spotting. All adults possess a pink spot on the dorsal surface of their head, a marking that is used by scientists to identify specific individuals (McDonald and Dutton 1996). Adult carapace lengths range from 119 to 176 cm with an average around 145 cm. Adult leatherbacks weigh between 200 and 700 kg (NMFS and USFWS 1998f).

Status—Leatherback turtles are classified as endangered under the ESA and are listed as critically endangered on the 2004 IUCN Red List (IUCN 2004). If current trends in mortality persist, leatherback turtles may become extinct in the Pacific Ocean within the next several decades. Lewison et al. (2004) estimated that more than 50,000 leatherbacks were taken as pelagic longline bycatch in 2000 and that thousands of these turtles die each year from longline gear interactions in the Pacific Ocean alone. Leatherbacks are seriously declining at most Pacific Ocean rookeries, including Indonesia, Malaysia, and southwestern Mexico (NMFS and USFWS 1998f). The Pacific Ocean may now contain as few as 2,300 adult females (Crowder 2000).

A number of western Pacific nesting populations have declined dramatically over the last 25 years. These declines have been attributed to a combination of egg harvesting and incidental bycatch in coastal and offshore fisheries. However, some scientists believe that indirect human interventions on leatherback nesting beaches, such as the clearing of vegetation, are currently playing an even greater role in the species' demise. Beach vegetation clearance has been known to cause increased temperatures on leatherback turtle nesting beaches and highly skewed female hatchling sex ratios. In turn, this increase in female production could be resulting in a severe shortage of adult males and a low probability of adult females finding a mate, also known as the Allee effect (Chaloupka 2003).

Habitat Preferences—There is limited information available regarding the habitats utilized by early juvenile leatherbacks because this age class is entirely oceanic. However, scientists are relatively certain that these individuals do not associate with floating debris or vegetation, as is the case for the other four sea turtle species found in the western North Pacific Ocean (NMFS and USFWS 1998f). It is also known that juveniles up to 100 cm in curved carapace length (CCL) are generally restricted to lower latitudes, where water temperatures are greater than 26°C. The transition at 100 cm is relatively abrupt, with leatherbacks as small as 107 cm CCL having been observed in waters as cold as 12°C. It appears that some juveniles migrate seasonally to higher latitudes, but only when water temperatures there reach 26°C and above (Eckert 2002).

Late juvenile and adult leatherback turtles are known to range from mid-ocean to the continental shelf and nearshore waters (Schroeder and Thompson 1987; Shoop and Kenney 1992; Grant and Ferrell 1993; Starbird et al. 1993). Juvenile and adult foraging habitats include both coastal feeding areas in temperate waters and offshore feeding areas in tropical waters (Frazier 2001). The movements of adult leatherbacks appear to be linked to the seasonal availability of their prey and the requirements of their reproductive cycle (Collard 1990; Davenport and Balazs 1991). Leatherbacks prefer

convergence zones and upwelling areas in the open ocean, along continental margins, or near large archipelagos (HDLNR 2002; Eckert personal communication).

Distribution—The leatherback turtle is distributed circumglobally in tropical and subtropical waters throughout the year and will often move into cooler temperate and sometimes boreal waters during late summer and early fall (Keinath and Musick 1990; Eckert personal communication). Of the seven living species of sea turtles, the leatherback is the most oceanic and has the widest range (Boulon et al. 1988). The oceanic distribution of the leatherback likely reflects the distribution and abundance of its macroplanktonic prey (e.g., jellyfish, salps, and siphonophores; NMFS and USFWS 1998f). The wide range of the leatherback can be attributed to its highly evolved thermoregulatory capabilities. Leatherbacks can maintain body core temperatures well above the ambient water temperature. For example, a leatherback caught off Nova Scotia, Canada had a body temperature of 25.5°C in water that was 7.5°C (Frair et al. 1972). A variety of studies have shown that leatherbacks have a range of anatomical and physiological adaptations that enable them to regulate internal body temperatures (Mrosovsky and Pritchard 1971; Greer et al. 1973; Neill and Stevens 1974; Goff and Stenson 1988; Paladino et al. 1990). As a result, they are more capable of surviving for extended periods of time in cool temperate and boreal waters than the hard-shelled sea turtles (Bleakney 1965; Lazell 1980).

Leatherback turtles also engage in some of the longest migrations of any sea turtle species. These extensive journeys often run along distinct depth contours for hundreds to thousands of kilometers (Morreale et al. 1996; Hughes et al. 1998). Using satellite telemetry, Morreale et al. (1996), Eckert and Sarti-M. (1997), and Eckert (1999) determined that post-nesting leatherbacks in the eastern Pacific Ocean use similar, and in some cases identical, migratory pathways. These studies, which were initiated on nesting beaches in Costa Rica and Mexico, demonstrated that leatherback turtles from eastern Pacific nesting stocks will navigate to South American waters after egg-laying is complete. Scientists believe that migratory corridors for Pacific leatherbacks also exist in offshore waters surrounding the Hawaiian Islands and along the eastern seaboards of Asia and Australia (Nitta and Henderson 1993; NMFS and USFWS 1998f; Eckert personal communication).

In the North Pacific Ocean, leatherback turtles are broadly distributed from the tropics to as far north as Alaska, where 19 occurrences were documented between 1960 and 2001 (Wing and Hodge 2002). This species has been reported from western Pacific waters as far north as the Bering Sea and as far south as Tasmania and New Zealand, with seasonal aggregations noted in the South China Sea (Eckert 1993). Leatherback sightings off Japan are few, although they are known to pass by the archipelago during developmental, foraging, or reproductive migrations (Uchida and Nishiwaki 1995; STAJ 2005a). Numerous strandings have also been recorded along the Sea of Japan during winter months (Kamezaki and Matsui 1997). The leatherback is not typically found around insular habitats, such as those characterized by coral reefs, yet individuals are occasionally encountered in deep ocean waters near prominent archipelagos such as the Hawaiian Islands and the Philippines.

Historically, some of the world's largest nesting populations of leatherback turtles were found in the Pacific Ocean (NMFS and USFWS 1998f). The Pacific coast of Mexico used to be regarded as the most important leatherback breeding ground in the world (Sarti-M. et al. 1996). In the late 1970s, roughly one-half of the world's leatherback population nested there (Pritchard 1982). Recent data, however, suggest that the world's largest nesting population of leatherbacks has collapsed (Sarti-M. et al. 1996). Other principal nesting sites in the Pacific Ocean include beaches in Malaysia, Indonesia, Papua New Guinea, and Costa Rica (Spotila et al. 1996; NMFS and USFWS 1998f). Leatherbacks generally do not nest in Japan (Uchida and Nishiwaki 1995), although two nests were recorded on Amami-Oshima Island in the central Ryukyu Islands in 2002 (Kamezaki et al. 2002).

- Information Specific to the Japan and Okinawa Complexes OPAREA—Leatherback turtles are rare inhabitants of the western North Pacific Ocean; thus, their occurrence is low or unknown throughout much of the OPAREA year round (**Figure B-6**). Leatherbacks are not expected to occur in continental shelf waters off eastern and southern Japan, as there is a lack of documented sightings and strandings in those areas. Nor are they expected to occur in shelf waters surrounding any of the Ryukyu or Ogasawara Islands, due to their weak association with

insular habitats (Eckert 1993). Leatherback occurrence is low or unknown in offshore waters of the OPAREA since the species is primarily oceanic. The species' occurrence is also low or unknown in the Sea of Japan and East China Sea since migratory pathways are believed to exist along the East Asian continent (NMFS and USFWS 1998f). Recently, a post-nesting leatherback migrated into the Sea of Japan through the East China Sea after laying its last nest of the season in Irian Jaya, Indonesia. This indicates that the proposed migratory pathway for leatherbacks off East Asia may encompass those two seas (Dutton personal communication). There have also been a number of winter strandings recorded along the Sea of Japan, indicating a potential low occurrence off Japan's west coast (Honma and Yoshie 1975; Kamezaki and Matsui 1997).

Behavior and Life History—Leatherback turtles feed upon gelatinous zooplankton such as cnidarians (jellyfish and siphonophores) and tunicates (salps and pyrosomas); however, a wide variety of other prey items are known (Bjorndal 1997; NMFS and USFWS 1998f). Although the dietary preferences of leatherbacks in the western Pacific Ocean have not been thoroughly investigated, much is known about their diets in the eastern and central Pacific. Eisenberg and Frazier (1983) recorded an adult leatherback feeding on *Aurelia* jellyfish in waters off the coast of Washington State while Stinson (1984) noted that sightings of leatherbacks off Oregon often corresponded with large aggregations of *Velella* jellyfish. In California's Monterey Bay, leatherbacks are believed to feed on several species of large jellyfish known as scyphomedusae (Starbird et al. 1993). In offshore waters of the central North Pacific Ocean, leatherbacks appear to feed primarily on pyrosomas, although they have also been known to ingest longline hooks baited with sama (tuna bait) and squid (swordfish bait) (Davenport and Balazs 1991; Skillman and Balazs 1992; Grant 1994; Work and Balazs 2002).

Leatherbacks feed throughout the water column and dive as deep as 1,200 m (Eisenberg and Frazier 1983; Davenport 1988; S. Eckert et al. 1989). In temperate waters of the North Pacific Ocean, leatherbacks spend most of their time foraging at depths less than 100 m, although occasionally they'll make a deep dive while feeding (Eckert personal communication). Studies of leatherback turtle diving patterns off St. Croix suggest that individuals in tropical waters forage at night on the deep-scattering layer (DSL), a strata of vertically migrating zooplankton (primarily siphonophores, salps, and jellyfish) that concentrates below 600 m during the day and moves to the surface at night (S. Eckert et al. 1989). During migrations or long distance movements, leatherbacks maximize swimming efficiency by traveling within 5 m of the surface (Eckert 2002; Eckert personal communication).

Mating is thought to occur prior to or during the migration from temperate to tropical waters in some populations (Eckert and Eckert 1988). However, in other populations, males have been shown to arrive one to two months before the onset of nesting and remain until peak nesting. This latter behavior is consistent with the expectation that mating takes place directly off the nesting beach 30 to 60 days before egg production (Eckert personal communication). In the western Pacific Ocean, nesting peaks in May and June in China, June and July in Malaysia, and December and January in Queensland, Australia. Typical clutches range in size from 80 to over 150 eggs and take between 55 and 75 days to incubate. Data collected at rookeries in southwestern Mexico indicate that Pacific leatherbacks lay between one and 11 clutches in a nesting season at 9 to 10 day intervals. Studies at Atlantic nesting beaches demonstrate that females remain in the general vicinity of the nesting habitat during inter-nesting intervals, with total residence in the nesting/inter-nesting habitat lasting up to four months (K. Eckert et al. 1989; Keinath and Musick 1993). Pacific leatherbacks typically return to nest on their natal beach every two to three years (NMFS and USFWS 1998f).

The leatherback is the deepest diving sea turtle (Eckert et al. 1986). Leatherbacks in deepwater (open ocean) environments frequently exhibit V-shaped dive patterns, in which they descend to a certain depth and then immediately ascend to the surface. Leatherbacks in shallow water (continental shelf) environments, such as the South China Sea, more often exhibit U-shaped dive patterns, in which they swim down to the ocean floor, remain near the bottom for several minutes, and then return directly to the surface (Eckert et al. 1996). The maximum dive depth recorded for a post-nesting leatherback in the South China Sea was 62 m, the maximum depth of the ocean floor in that area. Average dive depths for post-nesting leatherbacks off the continental shelf of St. Croix (a deepwater habitat) ranged from 35 to 122 m, with estimated maximum depths of over 1,000 m. Typical dive

durations in shallow water habitats averaged 7.9 to 12.1 min per dive, while those in deepwater habitats averaged 6.9 to 14.5 min. On average, day dives tended to be deeper, longer, and less frequent than those at night in both types of habitats (S. Eckert et al. 1989; Eckert et al. 1996).

3.2.3 Literature Cited

Abe, O., Y. Takada, T. Shibuno, K. Hashimoto, and S. Tanizaki. 1998. Nesting activity of sea turtles on Ishigaki Island, Ryukyu Islands, Japan. Page 115 in S.P. Epperly and J. Braun, eds. Proceedings of the Seventeenth Annual Sea Turtle Symposium. NOAA Technical Memorandum NMFS-SEFSC-415.

André, J., E. Gyuris, and I.R. Lawler. 2005. Comparison of the diets of sympatric dugongs and green turtles on the Orman Reefs, Torres Strait, Australia. Wildlife Research 32:53-62.

Arenas, P., and M. Hall. 1992. The association of sea turtles and other pelagic fauna with floating objects in the eastern tropical Pacific Ocean. Pages 7-10 in M. Salmon and J. Wyneken, eds. Proceedings of the Eleventh Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-302.

Balazs, G.H. 1976. Green turtle migrations in the Hawaiian archipelago. Biological Conservation 9:125-140.

Balazs, G.H. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. NOAA Technical Memorandum NMFS-SWFC-7:1-141.

Balazs, G.H. 1983. Recovery records of adult green turtles observed or originally tagged at French Frigate Shoals, Northwestern Hawaiian Islands. NOAA Technical Memorandum NMFS-SWFC-36:1-42.

Balazs, G.H. 1995. Status of sea turtles in the central Pacific Ocean. Pages 243-252 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Balazs, G.H. 2004. The Hawaiian green turtle (*Chelonia mydas*). Accessed 16 August 2005. http://www.turtles.org/hawgrnd.htm.

Balazs, G.H., and M. Chaloupka. 2004. Thirty-year recovery trend in the once depleted Hawaiian green sea turtle stock. Biological Conservation 117:491-498.

Balazs, G.H., and D.M. Ellis. 2000. Satellite telemetry of migrant male and female green turtles breeding in the Hawaiian Islands. Pages 281-283 in F.A. Abreu-Grobois, R. Briseño-Dueñas, R. Márquez, and L. Sarti, eds. Proceedings of the Eighteenth International Sea Turtle Symposium. NOAA Technical Memorandum NMFS-SEFSC-436.

Balazs, G.H., P. Craig, B.R. Winton, and R.K. Miya. 1994. Satellite telemetry of green turtles nesting at French Frigate Shoals, Hawaii, and Rose Atoll, American Samoa. Pages 184-187 in K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds. Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Bane, G. 1992. First report of a loggerhead sea turtle from Alaska. Marine Turtle Newsletter 58:1-2.

Bass, A.L. 1994. Population structure of hawksbill rookeries in the Caribbean and western Atlantic. Page 17 in K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds. Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Beavers, S.C., and E.R. Cassano. 1996. Movements and dive behavior of a male sea turtle (*Lepidochelys olivacea*) in the eastern tropical Pacific. Journal of Herpetology 30(1):97-104.

Berkson, H. 1967. Physiological adjustments to deep diving in the Pacific green turtle (*Chelonia mydas agassizii*). Comparative Biochemistry and Physiology 21:507-524.

Bjorndal, K. 1997. Foraging ecology and nutrition of sea turtles. Pages 199-231 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Bjorndal, K.A., ed. 1995. Biology and conservation of sea turtles. Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Bjorndal, K.A., and A.B. Bolten. 1988. Growth rates of immature green turtles, *Chelonia mydas*, on feeding grounds in the southern Bahamas. Copeia 1988(3):555-564.

Bjorndal, K.A., A.B. Bolten, and H.R. Martins. 2000. Somatic growth model of juvenile loggerhead sea turtles *Caretta caretta*: Duration of pelagic stage. Marine Ecology Progress Series 202:265-272.

Bleakney, J.S. 1965. Reports of marine turtles from New England and eastern Canada. Canadian Field-Naturalist 79:120-128.

Bolten, A.B., and B.E. Witherington, eds. 2003. Loggerhead sea turtles. Washington, D.C.: Smithsonian Institution Press.

Bolten, A.B., K.A. Bjorndal, H.R. Martins, T. Dellinger, M.J. Biscoito, S.E. Encalada, and B.W. Bowen. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. Ecological Applications 8:1-7.

Boulon, R.H., Jr., K.L. Eckert, and S.A. Eckert. 1988. *Dermochelys coriacea* (leatherback sea turtle). Migration. Herpetological Review 19(4):88.

Bowen, B.W., and S.A. Karl. 1997. Population genetics, phylogeography, and molecular evolution. Pages 29-50 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Bowen, B.W., F.A. Abreu-Grobois, G.H. Balazs, N. Kamezaki, C.J. Limpus, and R.J. Ferl. 1995. Trans-Pacific migrations of the loggerhead turtle (*Caretta caretta*) demonstrated with mitochondrial DNA markers. Proceedings of the National Academy of Sciences USA 92:3731-3734.

Brill, R.W., G.H. Balazs, K.N. Holland, R.K.C. Chang, S. Sullivan, and J. George. 1995. Daily movements, habitat use, and submergence intervals of normal and tumor-bearing juvenile green turtles (*Chelonia mydas* L.) within a foraging area in the Hawaiian Islands. Journal of Experimental Marine Biology and Ecology 185:203-218.

Burke, V.J., S.J. Morreale, P. Logan, and E.A. Standora. 1992. Diet of green turtles (*Chelonia mydas*) in the waters of Long Island, New York. Pages 140-142 in M. Salmon and J. Wyneken, eds. Proceedings of the Eleventh Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-302.

Byles, R.A. 1988. Behavior and ecology of sea turtles from Chesapeake Bay, Virginia. Ph.D. diss., College of William and Mary.

Carr, A. 1987. New perspectives on the pelagic stage of sea turtle development. Conservation Biology 1(2):103-121.

Carr, A. 1995. Notes on the behavioral ecology of sea turtles. Pages 19-26 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

CCC (Caribbean Conservation Corporation), and STSL (Sea Turtle Survival League). 2003. An introduction to sea turtles: An overview. Accessed 16 August 2005. http://www.cccturtle.org/overview.htm.

Chaloupka, M.Y. 2003. Is the decline in some western Pacific leatherback populations attributable to temperature-dependent sex-determination? Page 4 in J.A. Seminoff, ed. Proceedings of the Twenty-Second Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-503.

Chaloupka, M.Y., and J.A. Musick. 1997. Age, growth, and population dynamics. Pages 233-276 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Chan, S.K.F., J.K. Chan, L.T. Lo, and G.H. Balazs. 2003. Satellite tracking of the post-nesting migration of a green turtle (*Chelonia mydas*) from Hong Kong. Marine Turtle Newsletter 102:2-4.

Chandler, M. 1991. New records of marine turtles in Chile. Marine Turtle Newsletter 52:8-11.

Cheng, I.J. 2000. Post-nesting migrations of green turtles (*Chelonia mydas*) at Wan-An Island, Penghu Archipelago, Taiwan. Marine Biology 137:747-754.

Cheng, I.J., and T.H. Chen. 1997. The incidental capture of five species of sea turtles by coastal setnet fisheries in the eastern waters of Taiwan. Biological Conservation 82:235-239.

Cliffton, K., D.O. Cornejo, and R.S. Felger. 1995. Sea turtles of the Pacific coast of Mexico. Pages 199-209 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Coles, W.C., and J.A. Musick. 2000. Satellite sea surface temperature analysis and correlation with sea turtle distribution off North Carolina. Copeia 2000(2):551-554.

Collard, S.B. 1990. Leatherback turtles feeding near a watermass boundary in the eastern Gulf of Mexico. Marine Turtle Newsletter 50:12-14.

Cornelius, S.E. 1995. Status of sea turtles along the Pacific coast of Middle America. Pages 211-219 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Craig, P., D. Parker, R. Brainard, M. Rice, and G. Balazs. 2004. Migrations of green turtles in the central South Pacific. Biological Conservation 116:433-438.

Crowder, L. 2000. Leatherback's survival will depend on an international effort. Nature 405:881.

Davenport, J. 1988. Do diving leatherbacks pursue glowing jelly? British Herpetological Society Bulletin 24:20-21.

Davenport, J. 1997. Temperature and the life-history strategies of sea turtles. Journal of Thermal Biology 22(6):479-488.

Davenport, J., and G.H. Balazs. 1991. 'Fiery bodies' – Are pyrosomas an important component of the diet of leatherback turtles? British Herpetological Society Bulletin 37:33-38.

Diez, C.E., X. Veliz-Zuazo, and R.P. van Dam. 2003. Hawksbill turtles in seagrass beds. Marine Turtle Newsletter 102:8-10.

Dodd, C.K. 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). U.S. Fish and Wildlife Service Biological Report 88(14):1-110.

Donoso-P., M., P.H. Dutton, R. Serra, and J.L. Brito-Montero. 2000. Sea turtles found in waters off Chile. Pages 218-219 in H. Kalb and T. Wibbels, eds. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443.

Dutton, P., and D. McDonald. 1990. Status of sea turtles in San Diego Bay: 1989-1990 final report. Sea World Research Institute Technical Report 90-225:1-18.

Dutton, P.H. 2005. Personal communication between Dr. Peter Dutton, National Marine Fisheries Service-Southwest Fisheries Science Center, La Jolla, California, and Dr. Yoshimasa Matsuzawa, Sea Turtle Association of Japan, Osaka, Japan, 20 January.

Dutton, P.H., G.H. Balazs, and A.E. Dizon. 1998. Genetic stock identification of sea turtles caught in the Hawaii-based pelagic longline fishery. Pages 43-44 in S.P. Epperly and J. Braun, eds. Proceedings of the Seventeenth Annual Sea Turtle Symposium. NOAA Technical Memorandum NMFS-SEFSC-415.

Dutton, P.H., B.W. Bowen, D.W. Owens, A. Barragan, and S.K. Davis. 1999. Global phylogeography of the leatherback turtle (*Dermochelys coriacea*). Journal of Zoology, London 248:397-409.

Dutton, P.H., E. Bixby, R. LeRoux, and G. Balazs. 2000. Genetic stock origin of sea turtles caught in the Hawaii-based longline fishery. Pages 120-121 in H. Kalb and T. Wibbels, eds. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443.

Eckert, K.L. 1987. Environmental unpredictability and leatherback sea turtle (*Dermochelys coriacea*) nest loss. Herpetologica 43(3):315-323.

Eckert, K.L. 1993. The biology and population status of marine turtles in the North Pacific Ocean. NOAA Technical Memorandum NMFS-SWFSC-186:1-156.

Eckert, K.L. 1995. Anthropogenic threats to sea turtles. Pages 611-612 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Eckert, K.L., and S.A. Eckert. 1988. Pre-reproductive movements of leatherback sea turtles (*Dermochelys coriacea*) nesting in the Caribbean. Copeia 1988(2):400-406.

Eckert, K.L., and C. Luginbuhl. 1988. Death of a giant. Marine Turtle Newsletter 43:2-3.

Eckert, K.L., S.A. Eckert, T.W. Adams, and A.D. Tucker. 1989. Inter-nesting migrations by leatherback sea turtles (*Dermochelys coriacea*) in the West Indies. Herpetologica 45:190-194.

Eckert, S.A. 1999. Habitats and migratory pathways of the Pacific leatherback sea turtle. Final report to the National Marine Fisheries Service, Office of Protected Resources. Hubbs Sea World Research Institute Technical Report 99-290:1-15.

Eckert, S.A. 2002. Distribution of juvenile leatherback sea turtle *Dermochelys coriacea* sightings. Marine Ecology Progress Series 230:289-293.

Eckert, S.A. 2005. Personal communication between Dr. Scott Eckert, Wider Caribbean Sea Turtle Conservation Network, Beaufort, North Carolina, and Mr. William Barnhill, Geo-Marine, Inc., Plano, Texas, 18 March.

Eckert, S.A., and L. Sarti-M. 1997. Distant fisheries implicated in the loss of the world's largest leatherback nesting population. Marine Turtle Newsletter 78:2-7.

Eckert, S.A., D.W. Nellis, K.L. Eckert, and G.L. Kooyman. 1986. Diving patterns of two leatherback sea turtles (*Dermochelys coriacea*) during internesting intervals at Sandy Point, St. Croix, U.S. Virgin Islands. Herpetologica 42:381-388.

Eckert, S.A., K.L. Eckert, P. Ponganis, and G.L. Kooyman. 1989. Diving and foraging behavior of leatherback sea turtles (*Dermochelys coriacea*). Canadian Journal of Zoology 67:2834-2840.

Eckert, S.A., H.C. Liew, K.L. Eckert, and E.H. Chan. 1996. Shallow water diving by leatherback turtles in the South China Sea. Chelonian Conservation and Biology 2:237-243.

Ehrhart, L.M. 1995. A review of sea turtle reproduction. Pages 29-38 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Eisenberg, J.F., and J. Frazier. 1983. A leatherback turtle (*Dermochelys coriacea*) feeding in the wild. Journal of Herpetology 17:81-82.

Epperly, S.P., J. Braun, A.J. Chester, F.A. Cross, J.V. Merriner, and P.A. Tester. 1995. Winter distribution of sea turtles in the vicinity of Cape Hatteras and their interactions with the summer flounder trawl fishery. Bulletin of Marine Science 56:547-568.

Ernst, C.H., J.E. Lovich, and R.W. Barbour. 1994. Turtles of the United States and Canada. Washington, D.C.: Smithsonian Institution Press.

Frair, W., R.G. Ackman, and N. Mrosovsky. 1972. Body temperature of *Dermochelys coriacea*: Warm turtle from cold water. Science 177:791-793.

Frazer, N.B. 1986. Survival from egg to adulthood in a declining population of loggerhead turtles, *Caretta caretta*. Herpetologica 42(1):47-55.

Frazer, N.B., and L.M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles in the wild. Copeia 1985(1):73-79.

Frazier, J.G. 2001. General natural history of marine turtles. Pages 3-17 in K.L. Eckert and F.A. Abreu-Grobois, eds. Proceedings of the regional meeting: "Marine turtle conservation in the wider Caribbean region: a dialogue for effective regional management." Santo Domingo, Dominican Republic: WIDECAST, IUCN-MTSG, WWF, and UNEP-CEP.

Fritts, T.H., M.L. Stinson, and R. Márquez-M. 1982. Status of sea turtle nesting in southern Baja California, Mexico. Bulletin of the Southern California Academy of Sciences 81(2):51-60.

Goff, G.P., and G.B. Stenson. 1988. Brown adipose tissue in leatherback sea turtles: A thermogenic organ in an endothermic reptile? Copeia 1988(4):1071-1075.

Grant, G.S. 1994. Juvenile leatherback turtle caught by longline fishing in American Samoa. Marine Turtle Newsletter 66:3-5.

Grant, G.S., and D. Ferrell. 1993. Leatherback turtle, *Dermochelys coriacea* (Reptilia: Dermochelidae): Notes on near-shore feeding behavior associated with cobia. Brimleyana 19:77-81.

Greer, A.E., Jr., J.D. Lazell, Jr., and R.M. Wright. 1973. Anatomical evidence for a counter-current heat exchanger in the leatherback turtle (*Dermochelys coriacea*). Nature 244:181.

Gulko, D.A., and K.L. Eckert. 2004. Sea turtles: An ecological guide. Honolulu, Hawaii: Mutual Publishing.

Gutierrez, J. 2004. Guam sea turtle recovery annual progress report. Mangilao: Guam Division of Aquatic and Wildlife Resources.

Hatase, H., and W. Sakamoto. 2004. Forage-diving behaviour of adult Japanese female loggerhead turtles (*Caretta caretta*) inferred from Argos location data. Journal of the Marine Biological Association of the United Kingdom 84:855-856.

Hatase, H., M. Kinoshita, T. Bando, N. Kamezaki, K. Sato, Y. Matsuzawa, K. Goto, K. Omuta, Y. Nakashima, H. Takeshita, and W. Sakamoto. 2002a. Population structure of loggerhead turtles, *Caretta caretta*, nesting in Japan: Bottlenecks on the Pacific population. Marine Biology 141:299-305.

Hatase, H., K. Goto, K. Sato, T. Bando, Y. Matsuzawa, and W. Sakamoto. 2002b. Using annual body size fluctuations to explore potential causes for the decline in a nesting population of the loggerhead turtle *Caretta caretta* at Senri Beach, Japan. Marine Ecology Progress Series 245:299-304.

Hatase, H., N. Takai, Y. Matsuzawa, W. Sakamoto, K. Omuta, K. Goto, N. Arai, and T. Fujiwara. 2002c. Size-related differences in feeding habitat use of adult female loggerhead turtles *Caretta caretta* around Japan determined by stable isotope analyses and satellite telemetry. Marine Ecology Progress Series 233:273-281.

Hatase, H., Y. Matsuzawa, W. Sakamoto, N. Baba, and I. Miyawaki. 2002d. Pelagic habitat use of an adult Japanese male loggerhead turtle *Caretta caretta* examined by the Argos satellite system. Fisheries Science 68:945-947.

Hatase, H., Y. Matsuzawa, K. Sato, T. Bando, and K. Goto. 2004. Remigration and growth of loggerhead turtles (*Caretta caretta*) nesting on Senri Beach in Minabe, Japan: Life-history polymorphism in a sea turtle population. Marine Biology 144:807-811.

Hays, G.C., C.R. Adams, A.C. Broderick, B.J. Godley, D.J. Lucas, J.D. Metcalfe, and A.A. Prior. 2000. The diving behaviour of green turtles at Ascension Island. Animal Behaviour 59:577-586.

HDLNR (Hawai'i Department of Land and Natural Resources). 2002. Application for an individual incidental take permit pursuant to the Endangered Species Act of 1973 for listed sea turtles in inshore marine fisheries in the main Hawaiian Islands managed by the State of Hawaii. Honolulu, Hawaii: Division of Aquatic Resources.

Hirth, H.F. 1997. Synopsis of the biological data on the green turtle *Chelonia mydas* (Linnaeus 1758). U.S. Fish and Wildlife Service Biological Report 97(1):1-120.

Hirth, H.F., M. Huber, T. Frohm, and T. Mala. 1992. A natural assemblage of immature green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles on the fringing reef of Wuvulu Island, Papua New Guinea. Micronesica 25(2):145-153.

Hochscheid, S., B.J. Godley, A.C. Broderick, and R.P. Wilson. 1999. Reptilian diving: Highly variable dive patterns in the green turtle *Chelonia mydas*. Marine Ecology Progress Series 185:101-112.

Hodge, R.P., and B.L. Wing. 2000. Occurrences of marine turtles in Alaska waters: 1960-1998. Herpetological Review 31(3):148-151.

Honma, Y., and S. Yoshie. 1975. A record of the Pacific ridley turtle, *Lepidochelys olivacea*, from the coast of Niigata facing the Japan Sea, with description of some of the organs. Annual Activity Reports of the Sado Marine Biological Station, Niigata University 5:1-9.

Horikoshi, K., H. Suganuma, H. Tachikawa, F. Sato, and M. Yamaguchi. 1994. Decline of Ogasawara green turtle population in Japan. Page 235 in K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds. Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Houghton, J.D.R., A.C. Broderick, B.J. Godley, J.D. Metcalfe, and G.C. Hays. 2002. Diving behaviour during the internesting interval for loggerhead turtles *Caretta caretta* nesting in Cyprus. Marine Ecology Progress Series 227:63-70.

Houghton, J.D.R., M.J. Callow, and G.C. Hays. 2003. Habitat utilization by juvenile hawksbill turtles (*Eretmochelys imbricata*, Linnaeus, 1766) around a shallow water coral reef. Journal of Natural History 37:1269-1280.

Hughes, G.R., P. Luschi, R. Mencacci, and F. Papi. 1998. The 7000-km oceanic journey of a leatherback turtle tracked by satellite. Journal of Experimental Marine Biology and Ecology 229:209-217.

Ishikawa, H., and K. Osawa. 2002. Current status of the bekko industry in Japan. Page 226 in A. Mosier, A. Foley, and B. Brost, eds. Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-477.

IUCN (International Union for Conservation of Nature and Natural Resources). 2004. The 2004 IUCN red list of threatened species. Accessed 3 February 2005. http://www.redlist.org.

Iwamoto, T., M. Ishii, Y. Nakashima, H. Takeshita, and A. Itoh. 1985. Nesting cycles and migrations of the loggerhead sea turtle in Miyazaki, Japan. Japanese Journal of Ecology 35(4):505-511.

Iwao, K. 2004. Kerama Islands. Pages 185-189 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Kamezaki, N. 1986. Notes on the nesting of the sea turtles in the Yaeyama Group, Ryukyu Archipelago. Japanese Journal of Herpetology 11(3):152-155.

Kamezaki, N. 1987. Recapture of the hawksbill turtle, *Eretmochelys imbricata* (Linne), in the Yaeyama Islands, Ryukyu Archipelago. Galaxea 6:17-20.

Kamezaki, N. 1989. The nesting sites of sea turtles in the Ryukyu Archipelago and Taiwan. Pages 342-348 in M. Matsui, T. Hikida, and R.C. Goris, eds. Current herpetology in East Asia. Kyoto: Herpetological Society of Japan.

Kamezaki, N., K. Oki, K. Mizuno, T. Toji, and O. Doi. 2002. First nesting record of the leatherback turtle, *Dermochelys coriacea*, in Japan. Current Herpetology 21(2):95-97.

Kamezaki, N., and M. Matsui. 1997. A review of biological studies on sea turtles in Japan. Journal of Herpetology 17(1):16-32.

Kamezaki, N., Y. Matsuzawa, O. Abe, H. Asakawa, T. Fujii, K. Goto, S. Hagino, M. Hayami, M. Ishii, T. Iwamoto, T. Kamata, H. Kato, J. Kodama, Y. Kondo, I. Miyawaki, K. Mizobuchi, Y. Nakamura, Y. Nakashima, H. Naruse, K. Omuta, M. Samejima, H. Suganuma, H. Takeshita, T. Tanaka, T. Toji, M. Uematsu, A. Yamamoto, T. Yamato, and I. Wakabayashi. 2003. Loggerhead turtles nesting in Japan. Pages 210-217 in A.B. Bolten and B.E. Witherington, eds. Loggerhead sea turtles. Washington, D.C.: Smithsonian Institution Press.

Keinath, J.A., and J.A. Musick. 1990. *Dermochelys coriacea* (leatherback sea turtle). Migration. Herpetological Review 21:92.

Keinath, J.A., and J.A. Musick. 1993. Movements and diving behavior of a leatherback turtle, *Dermochelys coriacea*. Copeia 1993(4):1010-1017.

Kikukawa, A., N. Kamezaki, K. Hirate, and H. Ota. 1996. Distribution of nesting sites of sea turtles in Okinawajima and adjacent islands of the central Ryukyus, Japan. Chelonian Conservation and Biology 2(1):99-101.

Kikukawa, A., N. Kamezaki, and H. Ota. 1999. Current status of the sea turtles nesting on Okinawajima and adjacent islands of the central Ryukyus, Japan. Biological Conservation 87:149-153.

Landis, A.T., Jr. 1965. Research: New high pressure research animal? UnderSea Technology 8(12):21.

Lazell, J.D., Jr. 1980. New England waters: Critical habitat for marine turtles. Copeia 1980(2):290-295.

Lenhardt, M.L. 1994. Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (*Caretta caretta*). Pages 238-241 in K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds. Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Lenhardt, M.L., S. Bellmund, R.A. Byles, S.W. Harkins, and J.A. Musick. 1983. Marine turtle reception of bone-conducted sound. Journal of Auditory Research 23:119-123.

Lewison, R.L., S.A. Freeman, and L.B. Crowder. 2004. Quantifying the effects of fisheries on threatened species: The impact of pelagic longlines on loggerhead and leatherback sea turtles. Ecology Letters 7:221-231.

Limpus, C.J. 1995. The status of Australian sea turtle populations. Pages 297-303 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Limpus, C.J., and D.J. Limpus. 2003. Biology of the loggerhead turtle in Western South Pacific Ocean foraging areas. Pages 93-113 in A.B. Bolten and B.E. Witherington, eds. Loggerhead sea turtles. Washington, D.C.: Smithsonian Institution Press.

Lohmann, K.J., B.E. Witherington, C.M.F. Lohmann, and M. Salmon. 1997. Orientation, navigation, and natal beach homing in sea turtles. Pages 107-136 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Lutcavage, M.E., and P.L. Lutz. 1997. Diving physiology. Pages 277-296 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Lutcavage, M.E., P. Plotkin, B. Witherington, and P.L. Lutz. 1997. Human impacts on sea turtle survival. Pages 387-409 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Lutz, P.L., and J.A. Musick, eds. 1997. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Lutz, P.L., J.A. Musick, and J. Wyneken, eds. 2003. The biology of sea turtles, Volume II. Boca Raton, Florida: CRC Press.

Márquez-M., R. 1990. FAO species catalogue: Vol. 11. Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. FAO Fisheries Synopsis. No. 125, Vol. 11. Rome: Food and Agriculture Organization of the United Nations.

Matsunaga, H., and H. Nakano. 2003. The conservation and management activities for sea turtles in Japan. Pages 32-35 in N. Arai, ed. Proceedings on the 4th SEASTAR2000 Workshop. 11-13 December 2003. Bangkok, Thailand.

Matsuzawa, Y. 2005. Personal communication between Dr. Yoshimasa Matsuzawa, Sea Turtle Association of Japan, Osaka, Japan, and Dr. Jason See, Geo-Marine, Inc., Plano, Texas, 7 and 18 August.

Matsuzawa, Y., K. Sato, W. Sakamoto, and K.A. Bjorndal. 2002. Seasonal fluctuations in sand temperature: Effects on the incubation period and mortality of loggerhead sea turtle (*Caretta caretta*) pre-emergent hatchlings in Minabe, Japan. Marine Biology 140:639-646.

McDonald, D.L., and P.H. Dutton. 1996. Use of PIT tags and photoidentification to revise remigration estimates of leatherback turtles (*Dermochelys coriacea*) nesting in St. Croix, USVI, 1979-1995. Chelonian Conservation and Biology 2(2):148-152.

Meylan, A. 1995. Sea turtle migration - evidence from tag returns. Pages 91-100 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Meylan, A.B. 1988. Spongivory in hawksbill turtles: A diet of glass. Science 239:393-395.

Meylan, A.B. 1999. International movements of immature and adult hawksbill turtles (*Eretmochelys imbricata*) in the Caribbean region. Chelonian Conservation and Biology 3(2):189-194.

Meylan, A.B., and M. Donnelly. 1999. Status justification for listing the hawksbill turtle (*Eretmochelys imbricata*) as critically endangered on the 1996 IUCN Red List of Threatened Animals. Chelonian Conservation and Biology 3(2):200-224.

Miller, J.D. 1997. Reproduction in sea turtles. Pages 51-81 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Minamikawa, S., Y. Naito, K. Sato, Y. Matsuzawa, T. Bando, and W. Sakamoto. 2000. Maintenance of neutral buoyancy by depth selections in the loggerhead turtle *Caretta caretta*. Journal of Experimental Biology 203:2967-2975.

Moein Bartol, S., J.A. Musick, and M.L. Lenhardt. 1999. Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). Copeia 1999(3):836-840.

Moritz, C., D. Broderick, K. Dethmers, N. FitzSimmons, and C. Limpus. 2002. Population genetics of southeast Asian and western Pacific green turtles, *Chelonia mydas*. Final report to UNEP/CMS. Canberra, Australia: Department of the Environment and Heritage.

Morreale, S.J., and E.A. Standora. 1998. Early life stage ecology of sea turtles in northeastern U.S. waters. NOAA Technical Memorandum NMFS-SEFSC-413:1-49.

Morreale, S.J., E.A. Standora, J.R. Spotila, and F.V. Paladino. 1996. Migration corridor for sea turtles. Nature 384:319-320.

Mortimer, J.A. 1995. Feeding ecology of sea turtles. Pages 103-109 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Mrosovsky, N., and P.C.H. Pritchard. 1971. Body temperatures of *Dermochelys coriacea* and other sea turtles. Copeia 1971(4):624-631.

Musick, J.A., and C.J. Limpus. 1997. Habitat utilization and migration of juvenile sea turtles. Pages 137-163 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

Neill, W.H., and E.D. Stevens. 1974. Thermal inertia versus thermoregulation in “warm” turtles and tunas. Science 184:1008-1010.

Nichols, W.J. 2003. Biology and conservation of sea turtles in Baja California, Mexico. Ph.D. diss., University of Arizona.

Nichols, W.J. 2005. Following redwood logs, rubber ducks, and drift bottles: Transoceanic developmental migrations of loggerhead turtles in the North Pacific Ocean. Page 66 in M.S. Coyne and R.D. Clark, eds. Proceedings of the Twenty-First Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-528.

Nichols, W.J., P.H. Dutton, J.A. Seminoff, E. Bixby, F.A. Abreu, and A. Resendiz. 2000a. Poi or papas: Do Hawaiian and Mexican green turtles feed together in Baja California waters? Pages 14-15 in H. Kalb and T. Wibbels, eds. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443.

Nichols, W.J., A. Resendiz, and C. Mayoral-Russeau. 2000b. Biology and conservation of loggerhead turtles (*Caretta caretta*) in Baja California, Mexico. Pages 169-171 in H. Kalb and T. Wibbels, eds. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443.

Nichols, W.J., A. Resendiz, J.A. Seminoff, and B. Resendiz. 2000c. Transpacific migration of a loggerhead turtle monitored by satellite telemetry. Bulletin of Marine Science 67(3):937-947.

Nichols, W.J., L. Brooks, M. Lopez, and J.A. Seminoff. 2001. Record of pelagic East Pacific green turtles associated with *Macrocystis* mats near Baja California Sur, Mexico. Marine Turtle Newsletter 93:10-11.

Nishimura, W. 1994. Internesting interval and nest frequency for loggerhead turtles on Inakahama Beach, Yakushima Island, Japan. Marine Turtle Newsletter 67:21-22.

Nishimura, W., and S. Nakahigashi. 1990. Incidental capture of sea turtles by Japanese research and training vessels: Results of a questionnaire. Marine Turtle Newsletter 51:1-4.

Nitta, E.T., and J.R. Henderson. 1993. A review of interactions between Hawaii's fisheries and protected species. Marine Fisheries Review 55(2):83-92.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998a. Recovery plan for U.S. Pacific populations of the green turtle (*Chelonia mydas*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998b. Recovery plan for U.S. Pacific populations of the East Pacific green turtle (*Chelonia mydas*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998c. Recovery plan for U.S. Pacific populations of the hawksbill turtle (*Eretmochelys imbricata*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998d. Recovery plan for U.S. Pacific populations of the loggerhead turtle (*Caretta caretta*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998e. Recovery plan for U.S. Pacific populations of the olive ridley turtle (*Lepidochelys olivacea*). Silver Spring, Maryland: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service), and USFWS (U.S. Fish and Wildlife Service). 1998f. Recovery plan for U.S. Pacific populations of the leatherback turtle (*Dermochelys coriacea*). Silver Spring, Maryland: National Marine Fisheries Service.

NRC (National Research Council). 1990. Decline of the sea turtles: Causes and prevention. Washington, D.C.: National Academy Press.

Owens, D.W. 1980. The comparative reproductive physiology of sea turtles. American Zoologist 20(3):549-563.

Paladino, F.V., M.P. O'Connor, and J.R. Spotila. 1990. Metabolism of leatherback turtles, gigantothermy and thermoregulation of dinosaurs. Nature 344:858-860.

Parker, D.M., P.H. Dutton, K. Kopitsky, and R.L. Pitman. 2003. Movement and dive behavior determined by satellite telemetry for male and female olive ridley turtles in the Eastern Tropical Pacific. Pages 48-49 in J.A. Seminoff, ed. Proceedings of the Twenty-Second Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-503.

Parker, D.M., P. Dutton, S. Eckert, D.R. Kobayashi, J.J. Polovina, D. Dutton, and G.H. Balazs. 2004. Transpacific migration along oceanic fronts by loggerhead turtles released from Sea World San Diego. Pages 280-281 in M.S. Coyne and R.D. Clark, eds. Proceedings of the Twenty-First Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-528.

Parker, D.M., W.J. Cooke, and G.H. Balazs. 2005. Diet of oceanic loggerhead sea turtles (*Caretta caretta*) in the central North Pacific. Fishery Bulletin 103(1):142-152.

Parker, G.L. 1995. Encounter with a juvenile hawksbill turtle offshore Sapelo Island, Georgia. Marine Turtle Newsletter 71:19-22.

Pitman, R.L. 1990. Pelagic distribution and biology of sea turtles in the eastern tropical Pacific. Pages 143-148 in T.H. Richardson, J.I. Richardson, and M. Donnelly, eds. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278.

Pitman, R.L. 1992. Sea turtle associations with flotsam in the eastern tropical Pacific. Page 94 in M. Salmon and J. Wyneken, eds. Proceedings of the Eleventh Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-302.

Pitman, R.L. 1993. Seabird associations with marine turtles in the eastern Pacific Ocean. Colonial Waterbirds 16(2):194-201.

Polovina, J.J., D.R. Kobayashi, D.M. Parker, M.P. Seki, and G.H. Balazs. 2000. Turtles on the edge: Movement of loggerhead turtles (*Caretta caretta*) along oceanic fronts, spanning longline fishing grounds in the central North Pacific, 1997-1998. Fisheries Oceanography 9:71-82.

Polovina, J.J., E. Howell, D.M. Parker, and G.H. Balazs. 2003. Dive-depth distribution of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific: Might deep longline sets catch fewer turtles? Fishery Bulletin 101(1):189-193.

Polovina, J.J., G.H. Balazs, E.A. Howell, D.M. Parker, M.P. Seki, and P.H. Dutton. 2004. Forage and migration habitat of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific Ocean. Fisheries Oceanography 13(1):36-51.

Pritchard, P.C.H. 1977. Marine turtles of Micronesia. San Francisco, California: Chelonia Press.

Pritchard, P.C.H. 1982. Nesting of the leatherback turtle, *Dermochelys coriacea* in Pacific Mexico, with a new estimate of the world population status. Copeia 1982(4):741-747.

Renaud, M.L., and J.A. Carpenter. 1994. Movements and submergence patterns of loggerhead turtles (*Caretta caretta*) in the Gulf of Mexico determined through satellite telemetry. Bulletin of Marine Science 55:1-15.

Resendiz, A., B. Resendiz, W.J. Nichols, J.A. Seminoff, and N. Kamezaki. 1998. First confirmed east-west transpacific movement of a loggerhead sea turtle, *Caretta caretta*, released in Baja California, Mexico. Pacific Science 52(2):151-153.

Richardson, J.I., and P. McGillivary. 1991. Post-hatchling loggerhead turtles eat insects in *Sargassum* community. Marine Turtle Newsletter 55:2-5.

Ridgway, S.H., E.G. Wever, J.G. McCormick, J. Palin, and J.H. Anderson. 1969. Hearing in the giant sea turtle, *Chelonia mydas*. Proceedings of the National Academy of Sciences 64:884-890.

Sakamoto, W., I. Uchida, Y. Naito, K. Kureha, M. Tujimura, and K. Sato. 1990. Deep diving behavior of the loggerhead turtle near the frontal zone. Nippon Suisan Gakkaishi 56(9):1435-1443.

Sarti-M., L., S.A. Eckert, N. Garcia-T., and A.R. Barragan. 1996. Decline of the world's largest nesting assemblage of leatherback turtles. Marine Turtle Newsletter 74:2-5.

Sato, K., Y. Matsuzawa, H. Tanaka, T. Bando, S. Minamikawa, W. Sakamoto, and Y. Naito. 1998. Internesting intervals for loggerhead turtles, *Caretta caretta*, and green turtles, *Chelonia mydas*, are affected by temperature. Canadian Journal of Zoology 76:1651-1662.

Schroeder, B.A., and N.B. Thompson. 1987. Distribution of the loggerhead turtle, *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida area: Results of aerial surveys. Pages 45-53 in W.N. Witzell, ed. Proceedings of the Cape Canaveral, Florida Sea Turtle Workshop. NOAA Technical Report NMFS 53.

Seminoff, J.A., W.J. Nichols, A. Resendiz, and L. Brooks. 2003. Occurrence of hawksbill turtles, *Eretmochelys imbricata* (Reptilia: Cheloniidae), near the Baja California Peninsula, Mexico. Pacific Science 57(1):9-16.

Shanker, K., B. Pandav, and B.C. Choudhury. 2003. An assessment of the olive ridley turtle (*Lepidochelys olivacea*) nesting population in Orissa, India. Biological Conservation 115:149-160.

Shoop, C.R., and R.D. Kenney. 1992. Seasonal distributions and abundances of loggerhead and leatherback sea turtles in waters of the northeastern United States. Herpetological Monographs 6:43-67.

Skillman, R.A., and G.H. Balazs. 1992. Leatherback turtle captured by ingestion of squid bait on swordfish longline. Fishery Bulletin 90:807-808.

Song, X., H. Wang, W. Wang, H. Gu, S. Chan, and H. Jiang. 2002. Satellite tracking of post-nesting movements of green turtles *Chelonia mydas* from the Gangkou Sea Turtle National Nature Reserve, China, 2001. Marine Turtle Newsletter 97:8-9.

Southwood, A.L., R.D. Reina, V.S. Jones, and D.R. Jones. 2003. Seasonal diving patterns and body temperatures of juvenile green turtles at Heron Island, Australia. Canadian Journal of Zoology 81:1014-1024.

Spotila, J.R., A.E. Dunham, A.J. Leslie, A.C. Steyermark, P.T. Plotkin, and F.V. Paladino. 1996. Worldwide population decline of *Dermochelys coriacea*: Are leatherback turtles going extinct? Chelonian Conservation and Biology 2(2):209-222.

Spotila, J.R., M.P. O'Connor, and F.V. Paladino. 1997. Thermal biology. Pages 297-314 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

STAJ (Sea Turtle Association of Japan). 2005a. Sea turtles found in Japan. Accessed 25 July 2005. http://www4.osk.3web.ne.jp/~umigame/E/Sea%20Turtles%20Found%20in%20Japan.html.

STAJ (Sea Turtle Association of Japan). 2005b. Results so far. Accessed 25 July 2005. http://www4.osk.3web.ne.jp/~umigame/E/Results%20so%20far.html.

Starbird, C.H., A. Baldridge, and J.T. Harvey. 1993. Seasonal occurrence of leatherback sea turtles (*Dermochelys coriacea*) in the Monterey Bay region, with notes on other sea turtles, 1986-1991. California Fish and Game 79(2):54-62.

Starbird, C.H., Z. Hillis-Starr, J.T. Harvey, and S.A. Eckert. 1999. Internesting movements and behavior of hawksbill turtles (*Eretmochelys imbricata*) around Buck Island Reef National Monument, St. Croix, U.S. Virgin Islands. Chelonian Conservation and Biology 3(2):237-243.

Stinson, M.L. 1984. Biology of sea turtles in San Diego Bay, California, and in the northeastern Pacific Ocean. Master's thesis, San Diego State University.

Suganuma, H. 1985. Green turtle research program in Ogasawara. Marine Turtle Newsletter 33:2-3.

Suganuma, H. 1989. The green turtle (*Chelonia mydas*) in Ogasawara Islands, Japan. Page 344 in L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, eds. Proceedings of the Second Western Atlantic Turtle Symposium. NOAA Technical Memorandum NMFS-SEFC-226.

Suganuma, H. 2002. Population trends and mortality of Japanese loggerhead turtles, *Caretta caretta*, in Japan. Pages 77-78 in I. Kinan, ed. Proceedings of the Western Pacific Sea Turtle Cooperative Research and Management Workshop. Honolulu, Hawaii: Western Pacific Regional Fishery Management Council.

Suganuma, H., K. Horikoshi, H. Tachikawa, F. Sato, and M. Yamaguchi. 1996. Reproductive characteristics of the Ogasawara green turtles. Page 318 in J.A. Keinath, D.E. Barnard, J.A. Musick, and B.A. Bell, eds. Proceedings of the Fifteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-387.

Suganuma, H., N. Kamezaki, and A. Yusuf. 1999. Current status of nesting populations of the hawksbill turtle (*Eretmochelys imbricata*) in the Java Sea, Indonesia. Chelonian Conservation and Biology 3(2):337-343.

Tachikawa, H., H. Suganuma, F. Sato, M. Yamaguchi, K. Horikoshi, Y. Kurata, and J. Kimura. 1994. Long distance dispersal and remigration of adult green turtles in the Ogasawara Islands, Japan. Page 265 in B.A. Schroeder and B.E. Witherington, eds. Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-341.

Uchida, I. 1994. Some aspects of sea turtles in Japan. Pages 82-84 in G.H. Balazs and S.G. Pooley, eds. Research plan to assess marine turtle hooking mortality: Results of an expert workshop held in Honolulu, Hawaii, November 16-18, 1993. NOAA Technical Memorandum NMFS-SWFSC-201.

Uchida, I., and M. Nishiwaki. 1995. Sea turtles in the waters adjacent to Japan. Pages 317-319 in K.A. Bjorndal, ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

van Dam, R.P., and C.E. Diez. 1996. Diving behavior of immature hawksbills (*Eretmochelys imbricata*) in a Caribbean cliff-wall habitat. Marine Biology 127:171-178.

Whittow, G.C., and G.H. Balazs. 1982. Basking behavior of the Hawaiian green turtle (*Chelonia mydas*). Pacific Science 36(2):129-139.

Wing, B.L., and R.P. Hodge. 2002. Occurrence terminology for marine turtles. Marine Turtle Newsletter 95:15-16.

Witherington, B.E. 1994. Flotsam, jetsam, post-hatchling loggerheads, and the advecting surface smorgasbord. Pages 166-168 in K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds. Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Witherington, B.E., and K.A. Bjorndal. 1991. Influences of wavelength and intensity on hatchling sea turtle phototaxis: Implications for sea-finding behavior. Copeia 1991(4):1060-1069.

Witherington, B.E., and N.B. Frazer. 2003. Social and economic aspects of sea turtle conservation. Pages 355-384 in P.L. Lutz, J.A. Musick, and J. Wyneken, eds. The biology of sea turtles, Volume II. Boca Raton, Florida: CRC Press.

Witzell, W.N. 1983. Synopsis of biological data on the hawksbill turtle *Eretmochelys imbricata* (Linnaeus, 1766). FAO Fisheries Synopsis 137:1-78.

Work, T.M., and G.H. Balazs. 2002. Necropsy findings in sea turtles taken as bycatch in the North Pacific longline fishery. Fishery Bulletin 100:876-880.

Wyneken, J. 1997. Sea turtle locomotion: Mechanics, behavior, and energetics. Pages 165-198 in P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

4.0 FISH AND FISHERIES

4.1 FISH/INVERTEBRATES

Distribution and abundance of fishery species depend greatly on the physical and biological factors associated with the ecosystem, as well as the individual species. Physical parameters include habitat quality variables such as salinity, temperature, dissolved oxygen, and large-scale environmental perturbations (e.g., ENSO). Biological factors affecting distribution are complex and include variables such as population dynamics, predator/prey oscillations, seasonal movements, reproductive/life cycles, and recruitment success (Helfman et al. 1997). Rarely is one factor responsible for the distribution of fishery species, but a combination of factors. For example, pelagic species optimize their growth, reproduction and survival by tracking gradients of temperature, oxygen, or salinity (Helfman et al. 1997). Additionally, the spatial distribution of food resources is variable and changes with prevailing physical habitat parameters. Another major component in understanding species distribution is the location of highly productive regions such as frontal zones. These areas concentrate higher trophic-level predators such as tuna and provide visual clues for the location of target species for commercial fisheries (NOAA 2002).

The Kuroshio and Oyashio Currents and the transition region (Pearcy 1991) between these subtropical and subarctic currents to the east of Japan, and the Tsushima Current to the west of Japan greatly influence the distribution of fishes (e.g., more than 3,000 species; Ministry of the Environment 1995) within the Japan and Okinawa Complexes OPAREA. Highly productive fishing grounds are located at the juncture (from just beyond the east coast of Japan to 160°E and from 37°N to 50°N) of the warm Kuroshio and cold Oyashio Currents where highly migratory species (e.g. skipjack tuna [*Katsuwonus pelamis*] and bluefin tuna [*Thunnus thynnus*]) feed on smaller pelagic species (e.g. Japanese sardine, [*Sardinops melanostictus*], Pacific saury, [*Cololabis saira*] and anchovy [*Engraulis japonicus*]) taking advantage of temperature gradients and phytoplankton blooms (DoN 1994; Sassa 2002; URI 2005). This transitional region of the western North Pacific functions as a spawning and nursery grounds for various epipelagic, mesopelagic and myctophid fishes, including subtropical-tropical, transitional, and subarctic species (Watanabe et al. 1999; Sassa et al. 2002, 2004). In the East Japan study area, species associated with the Kuroshio Current include Japanese sardine, Pacific saury, anchovy, jack mackerel (*Trachurus japonicus*), bluefin tuna, frigate mackerel (*Auxis thazard thazard*), filefish, and herring (URI 2005). Species found in the Oyashio Current include Japanese sardine, walleye pollock (*Theragra chalcogramma*), tuna, squid, chub mackerel (*Scomber japonicus*), Pacific saury, anchovy, lantern fish, Pacific cod (*Gadus macrocephalus*), flounder, rockfish, shrimp, and chum (*Oncoryhnchus keta*) and pink salmon (*O. gorbuscha*) (Fujita et al. 1993; URI 2005). The Tsushima Current splits from the Kuroshio Current at the Korean peninsula and enters the Sea of Japan gradually losing tropical species as it moves north along the west coast of Japan. More than 800 species representing 38 Indo-Pacific ichthyofaunal families inhabit the West Japan study area (Kafanov et al. 2000). This current also plays an important role in the diamond squid (*Thysanoteuthis rhombus*) fishery in the Sea of Japan (Bower and Miyahara 2005).

Environmental variations, such as ENSO events, change the normal characteristics of water temperature, thereby changing the patterns of water flow. ENSO events alter normal current patterns, alter productivity, and have dramatic effects on distribution, habitat range and movement of pelagic species (NOAA 2002). In the western Pacific, El Niño events typically induce cool, wet summers, and warm, calm winters resulting in warm-water species moving north (extending their range), and cold-water species moving north or into deeper water (restricting their range). Surface-oriented, schooling fish often disperse and move into deeper waters. Fishes that remain in an affected region experience reduced growth, reproduction, and survival (NOAA 2002). El Niño events in the Pacific may cause an eastward shift of 1,000 km for fisheries such as the skipjack tuna (NOAA 2002; Sugimoto et al. 2001).

Japanese waters range for tropical to subarctic, with hard corals found from the southern Ryukyus north to Tokyo Bay along the eastern coast and to Sado Island in the Sea of Japan (Kimrua et al. 2004). The coral reef communities (true coral reefs, non-reefal, and outlying) found in the waters surrounding Japan are a result of a delicate mix of biology, climate, and chemistry. The warm equatorial waters of the Kuroshio Current contribute to the growth of the most diverse and northernmost reefs in the world

(Lecchini 2003). The Kuroshio Current is so efficient at transporting coral larvae that the biodiversity around Japan rivals that of the Phillipines (Burke 2002). Ninety percent of the coral reef population in Japan can be found around Okinawa (Wilkinson 2000).

True coral reef communites in the Ryukyu Islands are dominated by damselfishes which is common of most coral reef systems (Lecchini 2003). This is evident on Sesoko Island southeast of the Ie Shima Range and on Aka Island southeast of the Tori Shima and Idesuna Jima Ranges in the Okinawa studies area (Lecchini 2003). However, the individual abundance of other major reef taxa such as sugeonfishes, butterflyfishes, wrasses, and parrotfishes is surprisingly low on these islands (Lecchini 2003). On Diato Island which is north of the Okino Daito Jima Range in the Okinawa study area, the dominant reef fishes are butterflyfishes, the most highly diversified assemblage in the Ryukus archipelago (Cadoret et al. 1999; Nonaka 2004).

Non-reef coral communities in the West Japan study area are represented by various species encompassing the following major taxa: chaetodonitd (butterflyfishes/angelfishes), acanthuroids (sugeonfishes/rabbitfishes/moorish idols), and labroids (parrotfishes/damselfishes/wrasses; Choat and Bellwood 1991). The outlying coral communities in the East Japan study area (e.g., Izu Islands) are dominated by wrasses (Donaldson et al. 1994).

Japan is one of the world's leaders in fisheries production accounting for 45% to 55% of the total catch in the northwest Pacific, and fisheries play an important role providing a variety of fish and fishery products that account for approximately half of the animal protein intake of the Japanese nation (FAO 2000). Most of the commercial fishing in Japan is conducted at greater than 12 NM (22 km) from shore on the high sea, Commercial fishing occurs offshore of all prefectures of Japan and all islands of the Ryukyu Archipelago. Japanese marine fisheries are divided into three categories: coastal fisheries (operated mainly in waters adjacent to fishing villages), offshore fisheries (operated mainly in the domestic exclusive economic zone [EEZ], as well as in the EEZs of neighbouring countries), and distant-waters fisheries (operated mainly on the high sea, as well as in foreign countries' EEZs; FAO 2000). The most important fishes economically, culturally, and socially in the Pacific are the oceanic and pelagic species.

4.1.1 Fish Species

4.1.1.1 Convention on Trade in Endangered Species

The 'Washington' CITES, aims to protect certain plants and animals by regulating and monitoring their international trade (e.g., licensing system) before it reaches unsustainable levels (CITES 2005). CITES is an international agreement between countries (e.g., U.S. 1975 and Japan 1980) which voluntarily agree to be bound by the Convention. Each country (also referred to as a Party) provides a framework to be respected by each Party, which has to be adopted by its own domestic legislation to ensure that CITES is implemented at the national level (CITES 2005). All species (i.e., import, export, re-export, and introduction) covered by CITES are listed according to their degree of needed protection in the following Appendices. Appendix I includes species threatened with extinction; Appendix II covers species not necessarily threatened with extinction, but for which trade must be controlled in order to avoid utilization incompatible with their survival; and Appendix III contains species that are protected in at least one country, which asked other CITES Parties for assistance in controlling the trade (CITES 2005).

According to Chapter 13 of Japan's Environmental Governing Standards (DoD 2001), any species (flora or fauna) considered to be in danger under either U.S. law (ESA), Japanese wildlife law (outside of the continental U.S. [OCONUS] threatened and endangered animals and plants, List of Endangered Species of Wild Fauna & Flora in Japan [Domestic Species], and List of Natural Monument Species in Japan), or a treaty (CITES) in which the U.S. is a party, is afforded the proper protection, enhancement, and management. All reasonable measures are taken to protect and enhance known threatened/endangered species and host nation (e.g., Japan) protected species that could be adversely affected by DoD activities. Currently, 12 marine fish species are listed in the CITES database as potentialy occurring in the Japan and Okinawa Complexes OPAREA (CITES 2005; **Table 4-1**).

Table 4-1. Marine fishes listed in Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix.

Family/Species	Common Name	CITES Appendix
Laminidae	Mackerel Sharks	
Carcharodon carcharias	Great white shark	III
Rhincodontidae	Whale Sharks	
Rhincodon typus	Whale shark	II
Cetorhinidae	Basking Sharks	
Cetorhinus maximus	Basking shark	II
Labridae	Wrasses	
Cheilinus undulatus	Humphead wrasse	II
Acipenseridae	Sturgeons	
Acipenser mikadoi	Sakhalin sturgeon	II
Syngnathidae	Seahorses	
Hippocampus coronatus	Crowned seahorse	II
Hippocampus histrix	Thorny seahorse	II
Hippocampus kellogi	Great seahorse	II
Hippocampus kuda	Spotted seahorse	II
Hippocampus mohnikei	Japanese seahorse	II
Hippocampus sindonis	Dhiho's seahorse	II
Hippocampus trimaculatus	Three-spot seahorse	II

Source: CITES 2005.

For each fish species (except the seahorses which will be discussed as a family species), the status, distribution (including range), habitat preference (depth, bottom sustrate), life history (migration, spawning), and common prey species are described in the following paragraphs.

CITES Fish Species

- Great White Shark (*Carcharodon carcharias*)

  Status—The great white shark is a widely, but sparsely distributed top predator occurring in the Japan and Okinawa Complexes OPAREA (Compagno 1984, 2002). The very low reproductive potential (late maturity and small litter size), high vulnerablility to target and by-catch fisheries (commercial and recreational), and its highly valued products (e.g., fins, jaws, and teeth) for international trade have made this species vulnerable to exploitation (Cavanagh et al. 2003; Kyne et al. 2005). In addition to the CITES listing, this species is listed on the IUCN Red List of threatened species as vulnerable (Fergusson et al. 2000).

  Distribution—Great white sharks are wide-ranging in their distribution occurring mostly in temperate seas with large individuals penetrating some tropical regions and cold, boreal waters, such as Alaska and Canada (Hennemann 2001; Martins and Knickle 1999). In the western Pacific, this species ranges from Siberia to the Philippines and Australia to New Zealand (Compagno 1984, 2002).

Habitat Preference—The white shark is primarily an epipelagic species which often occurs inshore to the surfline penetrating shallow bays, estuaries and the intertidal zone in continental coastal waters (Compagno 1984, 2002). It also frequents offshore continental and oceanic islands (inhabited by pinnipeds: seal, sea lions, and walruses) and inshore/offshore fishing banks (Martins and Knickle 1999). This species can be found at the surface down to the bottom in epicontinental waters (i.e., 1,280 m; Compagno 1984, 2002), with the average depth being less than 80 m (Ebert 2005). Larger great white sharks are found in waters exhibiting a broad temperature range (7.2° to 26.7°C; Ebert 2005).

White sharks occur singly or in pairs but have also been observed in feeding aggregations of 10 or more (Compagno 1984, 2002). Juvenile great white sharks tend to migrate northward, following the movement of warm water masses and occasionally migrating into central and northern California waters during extreme El Niño periods (Ebert et al. 2005).

Life History—This species is ovoviviparous with embroyos nourished through oophagy (Martins and Knickle 1999). Length of gestation is unknown but could be a year or more where it may produce offsprings varing between 2 to 14 pups per litter (Camhi et al. 1998; Hennemann 2001). Known centers of abundance including nursery and probably pupping areas, in the Pacific include California, Baja California, southern Australia, New Zealand, and Japan (Compagno 1984, 2002).

Common Prey Species—The white sharks feeds on bony fishes, sharks, rays, seals, dolphins and popoises, sea birds, sea turtles, chimeras, carrion, squid, octopuses, and crabs (Compagno 1984, 2002; Hennemann 2001).

- Whale Shark (*Rhincodon typus*)

Status—Whale sharks occur in the Japan and Okinawa Complexes OPAREA (Compagno 1984, 2002). Directed whale shark fisheries (harpoon and incidental catches), its high value in international trade, a K-selected life history, along with a highly migratory nature, and low abundance have made this species vulnerable to exploitation (Cavanagh et al. 2003; Kyne et al. 2005). This species was classified as a highly migratory species in Annex I of the 1982 UN Convention on the Law of the Sea and identified with an unfavorable conservation status in Appendix II of the Bonn Convention for the Conservation of Migratory Species of Wild Animals in 1999 (Froese and Pauly 2005). In addition to the CITES listing, this species is listed on the IUCN Red List of threatened species as vulnerable (Norman 2000).

Distribution—The whale shark has a widespread distribution, occurring in all tropical and warm temperate seas, oceans and coastal areas around the globe. In the Pacific Ocean, it is found from Japan to Australia, off Hawai'i, and from California to Chile (Compagno 1984, 2002; Martins and Knickle n.d.).

Habitat Preference—Whale sharks are an epipelagic and neritic, oceanic and coastal, tropical and warm-temperate shark often occurring far offshore, but regularly coming inshore of beaches and coral reefs sometimes entering lagoons of coral atolls (Compagno 1984, 2002). In the western Pacific, this species apparently prefers areas where mixing layers of cool oceanic water (<17°C) upwell to warm surface water with temperatures between 21° to 25°C and salinity between 34.0 to 34.5 psu (Compagno 1984, 2002). Whale sharks are found at a depth range of 0 to 700 m (Froese and Pauly 2005).

The whale shark is usually found close to the surface as a single individual or in schools or aggregations (e.g., over 100 sharks) of similiar size and sex (Norman 2000). Whale sharks are also often associated with groups of pelagic fishes, especially scombrids (Compagno 1984, 2002). This species is highly mobile and may undertake either fairly local or large-scale transoceanic migrations seasonally with their movement patterns seemingly correlated with localized blooms of planktonic organisms (e.g., Ningaloo Reef, central western coast of Australia each March and April), changes in temperature of water masses (ENSO) or oceanographic features (e.g., sea mounts; Compagno 1984,

2002; Wilson et al. 2001; Ebert 2005; Martins and Knickle n.d.). They also have been reported to frequent shallow water areas near estuaries and river mouths, sometimes during seasonal shrimp blooms (Froese and Pauly 2005). In the western Pacific, whale sharks move as far nortrh as Honshu, Japan in the summer and move down toward the equator in the winter (Wilson et al. 2001).

Life History—The mode of reproduction of the whale shark is ovovivviparous with a litter size in excess of 300 (Camhi et al. 1998; Ebert 2005). The gestion period is not known, but the whale shark may reproduce every other year similar to the nurse shark (*Ginglymostoma cirratum*) (Compagno 1984, 2002).

Common Prey Species—Whale sharks feed on a wide variety of planktonic (copepods, invertebrate larvae) and nektonic prey such as small crustaceans (krill, pelagic crabs), small- to medium-sized schooling fishes including anchovies, sardines, and mackerels, occasionally on tuna and squids in addition to phytoplankton and macroalgae (Ebert 2005; Martins and Knickle n.d.).

- Basking Shark (*Cetorhinus maximus*)

Status—The basking shark occurs in the Japan and Okinawa Complexes OPAREA (Compagno 1984, 2002). Documented fisheries in several regions have characterized this species as a rapidly declining population resulting from short-term fisheries exploitation followed by very slow or no record of population recovery (Cavanagh et al. 2003; Kyne et al. 2005). There is also likely potential for similar population declines from directed and bycatch fisheries due to the demand for fins in international trade (Fowler 2000). This species was classified as a highly migratory species in Annex I of the 1982 UN Convention on the Law of the Sea (Froese and Pauly 2005). In addition to the CITES listing, this species is listed on the IUCN Red List of threatened species as vulnerable (Fowler 2000).

Distribution—The basking shark is circumglobal with a wide but possibly disjunct distribution throughout the world's arctic and temperate seas but rare in equatorial waters (Compagno 1984, 2002). In the western Pacific, this species is found off Japan, China, and Korea as well as western and southern Australia and along the coastlines of New Zealand (Knickle et al. n.d.).

Habitat Preference—Basking sharks are a coastal-pelagic and semi-oceanic or oceanic shark inhabitating continental and insular shelves. This species can be found well offshore as well as very close to land (just off the surf zone) and has been reported entering closed bays and estuaries (Compagn 1984, 2002; Knickle et al. n.d.). Basking sharks are found at a depth range of 0 to 4,000 m (Compagno 2002). These species are usually found in areas where the water temperature ranges between 7.8° to 23.8°C (Ebert 2005).

The basking sharks are often seen near the surface, singly, in pairs, triads, or schools up to 100 or more individuals (Knickle et al. n.d.). Basking sharks are highly migratory moving considerable distances using oceanic thermal fronts of differing water temperatures as cues or migrating vertically into deper water to locate preferred prey (Ebert 2005). Off the eastern North Pacific, they occur in greatest numbers during autumn and winter in the southern part of their range (California), but migrate to northern latitudes (Washington, British Columbia, and Alaska) during spring and summer (Compagno 1984, 2002). In tropical areas, these sharks may migrate following thermoclines of cooler, deeper water (Ebert 2005).

Life History—Reproduction in the basking shark seems to include a gestion period of more than a year and an ovoviviparous development with embroyos nourished through oophagy resulting in the production of a litter size of 2 to 6 young (Cahmi et al. 1998; Hennemann 2001; Knickle et al. n.d.). Mating appears to occur in inshore waters (e.g., United Kingdom) in the early summer (Compagno 1984, 2002; Hennemann 2001).

Common Prey Species—The basking shark is a near-surface filter feeder consuming vast quantities of zooplankton, such as small copepods (including calanids), the larvae of barnacles, decapod crustaceans, stomatopod larvae, and fish eggs (Compagno 1984, 2002; Ebert 2005).

- Humphead Wrasse (*Cheilinus undulatus*)

Status—The humphead wrasse occurs in the Okinawa study area of the Japan and Okinawa Complexes OPAREA (Myers 1999; WPRFMC 2001). This species is heavily exploited undergoing high levels of fishing pressure at the center of its range in southeastern Asia where its coral reef habitat is most abundant and particularly in key supply countries for the aquarium trade (Sadovy et al. 2003; Cornish 2004). Factors influencing the decline of this species include: (1) intensive and species-specific removal in the live reef food-fish trade, (2) spearfishing at night using SCUBA gear, (3) lack of coordinated, consistent national and regional management, (4) illegal (sodium cyanide), unregulated, or unreported fisheries, and (5) loss of habitat through coral bleaching and human activity (NMFS 2004a). In addition to the CITES listing, this species is listed on the IUCN Red List of threatened species as endangered (Cornish et al. 2004) and under the ESA as a Species of Concern (NMFS 2004b).

Distribution—The humphead wrasse is widely distributed throughout much of the tropical Indo-Pacific region from the Red Sea in the west to the Tuamotus in the east, and from the Ryukyus in the north, including China and Chinese Taipei, east to Wake Island, south to New Caledonia, and throughout Micronesia (Myers 1999).

Habitat Preference—The humphead wrasse is usually found in association with well-developed coral reefs (WPRFMC 2001). Adults are more common offshore than inshore, their presumed preferred habitat includes steep outer reef slopes, reef drop-offs, reef tops, channel slopes, reef passes, and lagoon reefs to at leasst 100 m (Cornish 2004). Juveniles are associated with coral-rich areas of lagoon reefs, usually among thickets of staghorn (*Acropora* spp.) corals, in seagrass beds, murky outer river areas with patch reefs, shallow sandy areas adjacent to coral reef lagoons, and inshore mangrove and seagrass areas (Myers 1999; Cornish 2004). The eggs and larvae of this species are pelagic (Sadovy et al. 2003). This species is most often observed in solitary male-female pairs or groups of 2 to 7 individuals (Cornish 2004). It can be found roaming the corals reefs by day and resting in reef caves and under coral ledges at night (Froese and Pauly 2005).

Life History—The humphead wrasse is hermaphroditic, slow growing, and long-lived species. It may spawn in small or large groups and spawning coincides with certain phases of the tidal cycle (Cornish 2004). This species is a daily spawner that does not migrate far from its spawning area (resident spawner; Sadovy et al. 2003). Humpheads may spawn during several or all months of the year associated with a range of different reef habitats (Sadovy et al. 2003).

Common Prey Species—The humphead wrasse feeds primarily on mollusks and a wide variety of other well-armored invertebrates including crustaceans, echinoids, brittlestars, sea urchins, COTS (*Acanthaster planci*), boxfishes, sea hares, and heavy shells of *Trochus* and *Turbo* spp. (WPRFMC 2001; Sadovy et al. 2003; Cornish 2004).

- Sakhalin Sturgeon (*Acipenser miladoi*)

Status—The Sakhalin sturgeon occurs in the West Japan study area of the Japan and Okinawa Complexes OPAREA (Birstein and Bemis 1997). Along with its minimum population doubling time (approximately 14 years; Froese and Pauly 2005), this species has also declined from overfishing, accidental by-catch of juveniles, poaching, and environmental degradation causing habitat loss and alterations of life cycles (migration, foraging, spawning, nursing, overwintering; Billard and Lecointre 2001). In addition to the CITES listing, this species is listed on the IUCN Red List of threatened species as endangered (Sturgeon Specialist Group 1996).

Distribution—Sakhalin sturgeons inhabitat the Sea of Japan from the Korean Peninsula to north of Hokkaido Island. It occurs in the mouths of small rivers in eastern Asia and the Korean Peninsula as well as the Amur River, rivers of the Sakhalin Island, and the Tummin (Datta) River in the eastern Russia (Birstein and Bemis 1997).

Habitat Preference—Young Sakhalin sturgeons inhabit the lower reaches of rivers and estuaries (FAO 2005). They utilize the mainstream or margins of the rivers inhabiting hard substrates on the bottom at depths ranging from a few meters to 26 m with current velocity range of 0.5 to 2.2 m/s (Birstein and Bemis 1997). After their reproductive period, this species migrates to the ocean to complete its life cycle (FAO 2005).

Life History—Small groups of the Sakhalin sturgeon run upstream with partners to spawn between late May and early July in water ranging from 7.2° to 11.5°C with young fish migrating to the sea in the autumn of the same year (FAO 2005). This species spawns in small rivers of the west coast of Hokkaido in April and May (Birstein and Bemis 1997; FAO 2005).

Common Prey Species—The Sakhalin sturgeon feed on benthic invertebrates, with fish becoming increasingly important prey as they increase in size (Moyle and Cech 2000).

- Seahorses (Syngnathidae)

Status—Seven seahorses occur in the Japan and Okinawa Complexes OPAREA (Lourie et al. 2004). Some of these species regularly appear in the trade for traditional medicine (Chinese), curios, and aquarium and hobbyist use (Paulus 1999). In addition to the CITES listing, the crowned seahorse (*Hippocampus coronatus*), thorny seahorse (*H. histrix*), great seahorse (*H. kelloggi*), and Dhiho's seahorse (*H. sindonis*), have been listed as data deficient while the spotted seahorse (*H. kuda*), Japanese seahorse (*H. mohnikei*), and three-spot seahorse (*H. trimaculatus*) as vulnerable on the IUCN Red List of threatened species (Vincent 1996; Project Seahorse 2001, 2002, 2003a, 2003b, 2003c, 2003d; Lourie et al. 2004).

Distribution—Pipefish and seahorses are circumtropical and temperate in their distribution occurring in the Atlantic, Indian, and Pacific oceans in marine, brackish, and freshwaters (Nelson 1994). The crowned and Dhiho's seahorses are endemic to Japan (Project Seahorse 2003a, 2003c) occurring in the West Japan (Hokkaido to Kyushu) and East Japan (Shiikoku to Kyushu) study areas, respectively (Project Seahorse 2003a; Lourie et al. 2004).

Habitat Preference—Syngnathids are small, inconspicuous bottom dwellers that occur in a wide variety of shallow habitats from estuaries and shallow sheltered reefs to seaward reef slopes (WPRFMC 2001a). Habitats include seagrasses, floating weeds, algae, corals, mud bottoms, sand, rubble, or mixed reef substrate from tidepools to lagoons and seaward reefs (Myers 1999). Demersal syngnathid populations occur in pairs or singly at depths ranging from a few centimeters to more than 400 m, although they are generally limited to water shallower than 50 m (Allen et al. 2003). Seahorse species found within the OPAREA range from approximately 15 to 150 m (Myers 1999; Project Seahorse 2001a; Project Seahorse 2003a; Lourie et al. 2004). Juveniles are occasionally found in the open sea in association with floating debris (WPRFMC 2001).

Life History—Spawning by seahorses involves the female depositing her eggs into a ventral pouch on the male, which carries the eggs until hatching at intervals of three to four days (WPRFMC 2001). Breeding populations occur throughout the salinity range from fresh to hypersaline waters (Dawson 1985). Breeding seasons for the seahorses found in the OPAREA vary by species from seasonally (crowned [spring and fall] and three-spotted seahorses [summer]) to year-round (thorny seahorse). Brood sizes range from several hundred individuals for the crowned seahorse to around 1,800 individuals for the three-spot seahorse. Gestation periods are only known for the thorny seahorse and three-spot seahorse and they last approximately 16 to 17 days (Vincent 1996; Project Seahorse 2001, 2002, 2003c, 2003d; Lourie et al. 2004)

Common Prey Species—Seahorses feed upon minute benthic and planktonic animals such as copepods (Dawson 1985; Myers 1999).

4.1.2 Japan Fisheries

The Japanese have a traditional reliance on fish consumption, with one of the highest per capita fish consumption rates in the world, providing almost 50% of their protein intake (Schmidt 2003; Sugiyama et al. 2004; Swartz 2004). Marine, inland (freshwater), and aquaculture fisheries provide fishery products to help support this high demand. The largest fisheries sector is marine fisheries, accounting for 90% of Japanese fishery production (FIGIS 2001; Swartz 2004). While still relying heavily on domestic fisheries, Japan has recently become one of the world's biggest importers of fishery products.

In 2000, Japan was ranked third in the world in fishery production (Swartz 2004). Landings from marine fisheries increased after WWII from 2.3 million tons in 1945 to a peak of 11.3 million tons in 1984. Landings then declined to 5.7 million tons by 2000 (Swartz 2004). The decline in landings was related to a variety of factors including the establishment of 200 NM national EEZs, which effectively reduced the amount of productive coastal shores that Japanese fishing fleets could operate in. Nevertheless, the Japanese had developed extensive fisheries and a formidable fishing fleet in the later half of the twentieth century and many of these are still active (Swartz 2004).

Japanese marine fisheries are divided into three categories: coastal, offshore, and distant water (Ruddle 1987; Swartz 2004).

- Coastal fisheries operate in coastal/nearshore waters and generally use boats less than 10 metric tons (**Table 4-2**). These boats are usually motorized, but older traditional sail powered vessels may still be seen (Japanese Coast Guard 2005). Landings are currently around 2 million tons. While this is lower than those from offshore or distant water fisheries they are considered very important economically because of high value species such as porgies and amber jack (Ruddle 1987; Schmidt 2003; Swartz 2004). High value coastal species play a major part in the economics of the fish market (Schmidt 2003). Coastal resources were depleted in the 1950's and impacted by pollution in the 1960's but some areas have recovered due to management and awareness efforts.

- Offshore fisheries operate in offshore waters beyond the coasts but within Japan's EEZ (as well as the EEZ of neighboring countries such as China, South Korea, and Russia). Offshore fisheries are the most important of the marine fisheries in Japan, in terms of weight landed (**Table 4-2**). These fisheries utilize vessels averaging 100 mt and generally target small pelagic and demersal (bottom) species in the Northwest Pacific, Sea of Japan, and East China Sea (west of Okinawa and the Ryukyu Islands). Tunas, swordfish, and billfishes are also important target species caught in offshore waters. Overall offshore landings in 2001 were 3.3 million tons (Ruddle 1987; Swartz 2004).

- Distant water fisheries are those that operate on the high seas (international waters beyond national EEZs—generally 200 NM from a country's shores). Distant water fishing fleets usually use vessels of 200 mt or more. In 1973, distant water fisheries production represented 41% of total marine fisheries landings. By 2001, the landings had decreased by 21% to 820,000 tons (Swartz 2004). Since distant water fisheries lie outside the scope of the study area, they will not be described further. Some elements of the offshore fisheries overlap with distant water fisheries, such as target species and vessel activity (some offshore vessels operate in high seas areas).

4.1.2.1 Coastal Fisheries

In 2000, 140,000 of 150,000 fishery enterprises operated in coastal waters, with 240,000 individuals participating (Schmidt 2003). Within the coastal fishing area off Japan, resources are parceled into jurisdictions that are "owned" and managed by individual fishery cooperative associations with exclusive rights to its harvest. Management of these areas includes species prohibitions, size and gear limitations, closed seasons, and the setting of conservation, recovery, and closed zone regulations (Ruddle 1987; Schmidt 2003). There are 6,245 fishing communities centered around 2,931 fishing ports in Japan

Table 4-2. Details of coastal and offshore fisheries of Japan, showing areas fished, vessel size, gears used, and species caught.

Coastal Fisheries		**Offshore Fisheries**	
Area: Coastal/nearshore waters		*Area:* Within EEZ beyond coastal areas	
Vessels: Up to 10 gross tons		*Vessels*: Average 100 gross tons	
Gear type:		*Gear type:*	
Trawls	Pole-and-line	Purse seines	Pole-and-line
Seines	Longlines	Trawls	Traps and pots
Gillnets	Traps and Pots	Longlines	FADs
Fixed nets	FADs		
Species:		*Species:*	
Salmon	Amber Jack	Japanese sardine	Yellow croaker
Eels	Porgies	Pacific saury	Large hairtail
Squids	Yellowtail	Anchovy	Bluefin tuna
Octopuses	Mackerels	Jack mackerel	Yellowfin tuna
Globe fishes	Dolphin-fish	Horse Mackerl	Bigeye tuna
Sea Urchins	Wahoo	Frigate mackerel	Albacore tuna
Sea Cucumbers	Sharks	Yellowtail	Skipjack tuna
Tunas	Marlins	Filefish	Swordfish
Jacks	Sea robins	Herring	Black marlin
Anchovy	Pollack	Sea robin	Dolphin-fish
		Parrot bass	Wahoo
		Alaska pollock	Striped marlin
		Squids	Sharks
		Snow crab	Cetaceans
		Chub mackerel	Halibut

(Schmidt 2003). Fishery activity in these areas can be high year round (Japan Coast Guard 2005). Typically, fishing gears include trawl nets, boat seines, purse seines, gill nets, fixed nets, pole-and-line gears, longlines, traps and pots, and FADs. Some of the net gears use two or more vessels at a time, such as purse seines and trawls. Gill nets include the varieties of surface, mid-water (drift), and bottom types. Longlines include both surface and bottom types (Japan Coast Guard 2005).

4.1.2.2 Offshore Fisheries

Fishes caught in offshore waters of the Oyashio and Kuroshio Current off the eastern coast of Japan include the Japanese sardine (pilchard), Pacific saury, anchovy, jack mackerel, frigate mackerel, yellowtail (*Seriola lalandi*), filefish, herring, sea robin, and parrot bass (NMFS 2003; Akiyama et al. 2004; Sugiyama et al. 2004). Many of these species migrate seasonally, moving south in the winter to breed off Kyushu and moving northward in the summer to feed (Pices 2004). The Japanese sardine had accounted for over 40% of marine fisheries landings until the fishery collapsed by the end of the 1980's. The effect of climate change on population sizes is thought to have played a part in declining anchovy stocks as well as those of other fish stocks in the western Pacific (Akiyama et al. 2004). Currently the most important fishes in offshore waters of Japan are Alaska pollock (walleye pollock), jack mackerel, saury, squid, and snow crab (*Chinonoecetes japonicus*; Schmidt 2003).

Fishing for diamond squid with traps and hooks is important in the Tsushima Current from the Tsushima straits to the Sea of Japan from July through February. Near Okinawa, fishing for diamond squid occurs from November through April (Bower and Miyahara 2005). Other major fisheries in the Sea of Japan use purse seines and trawls (Bayliff and Olson 2004). Common squid, Japanese sardine, chub mackerel, horse mackerel, anchovy, filefish, and Alaska pollack are the major species caught in the Sea of Japan including the West Japan study area (Chiba et al. 2004). Japanese sardine and common squid have been the most important of these fisheries. Fishing in the southern portion of the Sea of Japan is common year round (Chiba et al. 2004). Vessels from China and South Korea also often fish in the Sea of Japan (Chiba et al. 2004).

In the East China Sea, fisheries use large trawls (including pair trawls) and purse seines, targeting hairtail, filefish, and common squid (Bayliff and Olson 2004; Yoo and Kim 2004). Small yellow croaker (*Larimichthys polyactis*), largehead hairtail *(Trichiurus lepturus*), chub mackerel, and anchovy are caught in the southern Yellow Sea and northern East China Sea near portions of the West Japan and Okinawa study areas during the winter (November through February) (Yoo and Kim 2004).

Bluefin tuna are caught with a variety of gears off Japan. In the West Japan study area, south of Shikoku Island from July through October, these tuna are caught with trolling gear and from November through April they are caught west of Kyushu (Bayliff and Olson 2004). From May through September, bluefin are caught in the East Japan study area off Honshu with purse seines. In the Sea of Japan, they are caught using traps, gillnets, and other gears. They are also caught in coastal waters with longlines (Bayliff and Olson 2004).

4.1.2.2.1 Foreign fisheries

Foreign vessels, in addition to those of Japanese enterprises, may also be seen fishing in waters of the Japan and Okinawa complexes OPAREA. After the 1970's with the establishment of national EEZs, Japan was involved in negotiations that effectively allowed Soviet (Russian), Chinese, and Korean fisheries to operate in various parts of its EEZ, including the Sea of Japan and the East China Sea (Swartz 2004).

4.1.2.3 Gear Type

4.1.2.3.1 Longlines

Longlines are used in coastal, offshore, and distant water fisheries. Longline fishing effort in offshore waters has decreased since the 1980's. The primary species landed by longlines are tunas (yellowfin [*T. albacares]*, albacore [*T. alalunga]*, and bigeye [*T. obesus*], swordfish [*Xiphias gladius[*), and billfishes (striped marlin [*Tetrapturus audax*], blue marlin [*Makaira nigricans*], black marlin [*M. indica*], sailfish [*Istiophorus platypterus*], and shortbill spearfish [*T. angustirostris*]; Ogura et al. 2003). Albacore and bigeye tunas, swordfish, and billfishes are caught with longlines around coastal areas of Japan (Ogura et al. 2003). Longlines fisheries operate primarily near Honshu in the East Japan study area throughout the year. Some activity extends toward the West Japan study area near Shikoku and the Ryukyu Islands of the Okinawa study area in the later part of the year (October-December). Albacore is actively targeted near the Izu Islands in the East Japan study area from November through March. Swordfish and yellowfin tuna are targeted year round, with fishing for swordfish occurring at night (Ogura et al. 2003).

4.1.2.3.2 Pole-and-line

Like longlines, pole-and-line fishery landings have also decreased since the 1980's (Ogura et al. 2003). Pole-and-line fisheries primarily target skipjack, albacore, and yellowfin tunas. Fishing grounds of the pole-and line fishery shift seasonally, concentrating in the Okinawa study area off Okinawa and the Ryukyu Islands from January through March, then extending up to the waters (coastal and offshore) of northern Honshu in the East Japan study area from April through June, and then continuing to extend and concentrate further to the northeast in coastal and offshore waters through the end of the year. Pole-and-

line fishing in the Okinawa study area around the Okinawa and the Ryukyu Islands often targets FADs (Ogura et al. 2003).

4.1.2.3.3 Purse seines

Purse seining effort increased up through the early 1980s and has stabilized since the 1990s. The primary species targeted by purse seines is the skipjack tuna. Landed to a lesser degree are yellowfin and bigeye tunas. Fishing occurs year round in the West Japan study area between Kyushu and South Korea, starting primarily in the East China Sea in January and then diminishing in the area in December. The season off the East Japan study area starts in late April around the Izu Islands south of Tokyo. Fishing extends coastally and offshore of southern Honshu and offshore of northeastern Honshu within the East Japan study area, then diminishes off the Izu Islands starting in July and stops by the end of December. Some purse seining occurs in the East China Sea west of Okinawa and the Ryukyu Islands from April through August. FADs and other naturally occurring objects floating at sea are often targeted while fishing with purse seines for schools of tuna (Ogura et al. 2003; Japan Coast Guard 2005).

4.1.2.3.4 Trawls and dredges

Trawls and dredges are heavily used in the eastern study area north of Tokyo in offshore, coastal, and nearshore waters. They are used as well as in the nearshore waters around Kyushu and offshore waters in the northern Tsushima Strait between Kyushu and South Korea in the West Japan study area. Trawls also operate west of the Okinawa study area in the East China Sea (Watson et al. 2004; Japan Coast Guard 2005). Midwater trawls primarily catch jacks (Carangidae), porgies (Sparidae) and croakers (Scianidae) and a variety of other fishes such as anchovies (Engraulidae), grunts (Haemulidae), chubs (Kyphosidae), common squids (Loliginidae), salmonids (Salmonidae), and puffers (Tetraodontidae). Bottom trawls catch herring smelts (Argentinidae), shrimps, jacks, requiem sharks (Carcharhinidae), basking sharks (Cetorhinidae), anchovies, chubs, common squids, octopuses (Octopodidae), croakers, cuttlefishes (Sepiidae), dogfish sharks (Squalidae), and puffers. Dredges are primarily used to harvest a variety of bivalve mollusks (clams/scallops/oysters/mussels), gastropods (snails), and curstaceans such as barnacles.

4.1.2.3.5 Gillnets

Gillnets are generally placed in the path of moving schools of fish. They can be set to float at the surface, hang in midwater, or can be placed on the bottom. Surface and midwater gillnets can be either anchored or allowed to drift. Regardless of type, all gillnet gears are marked with floats. They are rarely set in highly trafficked waters. Mackerels are often targeted by drift gillnets. Bottom gillnets catch cods (Gadidae), yellowtail (*Seriola lalandi*), and mackerels (Japan Coast Guard 2005).

4.1.2.3.6 Traps and pots

Traps and pots are used to capture various fishes and invertebrates. Octopus and eels are the primary species targeted. These gears are usually set in coastal areas and are marked with floats at the surface. Fishing activity includes the process of setting the traps or pots on location then returing to retrieve them after a length of time, often overnight. A large number of traps or pots are usually strung together along a single line (Japan Coast Guard 2005). Traps are also used to catch diamond squid and bluefin tuna in the Tsushima Straits and southern Sea of Japan (Bayliff and Olson 2004; Bower and Miyahara 2005).

4.1.2.3.5 Fish aggregating devices

FADs, while not fishing gears themselves, play a role in several fishing techniques. The use of FADs is common around Okinawa and the Ryukyu Islands in the Okinawa study area. In 1996, there were 177 FADs. Yellowfin tuna is the primary species caught near FADs, but also caught are albacore, skipjack, and bigeye tunas, as well as other pelagic species like black marlin, dolphin-fish (*Coryphaena hippurus*), and wahoo (*Acanthocybium solandri*; Kakuma 1996).

4.2 LITERATURE CITED

Allen, G.R. R. Steene, P. Humann, and N. DeLoach. 2003. Reef fish identification: Tropical Pacific. Jacksonville, Florida: New World Publications Inc.

Bayliff, W. and R. Olson. 2004. Tuna. In: PICES. Marine ecosystems of the North Pacific. North Pacific Marine Science Organization (PICES) Special Publication 1. pp.211-219.

Billard, R., and G. Lecointre. 2001. Biology and conservation of sturgeon and paddlefish. Reviews in Fish Biology and Fisheries 10:355-392.

Birstein, V.J., and W.E. Bemis. 1997. How many species are there within the genus *Acipenser*? Environmental Biology of Fishes 48:157-163.

Bower, R. and K. Miyahara. 2005. The diamond squid (*Thysanoteuthis rhombus*): A review of the fishery and recent research in Japan. Fisheries Research 73:1-11.

Burke, L. 2002. Japan. Accessed 27 July 2005. http://reefsatrisk.wri.org/casestudy_text.cfm?ContentID=111.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). 2005. CITES. Accessed 20 June 2005. http://www.cites.org.

Cahmi, M., S. Fowler, J. Musick, A. Brautigam, and S. Fordham. 1998. Sharks and their relatives: Ecology and conservation. Occasional Paper of the IUCN Species Survival Commission No. 20. Gland, Switzerland: IUCN.

Cavanagh, R.D., P.M. Kyne, S.L. Fowler, J.A. Musick, and M.B. Bennett. 2003. The conservation status of Australasian Chondrichthyans. Report of the IUCN Shark Specialist Group Australia and Oceania regional red list workshop, Queensland, Australia, 7-9 March 2003. Brisbane: The University of Queensland, School of Biomedical Sciences.

Chiba, S., S. Davidova, N. Iguchi, J. Ishizaka, Y.-S. Kang, H. Kidokoro, S. Kim, S. McKinnell, S. Riser, Y. Sakurai, P. Tischenko, A. Trukhin, Y. Watanuki, S. Yoo, and C.-I. Zhang. 2004. Japan/East Sea. In: PICES. Marine ecosystems of the North Pacific. North Pacific Marine Science Organization (PICES) Special Publication 1. pp. 79-93.

Choat, J.H., and D.R. Bellwood. 1991. Reef fishes: Their history and evolution. Pages 39-66 in P.F. Sale, ed. The ecology of fishes on coral reefs. San Diego: Academic Press.

Compagno, L.J.V. 1984. FAO species catalogue. Volume 4 – sharks of the world: An annotated and illustrated catalogue of shark species known to date. Part 2: Carcharhiniformes. FAO Fisheries Synopsis. Volume 4, Part 1. Rome: Food and Agriculture Organization of the United Nations.

Compagno, L.J.V. 2002. FAO species catalogue. Sharks of the world: An annotated and illustrated catalogue of shark species known to date. Volume 2: Bullhead, mackerel, and carpet sharks (Heterodontiformes, Lamniformes, and Orectolobiformes). FAO Species Catalogue for Fishery Purposes No.1, Vol. 2. Rome: Food and Agriculture Organization of the United Nations.

Cornish, A.. 2004. *Cheilinus undulatus*. In: IUCN 2004. The 2004 IUCN Red List of Threatened Species. Accessed 20 July 2005. http://www.redlist.org.

Dawson, C.E. 1985. Indo-Pacific pipefishes (Red Sea to Americas). Ocean Springs, Mississippi: The Gulf Coast Research Laboratory.

DoD (Department of Defense). 2001. Chapter 13: Natural resources including endangered species. Pages 13-1 to 13-16 in Department of Defense, Japan Environmental Governing Standards, Version 1.1 (Revised June 2002). Pearl Harbor, Hawaii: Naval Facilities Engineering Command, Pacific Division.

DoN (Department of the Navy) 1994. Oceanographic forecaster's handbook. U.S. Naval Oceanography Command Detachment, Misawa, Japan.

Donaldson, T.J., R.F. Myers, J.T. Moyer, and P.J. Schupp. 1994. Zoogeography of fishes of the Mariana, Ogasdawara, and Izu Islands: A preliminary report. Natural History Research, Special Issue 1:303-332.

Ebert, D.A. 2003. Sharks, rays, and chimeras of California. California Natural History Guides No. 71. Los Angeles: University of California Press.

FAO (Food an Agriculture Organization of the United Nations). 2000. Fishery Country Profile: Japan. Accessed 28 July 2005. http://www.fao.org/fi/fcp/en/JPN/profile.htm.

FAO (Food and Agricultural Organization of the United Nations). 2005. Fisheries global information system (FIGIS) – FAO/SIDP Species identification sheet: *Acipenser mikadoi*. Accessed 18 July 2005. http://www.fao.org.figis/servlet/species?fif=10181.

Fergusson, I., L. Compagno, and M. Marks. 2000. *Carcharodon carcharias*. In: IUCN 2004. The 2004 IUCN red list of threatened species. Accessed 20 July 2005. http://www.redlist.org.

FIGIS (Fisheries Global Information System). 2001. FIGIS – Country profile fact sheet: Japan. Food and Agriculture Organization of the United Nations. Accessed 17 June, 2005. http://www.fao.org/figis/servlet/static?dom=country&xml=japan_fcp.xml.

Fowler, S.L. 2000. *Cetorhinus maximus* (North Pacific subpopulation). In: IUCN 2004. The 2004 IUCN red list of threatened species. Accessed 20 July 2005. http://www.redlist.org.

Froese, R., and D. Pauly, eds. 2005. FishBase. World wide web electronic publication. www.fishbase.org. Accessed 17 June 2005. http://www.fishbase.org/search.cfm.

Fujita, T., T. Inada, and Y. Ishito. 1993. Density, biomass and community structure of demersal fishes off the Pacific coast of northeastern Japan. Journal of Oceanography 49:211-229.

Helfman, G.S., B.B. Collette, and D.E. Facey. 1997. The diversity of fishes. 4th ed. Malden, Massachusetts: Blackwell Science, Inc.

Hennemann, R.M. 2001. Sharks and rays elasmobranch guide of the world: Pacific Ocean, Indian Ocean, Red Sea, Atlantic Ocean, Caribbean, and Arctic Ocean. Frankfurt: IKAN – Unterwasserarchiv.

Japan Coast Guard. 2005. For the safe navigation in Japanese coastal waters: Part 1 conditions in sea areas around Japan. Accessed 21 July, 2005. http://www.kaiho.mlit.go.jp/syoukai/soshiki/toudai/navigation-safety/download/d_02top.htm.

Kafanov, A.I., I.V. Volvenko, V.V. Fedorov, and D.L. Pitruk. 2000. Ichthyofaunistic biogeography of the Japan (East) Sea. Journal of Biogeography 27:915-933.

Kakuma, S. 1996. FAD fisheries of Okinawa, Japan. SPC Fish Aggregating Device Information Bulletin No. 2:8-12.

Kimrua, T., C.F. Dai, S. Pae, H. Hui, P.O. Ang, J.G. Je, and C. Choyce L.s. 2004. Status of coral reefs in east and north Asia: China, Hong Kong, Taiwan, Korea, and Japan. Pages 277-301 in C. Wilkinson, ed. Status of coral reefs of the world: 2004. Volume 1. Townsville, Australia: Australian Institute of Marine Science.

Knickle, C., L. Billingsley, and K. DiVittorio. 2005. Basking shark. Biological profiles. Accessed 20 July 2005. http://www.flmnh.ufl.edu/fish/Gallery/ Descript/baskingshark/baskingshark.html.

Kyne, P., R. Cavanagh, S. Fowler, and C. Pollock. 2005. IUCN Shark Specialist Group Red List assessments, 2000-2004. Gland, Switzerland and Cambridge, United Kingdom: IUCN.

Lecchini, D., M. Adjeroud, M.S. Pratchett, L. Cadoret, and R. Galzin. 2003. Spatial structure of coral reef fish communities in the Ryukyu Islands, southern Japan. Oceanologica Acta 26:537-547.

Lourie, S.A., S.J. Foster, E.W.T. Cooper, and A.C.J. Vincent. 2004. A guide to the identification of seahorses. Project Seahorse and TRAFFIC North America. Washington, D.C.: University of British Columbia and World Wildlife Fund.

Martins, C., and C. Knickle. 2005a. White shark. Biological profiles. Accessed 20 July 2005. http://www.flmnh.ufl. edu/fish/Gallery/Descript/Whiteshark/Whiteshark.html.

Martins, C., and C. Knickle. 2005b. Whale shark. Biological profiles. Accessed 20 July 2005. http://www.flmnh.ufl. edu/fish/Gallery/Descript/Whaleshark/Whaleshark.html.

Ministry of the Environment. 1995. Present status of biological diversity. In: National strategy of Japan on biological diversity. Accessed 14 July 2005. http://www.env.go.jp/en/pol/nsj/nsj-p1s3.html.

Moyle, P.B., and J.J. Cech, Jr. 2000. Fishes: An introduction to ichthyology. Fourth Edition. Upper Saddle River, New Jersey: Prentice Hall.

Myers, R.F. 1999. Micronesian reef fishes: A comprehensive guide to the coral reef fishes of Micronesia. Barrigada, Guam: Coral Graphics.

NMFS (National Marine Fisheries Service). 2001. Final environmental impact statement fishery management plan pelagic fisheries of the western Pacific region. Prepared for National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Regional Office by URS Corporation, Honolulu, Hawaii.

NMFS (National Marine Fisheries Service). 2004a. National Marine Fisheries Service Office of Protected Resources. Accessed 30 November 2004. http://www.nmfs.noaa.gov/pr/species/concern.

NMFS (National Marine Fisheries Service). 2004b. 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.

NOAA (National Oceanic and Atmospheric Administration). 2002. Impacts of El Nino on fish distribution. Accessed 16 February 2005. http://www.elnino.noaa.gov.

Nonaka, M. 2004. Daito Islands. Pages 199-201 in M. Tsuchiya, K. Nadaoka, H. Kayanne and H. Yamano, eds. Coral reefs of Japan. Tokyo, Japan: Ministry of the Environment.

Norman, B. 2000. *Rhincodon typus*. In: IUCN 2004. The 2004 IUCN red list of threatened species. Accessed 20 July 2005. http://www.redlist.org.

Paulus, T. 1999. Syngnathidae – pipefishes and seahorses. Pages 2264-2276 in K.E. Carpenter and V.H. Niem, eds. The living marine resources of the western central Pacific. Volume 4: Bony fishes, Part 2 (Mugilidae to Carangidae). Rome: Food and Agriculture Organization of the United Nations.

Pearcy, W.G. 1991. Biology of trhe transition region. Pages 39-55 in J.A. Wetherall, ed. Biology, oceanography, and fisheries of the North Pacific Transition Zone and Subarctic Frontal Zone. NOAA Technical Report NMFS 105.

PICES. 2004. Marine life in the North Pacific Ocean, the known, unknown, and unknowable. North Pacific Marine Science Organization (PICES). PICES Special Publication 2.

Project Seahorse. 2001a. *Hippocampus histrix*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 14 January 2004. http://www.redlist.org.

Project Seahorse. 20021. *Hippocampus kelloggi*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 14 January 2004. http://www.redlist.org.

Project Seahorse. 2003a. *Hippocampus coronatus*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 25 April 2005. http://www.redlist.org.

Project Seahorse. 2003b. *Hippocampus kuda*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 14 January 2004. http://www.redlist.org.

Project Seahorse. 2003c. *Hippocampus sindonis*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 25 April 2005. http://www.redlist.org.

Project Seahorse. 2003d. *Hippocampus trimaculatus*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 25 April 2005. http://www.redlist.org.

Ruddle, K. 1987. Administration and conflict management in Japanese coastal fisheries. FAO Fisheries Technical Paper – 273. FAO, Rome.

Sadovy, Y, M. Kulbicki, P. Labrosse, Y. Letourneur, P. Lokani, and T.J. Donaldson. 2003. The humphead wrasse, *Cheilinus undulatus*: Synopsis of a threatened and poorly known giant coral reef fish. Reviews in Fish Biology and Fisheries 13:327-364.

Schmidt, C. 2003. Fisheries and Japan: A case of multiple roles? Paris: Organisation for Economic Co-operation and Development (OECD).

Sturgeon Specialist Group. 1996. *Acipenser mikadoi*. In: IUCN 2004. The 2004 IUCN red list of threatened species. Accessed 20 July 2005. http://www.redlist.org.

Sugimoto, T., S. Kimura, and K. Tadokoro. 2001. Impact of El Niño events and climate regime shift on living resources in the western north Pacific. Progress in Oceanography 49:113-127.

Sugiyama, S., D. Staples, and S. Funge-Smith. 2004. Status and potential of fisheries and aquaculture in Asia and the Pacific. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok. FAO APFIC RAP Publication 2004/25.

Swartz, W. 2004. Global Maps of the growth of Japanese marine fisheries and fish consumption. Master of Science Thesis. The University of British Columbia.

URI (University of Rhode Island). 2005. Large marine ecosystems of the world. Accessed 18 August 2005. http://www.edc.uri.edu/lme/default.htm.

Vincent, A. 1996. *Hippocampus mohnikei*. In: IUCN 2004. 2004 Red List of Threatened Species. Accessed 25 April 2005. http://www.redlist.org.

Watanabe, H. M. Moku, K. Kawaguchi, and A. Ohno. 1999. Diel vertical migration of myctophid fishes (Family Myctophidae) in the transitional waters of the western North Pacific. Fisheries Oceanography 8(2):115-127.

Watson, R., E. Hoshino, J. Beblow, C. Revenga, Y. Kura, and A. Kitchingman. 2004. Fishing gear associated with global marine catches. Fisheries Centre Research Reports 12(6).

Wilkinson, C. eds. 2000. Status of coral reefs of the world: 2000. Cape Ferguson, Australia: Australian Institute of Marine Science.

Wilson, S.G., J.G. Taylor, and A.F. Pearce. 2001. The seasonal aggregation of whale sharks at Ningaloo Reef, Western Australia: currents, migrations, and the El Nino/Southern California. Environmental Biology of Fishes 61:1-11.

WPRFMC (Western Pacific Regional Fishery Management Council). 2001. Final fishery management plan for coral reef ecosystems of the western Pacific region. Volumes I-III including Amendment 7 bottomfish and seamount groundfish fisheries, Amendment 11 crustacean fisheries, Amendment 5 precious corals fisheries, and Amendment 10 pelagic fisheries. Honolulu: Western Pacific Regional Fishery Management Council.

Yoo, S. and S. Kim. 2004. Yellow Sea/East China Sea. In: PICES. Marine ecosystems of the North Pacific. North Pacific Marine Science Organization (PICES) Special Publication 1. pp. 59-77.

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5.0 ADDITIONAL CONSIDERATIONS

5.1 MARITIME BOUNDARIES: CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE

Maritime boundaries are critical elements that affect the planning of activities in the marine environment (GDAIS 2003). They delimit the extent of a nation's sovereignty, exclusive rights, jurisdiction, and control over the ocean areas off its coast. Maritime boundaries may include a 12 NM territorial sea, an 18 to 24 NM contiguous zone, a 200 NM EEZ, and a nation's continental shelf (**Figure 5-1**). Since maritime boundaries are delimited, rather than demarcated, there is generally no physical evidence of the boundary. As a result, there can often be confusion, disagreement, and conflicting versions of marine boundaries between distinct nations and/or territories (NOAA 2005).

Japan's territorial sea extends 12 NM offshore, measured from the baselines determined in accordance with the Japanese "Law on the Territorial Sea" enacted in 1977. The territorial sea extends 3 NM offshore in the following designated areas: the straits of Soya, Tsugaru, Osumi, and the eastern and western channels of the Tsushima Strait (APEC 2005). This baseline coincides with the mean lower low tide line found along the shore and is often termed the "normal" baseline (Kapoor and Kerr 1986; Prescott 1987; **Figure 5-1**). At the mouths of bays, rivers, or other areas where the coastline is not continuous, a straight baseline is drawn over the coastal feature. Rather than use the normal baseline, an increasing number of countries use either the straight baseline or archipelagic baseline system from which to measure their territorial waters (Kapoor and Kerr 1986; Prescott 1987).

The UN Convention on the Law of the Sea Treaty, created in 1982, delimited the international maritime sovereignties of coastal nations as 12 NM for territorial seas, 18 to 24 NM for a contiguous zone, and 200 NM for an EEZ (54 FR 777; **Table 5-1**). In February of 1983, Japan signed the Law of the Sea Treaty and later ratified it in June 1996 enforcing the UN guidelines for maritime boundaries, territorial seas, contiguous zones, and EEZs (APEC 2005).

Table 5-1. Timeline detailing the establishment of Japanese jurisdiction and maritime boundaries in the Japan and Okinawa Complexes OPAREA by legislation and agreements.

- **From Antiquity to the Early Twentieth Century:** nations individually established seaward boundaries of 3 to 9 NM under the "cannon shot" concept.
- **1958–UN Convention on the Law of the Sea I:** the UN convened the first international conference on maritime boundaries.
- **1960–UN Convention on the Law of the Sea II:** the second UN conference convened on international maritime boundaries.
- **1973–UN Convention on the Law of the Sea III:** the third UN conference convened on international maritime boundaries.
- **1982–UN Convention on the Law of the Sea Treaty:** the UN Convention on the Law of the Sea lays down a comprehensive regime of law and order in the world's oceans and seas by establishing rules governing all uses of the oceans and their resources. Most nations, including Japan, adhere to its guidelines for maritime boundaries, including territorial seas, contiguous zones, and EEZs.
- **1983–Japan signs the Law of the Sea Treaty.**
- **1994–UN Convention on the Law of the Sea:** the UN entered into force the 1982 Law of the Sea Treaty
- **1996–Japan ratifies the 1982 Law of the Sea Treaty adhering to the guidelines set forth for maritime boundaries, territorial seas, contiguous zones, and EEZs.**

Source: DOALOS (2004); APEC (2005).

The Japanese EEZ covers approximately 3.6 million km^2 of ocean space. Overlapping boundaries with other nations exist in 6 situations: China, the Republic of Korea, the Democratic People's Republic Korea, the Phillipines, Russia, and the U.S. (Northern Marianas; APEC 2005). International maritime boundaries are those agreed upon by one or more countries to resolve these overlapping claim issues. In cases

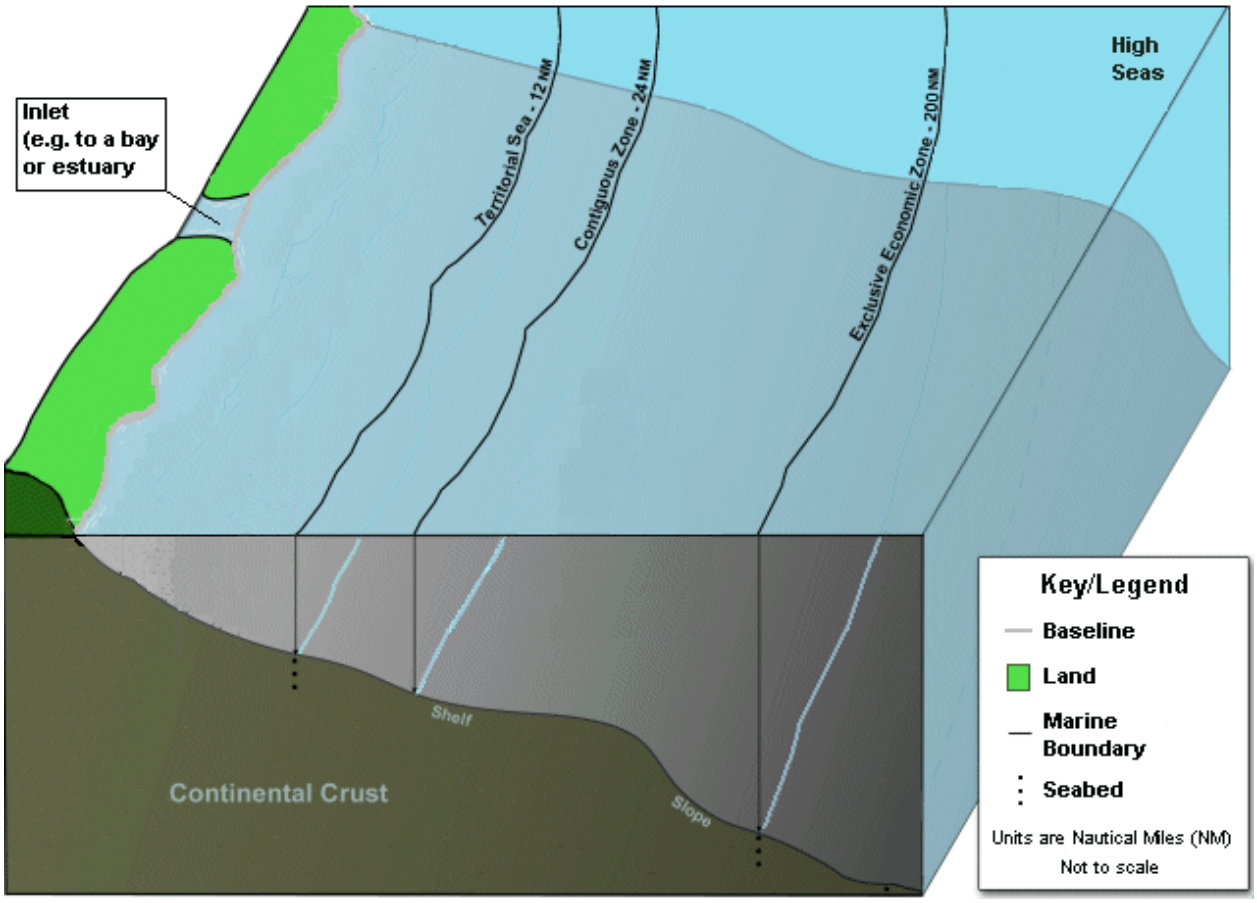

Figure 5-1. A generic 3D representation of the maritime boundaries. The baseline is defined as the mean low water/tide line along the coast or a straight line drawn across coastal bays or other inlets. Adapted from: NOAA (2005a).

where a nation's 200 NM EEZ overlaps with that of another country, both countries' EEZs are deemed to end at what is called the "median line," an imaginary line that is equidistant from the baseline of each country. The Japan and Okinawa Complex OPAREA is predominantly located within the Japanese EEZ (**Figure 5-2**). The northwest portion of the West Japan study area stretches beyond the Japanese EEZ and into the territorial sea of South Korea.

Oil exploration in the East China Sea has lead to boundary disputes between Japan, China, and South Korea (Gao and Wu n.d.). These disputes lead to an agreement between Japan and South Korea which formed a "Joint Development Zone" (Gao and Wu n.d.). The zone includes approximately 85,000 km^2 enclosed by each party's claims to the continental shelf and disregarded Chinese claims of sovereignty over the shelf extending to the Okinawa Trough (Gao and Wu n.d.). The East China Sea has also seen 30 years of seabed controversy between Japan and China (Gao and Wu n.d.). Recent progress between the nations has lead to the development of "conflict avoidance" regimes including joint fishing agreements and a prior notification scheme for scientific research (Gao and Wu n.d.).

5.1.1 Maritime Boundaries in the Japan and Okinawa Complexes OPAREA

All warning areas, restricted areas, and other Navy training areas lie within Japanese territorial waters and are located within or adjacent to Japan's territorial sea and contiguous zone (**Table 5-2**). Warning areas which occur in nearshore waters include W-174, W-176, W-178A, W-183, and W-183A.

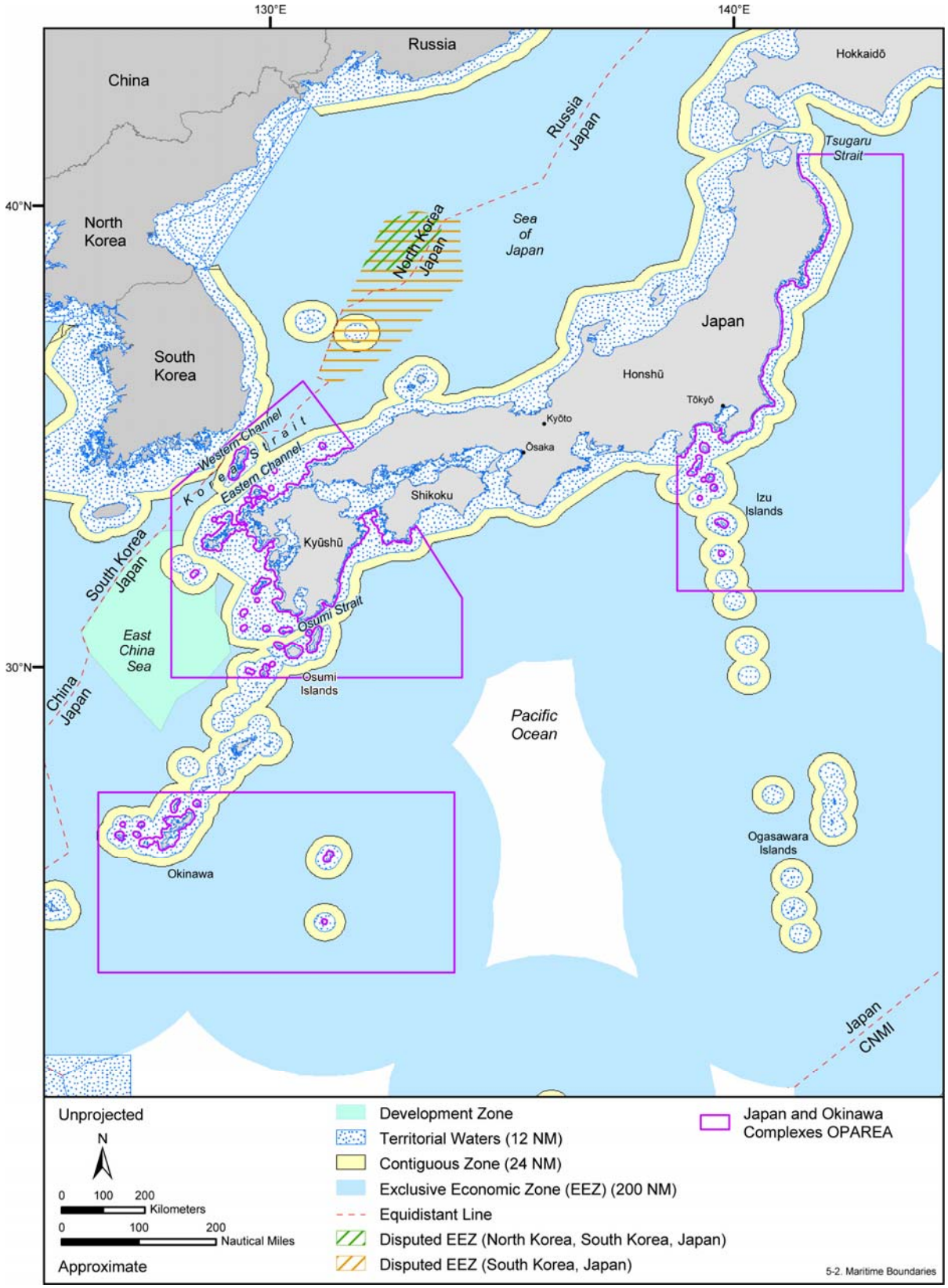

Figure 5-2. Proximity of the Japan and Okinawa Complexes OPAREA to the Japanese maritime boundaries. The territorial waters (12NM), contiguous zone (24 NM), and exclusive economic zone (200 NM) are each measured outward from the baseline (usually mean low-tide line) along the shore. Source data: GDAIS (2004).

Table 5-2. The maritime boundaries of Japan and their seaward and jurisdictional extents.

Maritime Boundary	Seaward Extent	Jurisdictional Extent
Territorial Waters	12 NM from Japanese baseline	Federal jurisdiction over the air, sea, and seabed
Contiguous Zone	24 NM from Japanese baseline	Power to prevent and punish for infringement of fiscal, customs, immigration, and sanitary laws
Exclusive Economic Zone	200 NM from Japanese baseline	Sovereign rights over all natural resources and jurisdiction to protect the marine environment

Source: DOALOS (2004).

5.1.2 Maritime Boundary Effects on Federal Legislation and Executive Orders

The following federal legislation and EOs have associated maritime zone or boundary limitations. The maritime boundary associations detailed in the legislation or orders relevant to the Japan and Okinawa Complexes OPAREA are listed below (see Section 1.3 for a full description of the legislation and their applications).

- The MMPA protects, conserves, and manages marine mammals in waters under the jurisdiction of the U.S., which are defined by the MMPA as the U.S. territorial seas, EEZ, and the eastern special areas between the U.S. and Russia. The act further regulates 'takes' of marine mammals on the global commons (i.e., the high seas or Antarctica) by vessels or persons under U.S. jurisdiction.

- The ESA regulates the protection, conservation, or management of endangered species in the U.S. territorial land and seas as well as on the high seas.

- The NEPA establishes a CEQ and a national policy that will encourage productive harmony between humans and their environment. It also promotes efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man. Jurisdiction of this act includes the territorial lands and waters of the U.S. to the limit of the territorial seas.

- The Marine Protection, Research, and Sanctuaries Act (MPRSA) regulates the dumping of materials in the ocean. It is applicable to material transported by any U.S. person, vessel, aircraft, or agency from any location in the world and by any person outside the U.S. intending to dump materials in U.S. territorial seas and the contiguous zone.

- EO 12114 extends environmental impact evaluation requirements for U.S. federal agencies beyond the territorial seas and contiguous zone to include the environments of other nations and the global commons outside the jurisdiction of any nation.

- The Marine Plastic Pollution Research and Control Act (MPPRCA) prevents pollution of the marine environment by any vessel with U.S. registry or under U.S. authority and all vessels in the U.S. territorial waters or EEZ.

5.2 MAJOR TRADE ROUTES AND SEAPORTS

The geography of Japan (a narrow island nation traversed in the center by steep mountains) dictates that most international trade and a large portion of domestic trade move by sea (Ministry of Land, Infrastructure, and Transport 2005). As such, shipping is characterized as a blend of dense traffic through straits and along coasts accompanied by long-distance, open-ocean transit (APEC 2005). Major sea lines of communication located around the Japan and Okinawa Complexes OPAREA include the straits of Tsushima and Tsugara, and the city of Tōkyō (APEC 2005; **Figure 5-3**). Japan is home to approximately 4,000 seaports, including fishing ports (Nagai 1994). Major Japanese ports include Nagoya, Chiba, Yokohama, Tomakomai, Mizusima, Kawasaki, Osaka, Kitakyuushu, Tōkyō, Kobe, Sakaisenboku, Kisarazu, Yokkaichi, and Oita (Chiba Prefecture 2005; **Figure 5-4**). Tōkyō Bay (6 harbors, including Yokohama and Tōkyō), Osaka Bay (5 harbors including Kobe and Osaka) and Ise Bay (5 harbors including Nagoya) are considered the three major bays, handling approximately 35% of all port cargo in Japan. The Japanese coastal ferry system represents one of the most extensive and best developed in the world, however, international ferry services linking Japan and Asia are less prevalent (Baird 2000). Domestic coastal shipping services accounted for 43% of all freight moved in 1995, second only to road transport (Baird 2000).

5.3 MARINE PROTECTED AREAS

MPAs, as defined in EO 13158, are "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Section 5 of EO 13158 stipulates, "Each federal agency whose actions affect the natural or cultural resources that are protected by MPAs shall identify such actions. To the extent permitted by law and to the maximum extent practicable, each federal agency, in taking such actions, shall avoid harm to the natural and cultural resources that are protected by an MPA." EO 13158 also calls for the preparation of annual reports by federal agencies describing the actions they have taken over the previous year to implement the order. EO 13158 proposes the development of a national system of MPAs and provides a formal but vague definition of an MPA. As such, the National MPA Center (U.S.) is developing an MPA classification system providing definitions and qualifications for the various terms within the EO. The new MPA definition will be narrower and will have stricter criteria. The new classification system is designed to objectively define MPAs by 6 fundamental characteristics: primary conservation goal, level of protection, permanence of protection, constancy of protection, scale of protection, and allowed extractive activities (NMPAC 2004). The intent of MPAs, both internationally and domestically, is to be an effective conservation tool for sustaining ocean ecosystems in which biodiversity, renewability, and resource productivity are maintained over time (Agardy 1999; NRC 2000).

The IUCN is a global network developed to promote the protection and identification of MPAs in order to safeguard the biodiversity of species, habitats, and ecosystems world-wide. Effective management, valuable legislation and evaluation of MPAs is necessary to achieve the goals of ensuring species and habitat longevity. Although each country establishes specific legislation regarding the management of their protected areas, the success of the project is dependent upon support from local agencies with similar conservation objectives (Chape et al. 2005). In Japan, several organizations participate in the decision making process related to the sustainable use and conservation of marine living resources. Likewise, various laws, regulations, and policies are in place to support Japan in issues of relevance to conservation and sustainability of the oceans and seas (ICM 1998; **Table 5-3**). Although **Table 5-3** briefly describes several guidelines set forth by the Japanese government and non-government agencies, it is by no means an all inclusive list of environmental legislation in Japan.

A set of MPA sites were compiled from MPA Global, an existing on-line list of marine protected areas world-wide. Data sets are at various stages and updates should be complete by September 2005, therefore, any inaccuracies or discrepancies may be explained by this delay in currently accessible information. Of the 130 MPAs within Japan's territorial lands and seas, 41 marine parks are located within the nearshore or open waters of the Japan and Okinawa Complexes MRA data extent (**Table 5-4**). Marine parks include areas of scenic beauty that encompass some portion of marine habitats and species therein.

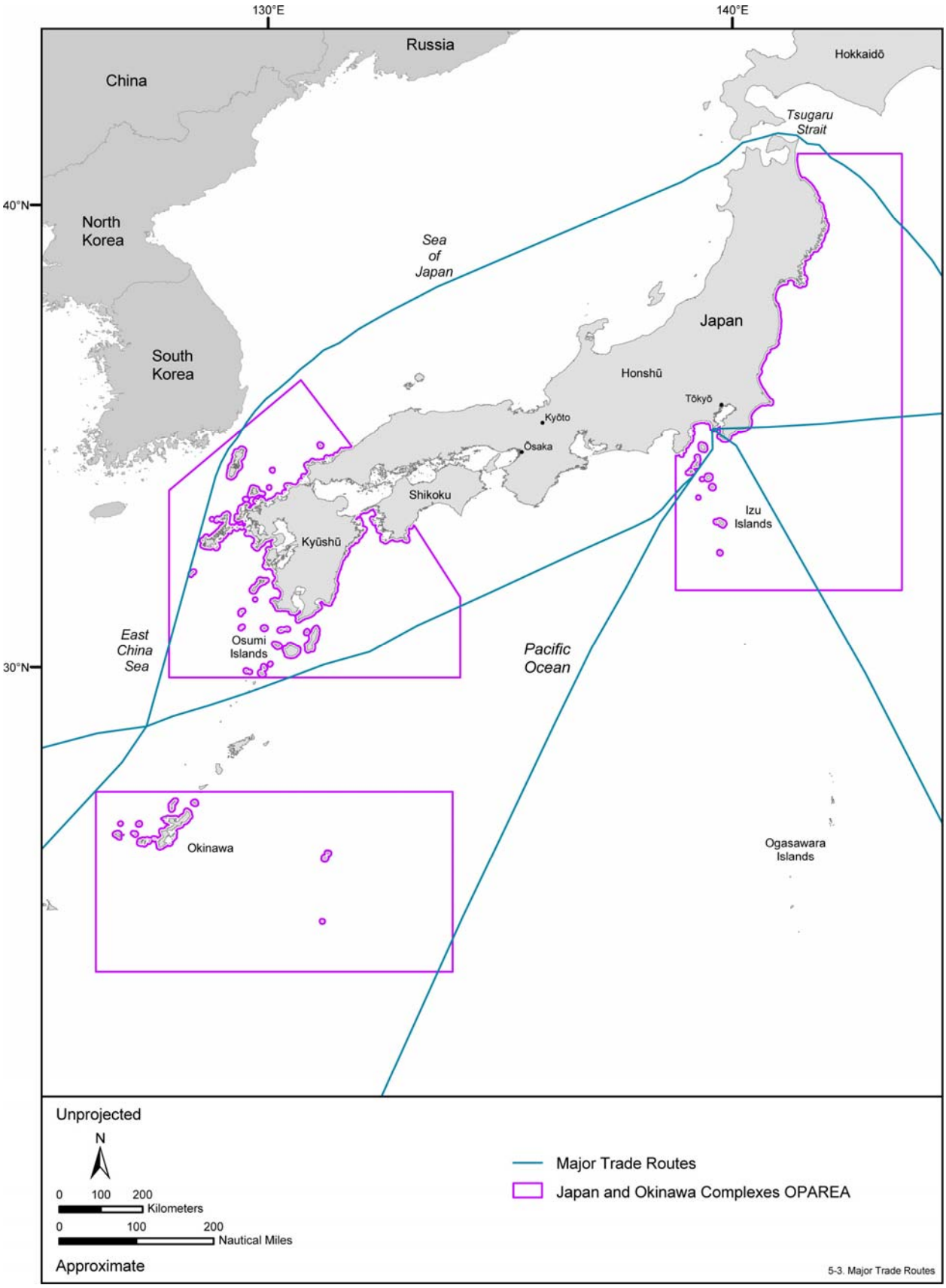

Figure 5-3. Major trade routes located within the Japan and Okinawa Complexes OPAREA and vicinity. Source map (scanned): Harstad (2002).

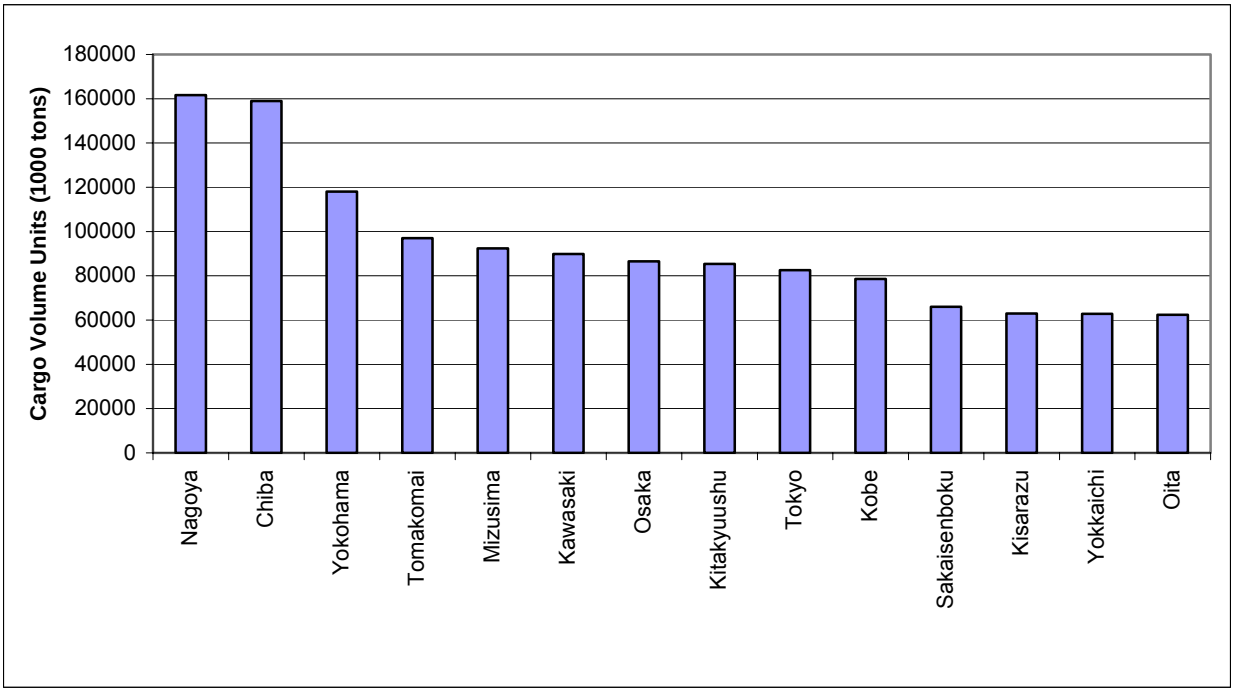

Figure 5-4. Major Japanese ports and cargo volumes for 2002. Source: Chiba Prefecture (2005).

Table 5-3. Environmental legislation, agencies and policies pertaining to the conservation and management of Japan's MPAs.

Agency	
Ministry of the Environment	Accountable for the overall management and conservation of the environment including marine issues such as coastal sewage, marine sustainability and biodiversity, ballast discharge and oil spills
Ministry of Foreign Affairs	Represents Japan in international negotiations and issues policies in regards to global environmental concerns that involve Japan
Ministry of Agriculture, Forestry and Fisheries	The fisheries division is responsible for issues and policies pertaining to fisheries, oil spills, ballast discharge, and the conservation of living marine resources
Council of Ministers for Global Environment Conservation	Sustains communication between agencies that participate in the promotion and implementation of environmental issues on a global scale
Policies and Plans	
National Strategy on Biological Diversity	Outlines the current biological status of Japan, policies of conservation and sustainability of biological diversity (current and proposed), and details how these policies will be most effectively implemented
Basic plan for Conservation and Management of Marine Living Resources	Outlines the responsibility of Japan in conserving and protecting living marine resources
Laws and Regulations	
Basic Environment Law	To ensure the longevity of present and future generations by promoting and implementing conservation policies that will support healthy living

Table 5-3. Environmental legislation, agencies and policies pertaining to the conservation and management of Japan's MPAs (continued).

Laws and Regulations (continued)	
Natural Parks Law	1957; Conserve and protect areas of natural scenic beauty and their ecosystems, to promote public awareness of the environment, and encourage their utilization
Wildlife and Hunting Law	1918; Regulate hunting activities and pest control to allow for the reproduction and survival of birds, mammals and marine mammals
Law for the Conservation of Endangered Species of Wild Fauna and Flora	1992; To ensure the protection and preservation of endangered species of wild fauna and flora as well as the conservation of their surrounding habitats
Law on the Conservation and Management of Marine Living Resources	1996; Details the regulations and conservation methods set forth by the Law of the Sea Convention to properly manage living marine resources in territorial waters, particularly within the EEZ

Source: ICM (1998); APEC (2005)

Table 5-4. MPAs within the Japan and Okinawa Complexes OPAREA designated as marine parks.

MPA Site Name	Date	Latitude	Longitude
Pacific Ocean Coast			
Awa-oshima	1971	33° 40' 0" N	134° 40' 0" E
Awa-takegashima	1972	33° 30' 0" N	134° 15' 0" E
Kamae	1974	32° 49' 60" N	132° 0' 0" E
Kashinishi.	1972	33° 0' 0" N	133° 30' 0" E
Kesennuma	1971	38° 51' 35" N	142° 12' 0" E
Kumano Nada Nigijima	1975	33° 55' 0" N	136° 10' 0" E
Kuroshima Kyanguch	1977	30° 13' 0" N	130° 30' 0" E
Kushimoto	1970	33° 30' 0" N	135° 49' 60" E
Miyakejima	1994	34° 0' 0" N	139° 30' 0" E
Nanbokuura	1974	32° 30' 0" N	131° 45' 0" E
Nichinan	1970	31° 30' 0" N	131° 30' 0" E
Okinoshima	1972	32° 49' 60" N	132° 30' 0" E
Sata Misaki	1970	31° 0' 0" N	130° 40' 0" E
Shirigai	1995	32° 49' 60" N	132° 45' 0" E
Shiro	1975	30° 30' 0" N	133° 0' 0" E
Takeno	1971	30° 30' 0" N	134° 45' 0" E
Tatsukushi	1972	32° 43' 59" N	132° 46' 33" E
Toyooka	1971	30° 30' 0" N	134° 49' 60" E
Tsutomezaki	1995	32° 49' 60" N	132° 45' 0" E
Uwakai	1972	33° 0' 0" N	132° 30' 0" E
Sea of Japan Coast			
Amakusa	1970	32° 30' 0" N	130° 0' 0" E
Fukue	1972	32° 30' 0" N	129° 0' 0" E

Table 5-4. MPAs within the Japan and Okinawa Complexes OPAREA designated as marine parks (continued).

Sea of Japan Coast (cont'd)			
Genkai	1970	33° 30' 0" N	130° 0' 0" E
Iki Tanagashima	1978	33° 30' 0" N	129° 30' 0" E
Iki-Tatsunoshima	1978	33° 30' 0" N	129° 30' 0" E
Iki-Tsumagashima	1978	33° 30' 0" N	129° 30' 0" E
Sakurajima	1970	31° 30' 0" N	130° 30' 0" E
Shimane Hanto	1972	140° 19' 60" E	132° 45' 0" E
Surikozaki	1974	30° 30' 0" N	129° 19' 60" E
Tomioka	1970	30° 30' 0" N	130° 0' 0" E
Tsushima Asowan	1978	34° 0' 0" N	129° 0' 0" E
Tsushima Kanzaki	1978	34° 30' 0" N	129° 30' 0" E
Ushibuka	1970	32° 15' 0" N	130° 0' 0" E
Wakamatsu	1972	33° 0' 0" N	129° 0' 0" E
Okinawa			
Kametoku	1974	28° 0' 0" N	129° 30' 0" E
Kasari Hanto Higashi	1974	28° 30' 0" N	129° 30' 0" E
Okinawa Kaigan	1972	26° 40' 0" N	128° 0' 0" E
Setouchi	1974	28° 0' 0" N	129° 0' 0" E
Tokashiki	1978	26° 8' 18" N	127° 26' 23" E
Yoronto	1974	27° 0' 0" N	128° 30' 0" E
Zamami	1978	26° 10' 0" N	127° 15' 0" E

Source: MPA Global (2005).

5.4 SCUBA AND FREE DIVING SITES

The Japanese Islands are one of the world's great diving destinations because of an abundant and diverse array of marine life, a multitude of professional dive charter boats, clear visibility, unique shipwreck dive sites, coral reef ecosystems, and a unique convergence of warm and cold currents. The diverse environments of Japan's islands (i.e., ice flows in the Okhotsk Sea in the north to the tropical waters of Okinawa) attract SCUBA divers from around the world (Outdoor Japan 2004). The warm Kuroshio Current from the south mixes with the cold Oyashio current from the Arctic Ocean in the north. This unusual combination brings both tropical and temperate species to the main Island of Honshū; this provides the unique opportunity to enjoy an array of dives from ice diving in northern Japan, kelp forests in mid-Japan, and tropical coral reefs among the scattered islands of the archipelago in southern Japan (Outdoor Japan 2004).

The Japanese Islands offer both natural and artificial marine habitat. Natural environments include vertical wall drop-offs, coral reefs, boulders and talus, sea arches, volcanic tunnels, pinnacles, and caves (Whipple 1998a; Outdoor Japan 2004). The most prominent underwater features are coral reef ecosystems and vertical walls or drop-offs. Vertical walls (submerged cliffs) are well-defined ledges that run parallel to the shore and are located anywhere from near the shore to approximately 300 m; this topography creates steep walls cut by ravines, caves, and grottos (Wallin 1991). In addition, there are numerous artificial habitats available within the Japanese Islands including FADs, artificial reefs, and sunken wrecks—ships, boats, and planes (Wallin 1991). These natural and artificial marine habitats attract abundant marine life. Each island offers a unique array of marine life, bottom depths, terrain, and underwater visibility.

The Izu Peninsula (Honshū) is the most popular dive region and has the largest number of dive sites in mainland Japan. Izu Oceanic Park, on the east coast, is the first dive site to have been explored on the peninsula and Osezaki, on the west coast, is the most popular dive site in Honshū (Outdoor Japan 2004). The 7 Islands of Izu, east of the Izu peninsula, is also a popular dive region; it offers warmer waters and better visibility than the dive sites on mainland Honshū. In northern Japan diving has recently become a popular sport, especially in the Aomori prefecture and Sado Island in the Sea of Japan. Further north in Hokkaidō, ice drifts can be found in the Okhotsk Sea for ice diving (Outdoor Japan 2004).

Some Japanese shores are subjected to harsh wind, wave, and water conditions; therefore, they are not suitable dive sites throughout the entire year. The suitability of a site for diving is based upon the accessibility and water conditions of a particular site. This is determined by marine weather conditions and coastal geography (Wallin 1991). The following description gives general information of the Izu Peninsula (Honshū), Okinawa, and Ogasawaras dive regions that are located within the Japan and Okinawa Complexes OPAREA and vicinity. In addition, the more popular dive sites and the associated marine life are detailed within these dive regions.

5.4.1 Izu Peninsula (Honshū)

Ito and Osezaki—Ito is a bay located on the west coast of the Izu Peninsula just south of Osezaki. This site is one of the most isolated diving locations in Izu and it can be subjected to harsh wind, wave, and water conditions in the winter season. It is accessed via a beach that is covered with large boulders that have piled up from surrounding cliffs during typhoon season and created a steep shelving rocky topography (Outdoor Japan 2004). Osezaki is located on the west coast of the Izu peninsula just north of Ito. It is a shallow dive (20 m) with a sandy bottom at the base of a drop-off. It features abundant marine life; it is common to see lionfish, frogfish, seahorses, and as usual in Izu, soft corals cover the substrate.

The dive sites at Ito and Osezaki include: Ito beach, Wannai, Ipponmatsu, and Misakinosentan. Ito beach is a steep rocky beach with a vertical wall drop-off 35 m from shore. Wannai is a sandy beach that gradually descends to 15 m. Ipponmatsu is a boulder beach with abundant coral. Misakinosentan is also a boulder beach with a stony reef; sunfish have been reported to occur in Misakinosentan (Outdoor Japan 2004).

Futo—Futo is located on the east coast of the Izu Peninsula south of Ito and just north of Izu Ocean Park. This east facing rocky bay experiences heavy swell and a harbor is at the north end of the bay. Futo offers easily accessible beach dives during favorable conditions (especially during the summer months); however, strong winds and swell can reduce visibility significantly making boat dives necessary (Outdoor Japan 2004). It is positioned at the base of volcanic cliffs; therefore, bathymetetry offers steep shelving of lava blocks atop a sandy bottom at about 45 m (Outdoor Japan 2004). Also, there is a sharp drop-off that leads to a sandy bottom at 15 m (Whipple 1998b). The marine life is abundant and diverse including sponges, anemones, macroflora, soft coral, seahorses, many unique fish, eagle rays, and moray eels (Whipple 1998b; Outdoor Japan 2004). There are two sites associated with Futo: Sankaku and Kurodaine. Sankaku is characterized by a series of three large volcanic boulders that stand out from the rocky substrate. These boulders are 7 m deep and are colonized with soft corals (Outdoor Japan 2004). A flat-rock outcrop that rises from sandy substrate at 25 m characterizes Kurodaine. This site is famous for the occurrence of eagle rays (Outdoor Japan 2004).

Atami—Atami is an enclosed bay on the east coast of Izu where the peninsula joins the mainland. A seawall encloses the bay providing calm and accessible waters for diving (Outdoor Japan 2004). Most of the dive sites are located off the rocky point at the west end of the bay. The substrate is predominately talus covered by coral; however, the site is characterized by a large shipwreck and a group of submerged rocks that rise 50 m from the bottom near the coast (Pascoe 2002; Outdoor Japan 2004). Abundant soft corals and sponges cover every rock surface on the Atami sites, which in turn provides habitats for a wide range of fish life from cryptic fish (those that live in crevices; e.g., moray eels, stonefish) to larger pelagic fishes (e.g. dorado) (Outdoor Japan 2004).

Chinsen, Sodaine, Bitagane, Kosogadokutsu, and Harbor are some of the more popular dive sites located at Atami. Chinsen is the most popular dive site in Atami because of a 120 m cargo vessel that lies in 30 m of water depth. Sodaine features a rock talus that rises from 28 m depth to approximately 14 m. Bitagane is similar to Sodaine; however, the shipwreck at Chinsen is accessible through Bitagane. Kosogadokutsu features a sea arch with a 40 m tunnel but it is only accessible during the winter months. Harbor is a popular night dive (Outdoor Japan 2004).

Izu Ocean Park—Besides Futo, Izu Ocean Park (IOP) is the most well known dive spot on the Izu Peninsula and was founded around 1965. It is located on a lava flow from previous volcanic activity (Pascoe 2002). It is a beach access dive and features an abundance of marine life, making it a favorite for photographers.

Kumomi—Kumomi is a naturally sheltered harbor located on West Izu Peninsula. There is a large rock outcrop that has formed small caves against the seafloor and it is common to see marine life inhabiting the caves including reef fish (e.g., anemone fish, angelfish, box fish, butterflyfish, parrotfish, surgeonfish, triggerfish, trunkfish, and wrasses), moray eels, stingrays, squid, and crab. Ushitsuki iwa and Kurozaki are two dive sites located at Kumomi. Ushitsuki iwa offers many holes and small caves. At the shallower depths, small reef fish can be seen while at the deeper depths larger pelagic fishes can be seen. Kurozaki is located on the right side of Kumomi Bay and features deep tunnels and caverns starting at 15 m of water depth.

Mikomoto—Mikomoto Jima is a small islet approximately 9 km off the southern tip of the Izu Peninsula. It ascends from deep water and the surrounding waters are upwelled from the Nankai Trough. These conditions bring clean, nutrient rich water, strong swells and currents, and abundant and diverse marine life including soft corals, abundant phytoplankton, reef fish, and many large pelagic fish (e.g., tuna, rays, hammerhead sharks; Outdoor Japan 2004). Three of the more popular sites in Mikomoto are Aone, Kamene, and Budaine. Aone is named after a distinctive rock formation covered in bright blue corals. Kamene is a drift dive with coral covered walls and trenches. The common marine life at Kamene includes large schools of yellowtails and, in deeper water, hammerheads are commonly seen in the autumn months. Budaine is also a drift dive; it features large scattered boulders between 13 and 20 m, a vertical wall drop-off, and a scattered field of spires from jagged pinnacles. Budaine also provides habitat for smaller fish, invertebrates, and sponges because it is sheltered from strong currents by Mikomoto Islet (Outdoor Japan 2004).

Hokkawa—Hokkawa is located on the east coast of the Izu Peninsula. It features a dive site known as Kajikaki, or rudder scraper, named for the series of shallow rocks that are exposed at low tide (fishermen scrape their rudders on them). The marine life at this site changes dramatically with the seasons. It has been noted that for many of the species of marine life found at Hokkawa, the entire lifecycle can be observed as the years progress (Whipple 1998c). Some of the common marine life includes soft corals, shrimp, nudibranchs, gorgonians, lobster, and fish (e.g. cardinalfish, scorpionfish, grouper, and flounder; Whipple 1998c).

5.4.2 Okinawa

Okinawa is the southernmost prefecture in Japan. The Okinawa Islands stretch to Taiwan with the Kerama Islands being the closest to the main island. Further south, Ishigaki, Iriomote and Yonaguni Islands are all areas with numerous dive sites (Outdoor Japan 2004). Okinawa had a major role in WWII; thus, the islands have dive sites dedicated to the many shipwrecks surrounding the islands. In addition, the Okinawa Islands offer warm waters that support a fringing reef and tropical habitats around all of the islands. These conditions gives the Okinawa Islands a multitude of dive sites featuring shipwrecks, beautiful corals, artificial reefs and FADs, great visibility, and for most sites, easy access with excellent beach dives.

Okinawa and it's surrounding islands host more than 70 species of corals (both hard and soft) and more than 250 marine animals (e.g., crabs, snails, mantas, turtles, stingrays, whales and hammerhead sharks in the winter months, and night dives yield abundant octopuses and cuttlefish; Outdoor Japan 2004).

On the main island of Okinawa there are more than 25 different beach dive sites, the more popular sites include the Sunabe seawall which boasts beautiful soft coral gardens, Maeda Point which support massive schools of fish, and Onna point which provides a rocky reef habitat for many cryptic organisms (Outdoor Japan 2004). In addition, Tengan Bay on the Pacific coast has been known to offer the highest concentrations of marine life found in the entire Okinawa region (Schalk 1997a). The Tengan pier acts as an artificial reef and has been known to support abundant Cowries (e.g., Pacific Deer Cowries, Arabian Cowries, and Tiger Cowries; Schalk 1997a)

The Keramas Islands are approximately 5 miles off the Okinawa coastline in the South China Sea and make up a chain of 28 islands, some inhabited and some not (Schalk 1997b; Outdoor Japan 2004). The Keramas have been credited as having some of the top diving in the world with more than 100 dive sites, some of the best corals in the Pacific, and nearly perfect visibility (Outdoor Japan 2004). Most of the diving is concentrated around the main island of Tokashiki; Tokashiki is home to some of the more famous dive sites including Ariga Cable, Nozaki point, and Gishippu (a protected bay with large schools of snapper and turtles; Outdoor Japan 2004).

Within the Keramas Islands, some of the smaller islands host popular dive sites including the Sand Island chain (composed of a series of 3 small islands), Zamami Island, Ie Island, the Chijbishi Island chain, and Ariga-kita. These Islands boast unlimited visibility (60 m) with pristine corals (e.g., staghorn, elkhorn, tabletop, and soft corals), white tip reef sharks, turtles, tuna, mantas, and tropical fish (e.g. schools of batfish; Schalk 1997b). Zamami Island also has several very popular dives; it features a pinnacle that rises 70 m above sea level that originates from solid rock at a water depth of 50 m. This dive site supports abundant pelagic and cryptic marine life including the blue ribbon eel and many pelagic sharks (Whipple 1998d). To the north, Ie Island offers diverse topography including several deep drop-offs and some large caves that support well-developed gorgonian corals and large schools of tuna (Outdoor Japan 2004). The Chijbishi Island chain consists of a group of 4 small islands and the marine life that is associated with these islands is known to be spectacular with coral gardens (e.g. staghorn coral, gorgonians, table coral), giant clams, and many tropical fish (e.g., wrasses, blennies, lionfish, damselfish, yellow tangs, surgeonfish, snappers, grunts, and yuzen angelfish; Whipple 1998d). Ariga-kita is a shallow dive over white sand substrate and coral heads which harbor tropical fish such as pyramid angelfish, lionfish, barracudas, and frogfish (Whipple 1998d).

5.4.3 Ogasawaras

The Ogasawaras, also known as the Bonin Islands, are located east of the Okinawa Islands and consist of four island groups: the Chichijimas, the Keitas, the Hahajimas, and the Volanoes (best known for Iwojima) (Whipple 1998a) The largest of the four island groups are the Chichijima Islands; the Chichijimas are just over 20 km^2 with some 1,800 inhabitants (Outdoor Japan 2004). The Islands are primarily basalt and sand with peaks that rise just above sea level; around the island there is an insular shelf located in approximately 90 to 150 m of water depth. At 30 to 40 m water depth there are many shipwrecks available for diving. In addition, at the edge of the insular shelf there is a vertical drop-off that is located approximately 180 m from shore (Whipple 1998a).

Shikoku is another diving area within the Ogasawaras Islands. In this region, most dive sites are located around Mugi, Kashiwajima, and the Kansai area. In the Kansai area most of the dive sites are located around the tip of the Kii peninsula between Shirahama and Kushimoto. In addition, recent dive sites have become popular along the eastern coast from Kushimoto to Toba (Outdoor Japan 2004). Just south of Chichijima, Minamijima has several dive sites that are often visited by bottlenose dolphins (Whipple 1998a).

The Ogasawaras Islands are littered with shipwrecks that serve as artificial reefs and dive sites. Anijima is an island north of Chichijima; a shipwreck is located in Takinoura Bay, Anijima. The Yayoi Maru was sunk by American bombers during WWII and now lies amid a covering of corals. The marine life associated with the coral is rich and includes an abundance of tropical fish (e.g., amalco and striped jacks, and yuzen angelfish [indigenous to the warmer Japanese Islands]; Whipple 1998a). Another famous shipwreck in the Ogasawaras Islands is the Fuju Maru. An explosion sank the Fuju Maru; it now sits upright between 28

and 50 m of water depth. It is loaded with cargo including ammunition, unexploded 250 kg bombs, and gunpowder from WWII. In addition, a truck lies beside the wreck. The entire surface of both the Fuju Maru and the truck is covered with coral (e.g., brain, ryumen, and ao coral) and the marine life is very similar to that found at the Yayoi Maru (Whipple 1998a). In the Sakaiura Inlet, the Hinko Maru was torpedoed at the mouth of the bay; subsequently, the Hinko Maru was grounded atop a reef in the bay (Whipple 1998a). The marine life associated with this shipwreck is especially abundant and rich with both natural and artificial reef habitat present. In 1945, Allied aircraft sank the Diami Maru; it settled to the bottom of Futami Bay near Kanme Rock in 33 m of water depth. The Diami Maru lies atop fine coral sand and supports several large nurse sharks (Whipple 1998b).

The dive sites at the Ogasawaras Islands provide an excellent opportunity to see humpback whales and bottlenose dolphins. Humpback whales migrate to the Ogasawaras Islands (breeding area) between December and May (Mori et al. 1998) and bottlenose dolphins are commonly seen in the Keitas Islands region during the summer months (Whipple 1998a). However, the Ogasawaras islands are commonly hit by typhoons and big Pacific swells; thus, the dive sites can be difficult to experience (Whipple 1998a).

5.5 Oil and Gas Structures

Currently very little information exists concerning oil and gas structures around Japan. The discovery of the potential for oil in the East China Sea has lead to boundary disputes between Japan, China, and South Korea. Japan contains almost no oil reserves of its own and currently imports between 98 and 99% of its oil (DoE 2004).

5.6 Whale Watching in Japan

Whale watching encompasses all commercial tours that aim to see, swim with, and/or listen to cetaceans (whales, dolphins, and porpoises) in the wild (Hoyt 2001). In Japan, whale watching offers a viable alternative to whaling and dolphin hunting. In some regions of Japan, whale watching and whaling businesses economically benefit from each other; they share information about the whales seen so that whale watch operators know where to locate the animals and whalers are more efficient hunters (Segi 2003). Japan's first formal whale watch trip departed from Tōkyō in 1988 and targeted humpback whales in the Ogasawara Islands (Hoyt 1993). Since then, the value of whale watching in Japan has almost doubled every year, and the industry has expanded to include over 45 operations and 30 communities (Hoyt 1993, 2001). Whale watching is a seasonal or full-time business that provides extra income in fishing communities during off or low fishing seasons but is also considered the primary business in some areas (Hoyt 2001). Whale watching has also replaced whaling in many communities since the International Whaling Commission's moratorium on whaling (Dudzinski 1998). Over 95% of whale watch tourists are Japanese; whale watching contributes to the domestic tourism economy and has the potential to attract more international travelers through marketing and advertising (Hoyt 2001).

In Japan, whale watch operators mostly offer boat-based tours; over 185 boats are used for part-time or full-time whale watching. These boats are generally small and carry 10 to 12 passengers (Hoyt 2001). Most whale watch tours in Japan involve locating and watching large whales in the wild; however, dolphin and porpoise tours are becoming increasingly popular, particularly since the development of swim-with programs in the early 1990s (Dudzinski 1998; Mori 1999). Several swim-with programs operate seasonally in the southern areas of Japan where warmer water temperatures are more conducive to swimming with wild cetaceans (Dudzinski 1998). Whale watching and swim-with programs operate year-round in Japanese waters, but some are seasonal businesses. The peak whale watch season is during the spring and summer (Hoyt 1993).

Whale watch operations are located throughout Japan from northern Hokkaidō south to the Okinawa and Ogasawara Islands. In Hokkaidō, tours operate from Nemuro, Shibetsu, Rausu, and Shari along the east coast and from Muroran along the southern part of the island (Hoyt 1993, 2001). These tours operate between March and October and target Pacific white-sided dolphins, Dall's porpoises, harbor porpoises, killer whales, short-finned pilot whales, minke whales, and Baird's beaked whales in Volcano Bay and along the Pacific coast of Hokkaidō (Hoyt 1993, 2001). Several whale watch operations are located near

Tōkyō. Tours in Chōshi and Kamisu, just east of Tōkyō along the Pacific coast of Honshū, offer opportunities to view finless porpoises; Baird's beaked whales; short-finned pilot whales; and Pacific white-sided, bottlenose, and common dolphins (Hoyt 1993, 2001). One of the most popular dolphin watching locations is around the Mikura, Miyake, and Toshima Islands which are part of the Izu Islands chain about 160 km south of Tōkyō. Dolphin watch tours and swim-with-dolphin programs in this area primarily target bottlenose dolphins which are routinely found within 200 m of the islands (Uchida 1997; Dudzinski 1998). In southeastern Honshū, popular whale watch tours operate from Kushimoto, Koza, and Nachi-katsuura near Taiji and target sperm whales and Risso's dolphins. In addition, finless porpoises attract tourists offshore of Mihama (Hoyt 2001).

Several whale watch tours operate along the coast of Shikoku, specifically around the Kochi Prefecture. The main whale watch area extends from Saga to Tosa-Shimizu (Hoyt 1993). Saga and Ogata are the best places in the world to view Bryde's whales which occur close to shore year-round but in greater densities during the spring and summer (Kato et al. 1996). Common dolphins are also frequently found off the coast of Ogata and Saga (Hoyt 2001). Most tours in this region pass through Tosa Bay enroute to waters off Cape Muroto. In Cape Muroto, the continental slope comes in close to shore providing one of the best locations for viewing sperm whales (Hoyt 2001). Risso's dolphins, short-finned pilot whales, and bottlenose dolphins are also common in this area (Hoyt 1993).

Popular whale watch tours in Kyūshū are located in Itsuwa and Reihoku along the west central coast and Kasasa on the southern tip of the island. These tours primarily target Bryde's whales and bottlenose dolphins (Hoyt 2001). Dolphin watching also takes place around the Amakusa Islands off the southwest coast of Kyūshū (Uchida 1997). Whale watch destinations around the Ryukyu Archipelago include the Amami, Kerama, and Okinawa Islands (Uchida 1997). During the winter and spring, tours mainly target humpback whales which use the islands as a primary breeding ground (Hoyt 1993). Tourists can also view rough-toothed and bottlenose dolphins throughout the year (Hoyt 1993). The Ogasawara Islands off the southeast coast of Japan are also a main breeding area for humpback whales. In addition to humpback whales, whale watch tours in this region target spinner and bottlenose dolphins in coastal waters and spotted dolphins and sperm whales further offshore (Mori 1999). Swim-with-dolphin programs are also common around the Ogasawara Islands (Mori 1999).

5.7 LITERATURE CITED

Agardy, T. 1999. Creating havens for marine life. Issues in Science and Technology 16(1):37-44.

APEC (Asia-Pacific Economic Cooperation). 2005. Inventory of Integrated Oceans Management Arrangements in APEC Economies: Japan. Accessed 17 August 2005. http://www.apec-oceans.org/inventory.htm.

Baird, A.J. 2000. The Japan coastal ferry system. Maritime Policy and Management 27(1):3-16.

Chiba Prefecture. 2005. The Port of Chiba. Accessed 8 August 2005. http://www.pref.chiba.jp/business/kowan/chibaport-e.html.

Chape, S., J. Harrison, M. Spalding, and I. Lysenko. 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of Royal Society B. 360:443-455.

DOALOS (Division for Ocean Affairs and the Law of the Sea). 2004. Maritime space: Maritime zones and maritime delimitation. Accessed 23 May 2005. http://www.un.org/Depts/los/LEGISLATIONANDTREATIES/index.htm.

DoE (Department of Energy). 2004. Japan country analysis brief. Accessed 17 August 2005. http://www.eia.doe.gov/emeu/cabs/japan.html.

Dudzinski, K. 1998. The best-kept secret in dolphin swim programs is in Japan. Whalewatcher Journal of the American Cetacean Society 31(2):14-17.

GDAIS (General Dynamics Advanced Information Systems). 2003. Global maritime boundaries database. Accessed 14 June 2005. http://www.maritimeboundaries.com.

GDAIS (General Dynamics Advanced Information Systems). 2004. The global maritime boundaries database. [CD-ROM]. Fairfax, Virginia: General Dynamics Corporation.

Gao, Z, and J. Wu. No Date. Key issues in the East China Sea: A status report and recommended approaches. Accessed 19 August 2005. http://wwics.si.edu/index.cfm?topic_id=1462&fuseaction=topics.documents&group_id=132299.

Hoyt, E. 1993. Kujira watching - Whales and dolphins: Alive and being watched Japanese-style. Bath, Avon, UK: Whale and Dolphin Conservation Society.

Hoyt, E. 2001. Whale watching 2001: Worldwide tourism numbers, expenditures, and expanding socioeconomic benefits. International Fund for Animal Welfare, Yarmouth Port, MA, USA, pp. i-vi; 1-158.

ICM (Integrated Coastal Management) 1998. Japan. Accessed 10 August 2005. http://www.globaloceans.org/country/Japan.html.

Kapoor, D.C., and A.J. Kerr. 1986. A guide to maritime boundary delimitation. Toronto: The Carswell Company, Ltd.

Kato, H., E. Shinohara, T. Kishiro, and S. Noji. 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.

Ministry of Land, Infrastructure, and Transport. 2005. Ports and Harbours in Japan. Accessed 17 August 2005. http://www.mlit.go.jp/kowan/english/index.html.

Mori, K., F. Sato, M. Yamaguchi, H. Suganuma, and S. Ueyanagi. 1998. Distribution, migration and local movements of humpback whale (*Megaptera novaeangliae*) in the adjacent waters of the Ogasawara (Bonin) Islands, Japan. Journal of the School of Marine Science and Technology, Tokai University 45:197-213.

Mori, K. 1999. Whale and dolphin watching and associated research programs in the Ogasawara Islands, Japan. Wild Dolphin Swim Program Workshop: A workshop held in conjunction with the 13th Biennial Conference on the Biology of Marine Mammals. 28 November. Maui, Hawaii. Society of Marine Mammalogy.

MPA Global. 2005. A database of the world's Marine Protected Areas. Accessed 18 August 2005. http://www.mpaglobal.org/home.html

Nagai, T. 1994. Japanese transport – much to be done for infrastructure. Japanese Railway and Transport Review: Special Feature pp. 8-11.

NMPAC (National Marine Protected Areas Center). 2004. MPA connections—Special edition. Accessed 20 May 2005. http://www.mpa.gov/information_tools/connections/connections_apr04.pdf.

NOAA (National Oceanic and Atmospheric Administration). 2005a. U.S. Marine Cadastre. Accessed 23 May 2005. http://www.csc.noaa.gov/mbwg/htm/cadastre.htm.

NRC (National Research Council). 2000. Marine protected areas: Tools for sustaining ocean ecosystems. Washington, D.C.: National Academy Press.

Outdoor Japan. 2004. Scuba diving in Japan. *Eds*. Gardner Robinson. http://www.outdoorjapan.com/activities/scuba/scuba-diving-introduction.html. Accessed 4 August 2005.

Pascoe, J.A. 2002. Dive Japan. http://www.divejapan.com/. Accessed 4 August 2005.

Prescott, J.R.V. 1987. Straight and archipelagic baselines. Pages 38-51 in G.H. Blake, ed. Maritime boundaries and ocean resources. Totowa, New Jersey: Barnes and Noble Books.

Schalk, S. 1997a. Night diving for Cowries – Okinawa. SeaHorse Tales, Waterlogged. City Seahorse, Inc. Archive IV. http://www.seahorsetales.com/logs/Okinawa/Cowries.html. Accessed 4 August 2005.

Schalk, S. 1997b. Just another day at Sand Island – Okinawa. SeaHorse Tales, Waterlogged. City Seahorse, Inc. Archive IV. http://www.seahorsetales.com/logs/Okinawa/SandIsland.html. Accessed 4 August 2005.

Segi, S. 2003. The coexistence of whaling and whale watching in a traditional whaling region: The case of Taiji, Wakayama Prefecture, Japan. SPC Traditional Marine Resource Management and Knowledge Information Bulletin 15:21-25.

Uchida, S. 1997. In search of humpbacks (A 1991-1995 survey of cetaceans in Japanese waters). Pages 18-33 in S. Uchida, ed. Kings of the sea: Humpback whales: A 1991-1995 survey of cetaceans in Japanese waters. Tokai, Japan: Tokai Foundation.

Wallin, D. 1991. Diving and snorkeling guide to the Hawaiian Islands. New York: Pisces Books.

Whipple, C.T. 1998a. Diving the door to prosperity. Dive Japan. http://www.divejapan.com/ctw_futo.htm. Accessed 4 August 2005.

Whipple, C.T. 1998b. The wrecks of Ogasawara. Dive Japan. http://www.divejapan.com/ctw_ogasawara.htm. Accessed 4 August 2005.

Whipple, C.T. 1998c. Rudder-Scrapin' dive – Hokkawa Report. Dive Japan. http://www.divejapan.com/ctw_hokkawa.htm. Accessed 4 August 2005.

Whipple, C.T. 1998d. Dive Okinawa, dive a different world. Dive Japan. http://www.divejapan.com/ctw_okinawa.htm. Accessed 4 August 2005.

6.0 RECOMMENDATIONS

The following recommendations, created by the MRA authors, are designed to improve our understanding of the marine resources in the waters off Japan and Okinawa, especially those resources that may be potentially affected by Navy operations. Each recommendation is assigned a priority value of 1, 2, or 3; 1 is the highest priority while 3 is the lowest. The priority designations are relative to each other and in no way refer to a recommendation's overall value. The relative cost of each recommendation is labeled low, moderate, or high. Low-cost recommendations may be completed at a cost of several hundred to a few thousand dollars. Moderate-cost projects could range from thousands to tens of thousands of dollars, while high-cost research initiatives range from tens of thousands to over one hundred thousand dollars.

The recommendations are grouped into those related to the production and evaluation of the MRA and those needed to adequately complete environmental documentation for the study area of the Japan and Okinawa Complexes OPAREA MRA.

6.1 MARINE RESOURCES ASSESSMENTS

- Revise the Japan and Okinawa Complexes MRA once every five years. The MRA would need a full investigation, interpretation, and plotting of data sources along with revision of the text, GIS maps, MPAs, and other informational components so that available datasets and published literature can be incorporated. Site visits in Japan for briefing data providers and collection of all data would be necessary. The Navy needs the best (i.e., most recent, most complete, and most accurate) available information to evaluate future actions and consider adjustments to training exercises or operations in order to mitigate any potential impacts to protected marine resources. Periodic updates would be of moderate cost relative to the initial MRA. Cost: Moderate. Priority: 1.

- Subject the Japan and Okinawa Complexes OPAREA MRA to peer review. Peer review by regulatory agencies (e.g., NMFS and USFWS), the general scientific community, and potential government users (e.g., USMC) would increase the effectiveness of this MRA. Biologists from universities and agencies (**Table 6-1**) could evaluate the collection, synthesis, and interpretation of data (including data completeness) and provide suggestions for improvements to the MRA. Cost: Low. Priority: 1.

Table 6-1. Suggested expert reviewers for the Japan and Okinawa Complexes OPAREA MRA.

Name	Affiliation	Expertise
Makoto Tsuchiya, Ph.D.	University of the Ryukyus	Coral reefs
Robert van Woesik, Ph.D.	Florida Institute of Technology	Coral reefs
Bo Qiu, Ph. D.	University of Hawaii at Manoa	Oceanography
Ken Furuya	The University of Tokyo	Oceanography
Robert Brownell, Jr., Ph.D.	NMFS-SWFSC	Large whales
Toshio Kasuya, Ph.D.	Teikyo University of Science and Technology	All marine mammals
Helene Marsh, Ph.D	James Cook University	Dugong
Nobuyuki Miyazaki, Ph.D	University of Tokyo	All marine mammals
Scott Eckert, Ph.D.	WIDECAST, Duke University	Sea turtles
Hideo Hatase, Ph.D.	Ocean Research Institute, University of Tokyo	Sea turtles
George Balazs	NMFS-PIFSC	Sea turtles
John E. Randall, Ph.D.	Bishop Museum	Fish and fisheries
Chiyuki Sassa	Seikai National Fisheries Research Institute Fisheries Research Agency	Fish and fisheries
Louisa Wood	University of British Columbia	Additional considerations

- Fund a compilation of literature (primarily concerning marine mammals and sea turtles) that is published in Japanese and have these translated. Literature could be prioritized by level of importance (if necessary) and should be translated by subject matter experts fluent in both Japanese and English. Such information is critical for a better understanding of marine protected species occurrence in the OPAREA. Cost: Low to Moderate. Priority: 1.

6.2 ENVIRONMENTAL DOCUMENTATION

- A marine biological survey of the nearshore habitats in the Idesuna Jima range, Tori Shima range, Ie Shima range, and Okino Daito Jima range within the Okinawa study area is lacking and is needed to assess the condition and population levels of corals, seagrasses, dugongs and other marine mammals, fishes, and sea turtles. Cost: High. Priority: 1.

- While mapping of reefs of Japan was conducted in the past (see Kimura 2004), a high-resolution mapping (aerial photography, hyperspectral imagery) of the nearshore habitat should be conducted to provide comprehensive and detailed characterizations of the nearshore habitat distribution (including the location of seagrass beds) in the Japan and Okinawa Complexes OPAREA. The shapefiles of mapping products are needed to quantify and improve the depiction of nearshore habitats. Cost: Moderate. Priority: 1.

- Assessments of deep-water coral communities on the shelf edge, shelf slope, and on seamounts in the Japan and Okinawa Complexes OPAREA are needed. Cost: High. Priority: 2.

- High-resolution sampling of the bottom substrate should be undertaken to provide better resolution of sediment variability and to locate potential deep-water hardbottom habitats of the southern and offshore regions of the Japan and Okinawa Complexes OPAREA. Cost: High. Priority: 2.

- Support a survey of the Japan and Okinawa Complexes OPAREA to obtain high-resolution bathymetry data. Currently, bathymetry is only available at 2 min resolution, preventing accurate modeling of the continental shelf and shelf break around a number of the small islands in the region. Cost: High. Priority: 2.

- Fund a compilation and interpretation of large whale movements in the North Pacific much like Clapham et al. (2004) did by analyzing monthly occurrence records for the North Pacific right whale. The fin and blue whale would be relatively easy subjects. Cost: Low. Priority: 1.

- Fund a compilation and interpretation of pinniped occurrence literature in the western North Pacific Ocean, particularly for species with occurrence in Japanese waters. Literature could be prioritized by level of importance by at least providing an English abstract or summary since much of the literature has neither. Cost: Low. Priority: 1.

- Obtain marine mammal and sea turtle datasets for plotting occurrence records for better determination or refinement of occurrence patterns displayed in this MRA. Additionally, this will aid in determination of areas that the Navy could fund survey effort to address data and information gaps. Cost: Moderate to High. Priority: 1.

- Fund aerial surveys for the critically endangered dugong at Okinawa. Current aerial surveys should be expanded to the entire range of possible dugong habitats in the Ryukyu Islands. In some focal areas, aerial surveys should be repeated several times a year for better understanding of abundance and habitat use of dugongs. Individual identification using photographs should be attempted. Support the Dugong Network in their efforts to compile and analyze occurrence records for dugongs in this area. Cost: Low to Moderate. Priority: 2.

- Fund nesting and in-water surveys for sea turtles at the four Navy ranges located in the Okinawa study area. Nesting surveys have been conducted at multiple locations on Okinawa and its smaller surrounding islands, yet there is no information available on whether surveys have been conducted at

the Navy-controlled ranges. At least three species of sea turtles are known to occur and nest in the Okinawa study area. Nesting and in-water surveys would help to demonstrate the importance of the four Navy ranges in terms of providing suitable foraging and nesting habitat. Cost: Low to Moderate. Priority: 2.

- Support the marine mammal and sea turtle stranding networks, particularly with mapping and analysis of their collected data. Stranding network data could be utilized to determine the species diversity in the area, collect life history information on diet and reproduction, assist with stock determination, and assess impacts of human activities. Cost: Low. Priority: 3.

- Support the utilization of satellite-tracking technology to monitor the movements of species of special interest. Several species of endangered marine mammals and sea turtles occur in the OPAREA, yet comparatively little is known about their movements. Knowledge of their potential movements would greatly aid our understanding of their behavior and ecology. Given the endangered status of certain whales, sea turtles, and other protected species, such studies are tremendously important. Satellite-tracking programs are expensive, precluding the study of more than a few individuals. While insights on an individual's behaviors or movements may be gained, questions at the population level may go unanswered. Cost: Moderate. Priority: 2.

6.3 LITERATURE CITED

Clapham, P.J., C. Good, S.E. Quinn, R.R. Reeves, J.E. Scarff, and R.L. Brownell, 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.

Kimura, T. 2004. Coral monitoring in Japan. Pages 78-103 in M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano, eds. Coral Reefs of Japan. Tokyo, Japan: Ministry of the Environment.

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7.0 LIST OF PREPARERS

Name/Title/Affiliation	Education	PROJECT ROLE
Vanessa Pepi Naval Facilities Engineering Command Pacific Pearl Harbor, Hawaii	M.S., Animal Sciences University of Hawaii B.S., Fish and Wildlife Biology and Management University of Minnesota	Navy Technical Representative
Dan L. Wilkinson Vice President, Special Projects Geo-Marine, Inc. Plano, Texas	Ph.D., Botany Texas A&M University M.S., Zoology Stephen F. Austin State University B.S., Biology Central State University	Program Director
Julie Rivers Fish and Wildlife Biologist Naval Facilities Engineering Command Pacific Pearl Harbor, Hawaii	B.S., Biology Beloit College	Navy Technical Representative, Alternate
Jason See Oceanographer Geo-Marine, Inc. Plano, Texas	Ph.D., Marine Sciences Virginia Institute of Marine Sciences B.S., Zoology Texas A&M University	Project Manager, Physical Environment, and Technical Review
William Barnhill III Marine Resource Specialist Geo-Marine, Inc. Plano, Texas	M.E.M., Coastal Environmental Management Duke University B.S., Biology Denison University	Introduction co-PI, Species of Concern: Sea Turtles, and Additional Considerations
Chad Burrows Fisheries Biologist Geo-Marine, Inc. Plano, Texas	M.S., Environmental Science Stephen F. Austin State University B.S., Limnology Stephen F. Austin State University	Additional Considerations PI, Fish and Fisheries, and Technical Review
Brian Chastain GIS Analyst Geo-Marine, Inc. Plano, Texas	M.A., Geography Ohio State University B.S., Computer Science Baylor University	GIS Map Production
Ross Crossland GIS Analyst Geo-Marine, Inc. Plano, Texas	B.S., Geography Texas A&M University	GIS Map Production
Ken Deslarzes Senior Marine Ecologist Geo-Marine, Inc. Plano, Texas	Ph.D., Oceanography Texas A&M University Diploma Biology University of Lausanne, Switzerland License of Biology University of Lausanne, Switzerland	Physical Environment
David Evans Marine Biologist Geo-Marine, Inc. Plano, Texas	B.S., Marine Biology Texas A&M University	Fish and Fisheries
Todd Fagin GIS Analyst Geo-Marine, Inc. Plano, Texas	Ph.D., (ABD) Geography, candidate December 2005 University of Oklahoma B.A., Letters University of Oklahoma	GIS Map Production

LIST OF PREPARERS
(Continued)

Name/Title/Affiliation	Education	PROJECT ROLE
Dagmar Fertl Senior Marine Mammal Biologist Geo-Marine, Inc. Plano, Texas	M.S., Wildlife and Fisheries Science Texas A&M University B.S., Biology Trinity University	Species of Concern PI, Marine Mammals, and Technical Review
Gregory Fulling Senior Fisheries Ecologist Geo-Marine, Inc. Plano, Texas	Ph.D., Marine Biology The University of Southern Mississippi M.S., Biology Angelo State University B.S., Biology Eastern Washington University	Technical Review
Peter Gehring GIS Manager Geo-Marine, Inc. Plano, Texas	M.S., Environmental Science Miami University B.S., Zoology/Biochemistry Miami University	GIS Project Oversight and Graphics
Mary Grushka Library Coordinator Geo-Marine, Inc. Plano, Texas	B.S., Education Northern Illinois University	Literature and Library
Jennifer Paschal Biologist Geo-Marine, Inc. Plano, Texas	M.S., Human Biology University of Indianapolis B.S., Biology University of North Texas	Introduction co-PI, Executive Summary, and Additional Considerations
Jacqueline Karle Report Production Geo-Marine, Inc. Plano, Texas	B.S., Zoology – Biomedical Sciences University of Oklahoma	Report Production, Acronyms and Abbreviations, List of Preparers, and Glossary
Joseph Kaskey Senior Environmental Scientist Geo-Marine, Inc. Plano, Texas	M.S., Botany Southern Illinois University B.A., Biological Sciences Southern Illinois University	Fish and Fisheries
Kevin Knight Senior GIS Analyst Geo-Marine, Inc. Plano, Texas	B.S., Geology University of Texas	GIS Data Manager, GIS Documentation PI, and Map Production
Patricia Knowles Technical Editor Geo-Marine, Inc. Plano, Texas	B.S., Education University of Tulsa	Editorial Review
Anu Kumar Marine Scientist/ Acoustician Geo-Marine, Inc. Newport News, VA	M.S., Marine Science California State University B.S., Biology-Ecology California State University	Physical Environment
Tamara Lunsman Marine Scientist Geo-Marine, Inc. Plano, Texas	Ph.D., Marine Science University of California B.S., Marine Biology Texas A&M University	Physical Environment PI, Additional Considerations, and Technical Review
Jason Lyon GIS Analyst Geo-Marine, Inc. Plano, Texas	M.P.A., Planning/Emergency Management University of North Texas B.A., Geography/Political Science University of North Texas	GIS Map Production

LIST OF PREPARERS
(Continued)

Name/Title/Affiliation	Education	PROJECT ROLE
Paula Trent Executive Assistant Geo-Marine, Inc. Plano, Texas	B.A., Arts & Humanities University of Texas at Dallas	Report Production
Amy Whitt Marine Scientist Geo-Marine, Inc. Plano, Texas	M.E.M., Coastal Environmental Management Duke University B.S., Biology Lyon College	Species of Concern: Marine Mammals and Additional Considerations

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8.0 GLOSSARY

Abiotic—nonliving

Abundant—an indication of the plentifulness of a species at a particular place and time; an abundant species is more plentiful than an occasional or rare species

Abyssal plain—flat, sediment-covered part of the ocean floor between the continental rise and the mid-ocean ridge at a depth greater than 4,000 to 5,000 m

Abyssal zone—flat, sediment-covered part of the ocean floor between the continental rise and the mid-ocean ridge at a depth between 4,000 and 7,000 m

Acanthuroids—coral reef fishes comprising the families of surgeonfishes, rabbitfishes, and Moorish idols

Active margin—a continental margin that is tectonically deformed as it collides with another tectonic plate. It is the leading edge of a continent as it moves away from an oceanic spreading center

Adult—developmental stage characterized by sexual or physical (full size and strength) maturity

Aerobic—life or biological processes that can occur only in the presence of oxygen

Aggregation—group of animals that forms when individuals are attracted to an environmental resource to which each responds independently; the term does not imply any social organization

Aggression—a set of social interactions ranging from threats to open fights, reflecting a conflict of interest over limited resources and having the potential to cause injuries and sometimes death to participants. Generally refers to conflict involving members of the same species by may refer to any interaction of this kind

Agonistic behavior—see aggression

Ahermatypic coral—non-reef building types of coral that lack symbiotic zooxanthallae and are not restricted by depth, temperature, or light penetration; may be solitary or colonial

Akaumigame—Japanese for loggerhead turtle

Algae—a number of primarily aquatic, photosynthetic groups (taxa) of plants and plant-liked protists ranging in size from single cells to large, multicellular forms (i.e., giant kelp) that have no seeds, roots, stems, flowers or leaf systems

Allee effect—a phenomenon seen in animal populations with extremely low numbers where a small number of individuals result in difficulties in finding a mate and possible inbreeding; this effect can drastically reduce the fitness and genetic diversity of an animal population

Alpha male—the dominant male

Amphipod—an order of laterally compressed (shrimp-like) crustaceans with thoracic gills, no carapace, and similar body segments. An important component of zooplankton and benthic invertebrate communities

Anaerobic—life or biological processes that occur in the absence of oxygen

Anchialine pools—land-locked, marine or brackish pools of water located along rocky coasts and connected to the sea via underground caves, tunnels, or fissures

Anemone—a cnidarian of the Class Anthozoa that possess a flexible cylindrical body and a central mouth surrounded by tentacles

Annelids—invertebrate animals of the Phylum Annelida in which the body is typically made up of a series of rings or segments covered by a soft cuticle and lacking jointed appendages (e.g., marine worms)

Anomaly—something irregular or abnormal

Anthozoan—a class of the coelentrates in which the medusiod stage is absent and the polyp (hydroid) stage is better developed than in other coelentrates (e.g., sea anemones, corals, alcyonarians, sea fans, sea pens, sea pansies, sea feathers)

Anthropogenic—describing a phenomenon or condition created, directly or indirectly, as a result of human activity

Anticyclonic—clockwise circulation in the Northern Hemisphere and counterclockwise circulation in the Southern Hemisphere; in oceanography, synonymous with warm-core ring

Aoumigame—Japanese for green turtle

Archipelago—group of islands more or less adjacent to each other and arranged in groups covering portions of the sea

Artificial habitat—a human-made, estuarine/marine habitat (sunken ships, artificial reefs: rubble, concrete igloos, FADs) created in navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Artificial reef—a human-made, marine habitat (sunken ships, concrete igloos, rubble) created in the navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Ascidians—sea squirts; taxonomic class of globular or cylindrical animals that inhabit shallow and deep water, attach themselves to substrates (rocks, pilings, the bottom of ships, and coral reefs), and may be solitary or colonial

Assemblage—the populations of various species from a larger taxon characteristically associated with a particular environment that can be used as an indicator of the environment

Atoll—an organic reef that surrounds a lagoon and is bordered by open sea, often with low sand islands

Audiogram—a hearing sensitivity curve drawn as a function of frequency and sound pressure level; describes the hearing ability of an animal

Back-arc—referring to the region behind the island arc (the concave side of the arc)

Baiu Zensen—rainy front where a cold mass over the Okhotsk sea and a warm mass over the Pacific Ocean meet

Baleen—the interleaved, hard, fibrous plates made of keratin (protein in fingernails and hair) that hang side by side in rows from the roof of the mouth of mysticete whales; baleen takes the place of teeth and serves to filter the whale's food from the water

Bandwidth—the difference between the highest and lowest frequencies; measured in Hertz

Barnacles—sedentary marine crustacean of the order Cirripedia with free-swimming larvae; live in calcareous shells, feed by extending feather-like cirri or feet out of the shell into seawater to catch prey; are parasitic and burrow into shells of other sea animals or attach themselves to fixed or floating objects

Basking—an activity performed by pinnipeds and sea turtles while on land or at the water surface in which they expose themselves to pleasant warmth

Bathymetry—the topography of the ocean floor; study and mapping of the ocean depths

Bay—a body of water partially enclosed by land, but with a large outlet to the sea or ocean

Beaked whales—members of the Family Ziphiidae, includes the Genus *Ziphius*, *Mesoplodon*, *Indopacetus*, *Berardius*

Behavioral audiogram—a graphic representation of an animal's auditory threshold that is determined by tests with trained animals; measures the hearing ability of an animal

Benthic—organisms living on or near the ocean floor; the term is used irrespective of whether the sea is shallow or deep

Benthopelagic—the ecological zone from the seabed to 100 m above the seabed

Benthos—organisms that live in, on, or are attached to the ocean bottom substrate

Biomass—the amount of living matter per unit of water surface or water volume

Biotic—pertaining to life or living organisms

Bivalve—group of marine or freshwater bilaterally symmetrical mollusks that consist of a soft body protected by two hinging calcareous shells (e.g., clams, oysters, scallops, mussels); are mostly sedentary filter feeders

Blackfish—a colloquial term adopted from American whalers and sometimes applied to pilot whales and other superficially similar species including false killer, pygmy killer, and melon-headed whales

Bloom—the usually seasonally dense growth of algae or phytoplankton that is triggered by an increase in the nutrient concentration or increased availability of light

Blow—air exhaled through the blowhole of a cetacean mixed with surrounding water that is displaced by the exhalation

Blowhole—the nostrils or nasal openings on top of the head of a cetacean

Blubber—a specialized layer of fat found between the skin and underlying muscle of many marine mammals; it is used primarily for insulation and energy storage

Boreal—comprising or throughout far northern regions

Bottlenose dolphin—the former common name for *Tursiops truncatus,* now called the common bottlenose dolphin

Boxfishes—any of numerous small tropical fishes of the family Ostraciidae having body and head encased in bony plates

Brackish—having a salinity between that of fresh and sea water

Brittlestar—starfishlike echinoderm belonging to Class Ophiuroidea that has 5 to 8 elongate, slender, cylindrical arms distinctly radiating from a flat central disc

Brown algae—division of algae (Phaeophycophyta) consisting of large macroscopic forms occurring widespread in marine habitats attached either to rocks, stones or coarser algae (kelp); commonly found relatively shallow water in the intertidal and subtidal zones along the coast, in estuaries, and muddy bottoms of salt marshes

Bryozoan—phylum of small, aquatic colonial animals that are commonly called moss animals; each zooid or animal in the colony has a crown of ciliated tentacles

Bubble netting—a coordinated feeding technique of humpback whales, in which they use bubbles to corral and trap small fish or invertebrates

Bull—a male seal or whale, especially an adult male

Buoy—a bright-colored float attached by rope to the seabed to mark channels in a harbor or underwater hazards

Bycatch—marine species caught along with targeted species in a fishery, but which are not sold or kept for personal use, and includes economic and regulatory discards

Calanoids—most numerous in size and species of planktonic copepods

Calcareous—composed of calcium or calcium carbonate

Calf—a young animal dependent on its mother

Callosity—a patch of thickened, keratinized tissue on the head of a right whale, inhabited by large numbers of whale lice

Calving—the process of giving birth by a whale, dolphin, porpoise, or manatee

Calving interval—the period of time from one birth to the next, generally applicable to cetaceans

Canopy—a fairly continuous layer in forests produced by the intermingling of branches of trees

Cape—a darker region on the back of many species of dolphins and small whales, generally with a distinct margin

Carangids—a percoid fish of the family Carangidae

Carapace—the outer covering of the back of a sea turtle, which is bony for all sea turtle species with the exception of the leatherback, which has a leathery covering

Carbonate—type of rock or sediment formed of carbonate (CO_3^{-2}) and another element such as calcium or magnesium; limestone and dolomite are common carbonate rocks

Caridean shrimp—a caridoid decapod crustacean with phyllobranchiate gills, second abdominal pleura forming a caridean saddle, and usually two pairs of chelae but never three

Carnivore—an animal that feeds exclusively on another animal's tissue

Carrion—dead and rotting body of an animal

Catch per unit effort (CPUE)—measure of a species relative abundance

Cephalopods—any marine mollusk of the Phylum Mollusca with a well-developed pair of eyes and a ring of tentacles surrounding the mouth; shell is absent or internal (squid, octopus, cuttlefish)

Cetaceans—whales, dolphins, and porpoises

Chaetodontids—fishes comprising two major circumtropical reef-associated families, butterflyfishes and angelfishes

Chaetognaths—known as arrowworms that are active elongated, transparent predators in marine plankton

cheloniidae—the family of hard-shelled sea turtles that includes the green, hawksbill, Kemp's ridley, Olive ridley, and loggerhead turtles

Chemoautolithotrophic bacteria—an organism that depends on inorganic chemicals for its energy and principally on carbon dioxide for its carbon. Also called *chemolithotroph* or chemoautotroph

Chemosynthesis—the formation of organic compounds from inorganic substances using energy derived from oxidation

Chevron—a V-shaped stripe

Chimeras—a deep-sea cartilaginous fish of the Family Chimaeridae having a smooth-skinned tapering body and a whip-like tail

Chitons—marine mollusks of the Order Polyplacophora that consist of long oval bodies covered by calcareous plates which are partially or totally covered by thick, bristly girdle; lives on rocks

Chlorophyte—green algae

Circumglobal—the distribution pattern displayed by organisms around the world, within a range of latitudes

Circumpolar—ranging all the way around high northern or southern latitudes

Circumtropical—organisms which occur around the tropics of the world (land or sea)

Cladocerans—order of microscopic crustaceans with trunk limbs enclosed in a carapace used for feeding and antennae used for swimming; called water fleas

Click—a broad-frequency sound used by toothed whales for echolocation and which may serve a communicative function; usually with peak energy between 10 kHz and 200 kHz

Clutch—a total number of eggs from one nesting

Cnidarians—the phylum of animals that includes corals, sea fans, sea anemones, hydroids, and jellyfish; known for the stinging cells on their tentacles; these animals exhibit two body types, polyps (may be attached or planktonic) or medusa, sometimes at different periods of one species development

Coast—the boundary where land and water meets

Coastal water—water that is along, near, or relating to a coast

Cochlea—a spiral bony structure in the inner ear that looks like a snail shell and contains over 10,000 tiny hair cells, which are the receptor organs essential for hearing and that bend in response to sound waves, the bending of the hair cells in stimulates nerve cells to send messages to the brain, which the brain interprets as sound

Coda—a patterned series of 3 to 20 clicks lasting about 0.5 to 2.5 seconds, used by sperm whales for communication

Cold-stunning—the behavior exhibited by sea turtles in response to cold water temperatures; turtle becomes lethargic and adopts a stunned floating posture

Colony—highly integrated group of animals; herein refers specifically to birds and land-breeding pinnipeds

Commercial fishing—the stock of fisheries where fish and other seafood resources are taken for the purpose of marketing them

Common—in the case of sea turtles, common means that sea turtles have been recorded in all, or nearly all, proper habitats, but some areas of the presumed habitat are occupied sparsely or not at all and/or the region regularly hosts large numbers of the species

Concentrated occurrence—a subarea of a species' expected occurrence where there is the highest likelihood of encountering that species; based primarily on areas of concentrated sighting/nesting records and preferred habitat

Conspecific—member of the same species, and in many cases, the same age or even sex

Continental margin—the boundary or transition between the continents and the ocean basins that consists of the physiographic provinces of the continental shelf, continental slope, and continental rise

Continental rise—the province of the continental margin with a sloping seabed (1:100-1:700 gradient change) and a generally smooth surface, which lies between the abyssal plains and continental slope

Continental shelf—the province of the continental margin with a gently seaward-sloping seabed (1:1,000 gradient change) extending from the low-tide line of the shoreline to 100 to 200 m water depth where there is a rapid gradient change

Continental shelf break—the area where the slope of the seabed rapidly changes from gently sloping (1:1,000) to steeply sloping (1:40) where the continental shelf transitions into the continental slope

Continental slope—the province of the continental margin with a relatively-steeply sloping seabed (1:6 to 1:40 gradient change) that begins at the continental shelf break (usually around 100 to 200 m) and extends down to the continental rise; along many coasts of the world, the slope is furrowed by deep submarine canyons

Contour—a line of connected points of equal value on a surface

Copepods—very small planktonic crustaceans present in a wide variety and great abundance in marine habitats, forming an important basis of ecosystems; they are a major food of many marine animals and are the main link between phytoplankton and higher trophic levels

Coral patches—rocky outcrops colonized by sessile organisms including hard coral, soft corals, hydroids, algae, and sponges

Coral polyps—are small marine animals with a tube-shaped body with a mouth which is surrounded by tentacles; polyps can be either solitary or colonial

Coral reef—a massive, wave-resistant structure built largely by colonial, stony coral via deposition of calcium carbonate

Coral reef ecosystem (CRE)—those species, interactions, processes, habitats and resources of the water column and substrate located within any waters less than or equal to 50 fathoms (100 meters) in total depth

Coralline algae—family of red algae (Corallinaceae) having bushy or encrusting form and deposits of calcium carbonate either on branches or as crusts

Corallivores—an organism that eats coral

Cosmopolitan—having a broad, wide-ranging distribution

Countershading—a form of camouflage exhibited by many fish and cetaceans, with dark upper body surfaces and lighter undersides. When viewed from above the darker dorsal surface blends in with the water; from below the lighter ventral surface matches the light coming from the sky, making the animal hard to see

Critical habitats—the portion (minimum) of the habitat that is essential for the survival of threatened and endangered species and may include areas essential for feeding or reproduction by those species

Critically Endangered Species (IUCN Red List)—a species that is considered to be facing an extremely high risk of extinction in the wild

Crust—the outer shell of the planet. It is composed of sedimentary, metamorphic, and igneous rock

Crustaceans—arthropods that have two pairs of antennae and a hard exoskeleton; lobster, shrimp, and crabs are the most familiar examples

Crustose—having a thin crusty thallus that adheres closely to the surface on which it is growing

Cryptic—hidden; living in holes, caves, burrows

Curios—objects valued for their rarity or unusualness

Curved carapace length (CCL)—the length of a sea turtle's carapace measured by researchers working on nesting beaches with a flexible tape measure

Cuttlefish—marine mollusk of the Class Cephalopoda that has 10 arms including two long tentacles it can draw back into its body

Cyanobacteria—large and varied group of bacteria which possess chlorophyll a and carry out photosynthesis in the presence of light and air, with concomitant production oxygen; formerly regarded as algae and called blue-green algae; may be single-celled or filamentous and may or may not be colonial; many species carry out the fixation of atmospheric nitrogen; widely distributed in marine and freshwater environments in littoral zone on soil, rocks, and plants as epiphytes or symbionts; may produce harmful algal blooms in low-salinity systems with excessive nutrients

Data deficient species (IUCN Red List)—a species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status; a species for which appropriate data on abundance and/or distribution are lacking

Decapod—order of freshwater, marine, and terrestrial crustaceans having five pairs of legs on the thorax and a carapace completely covering the throat (e.g., shrimps, crabs, lobsters)

Decibel (dB)—a logarithmic measure of sound strength; it is a ratio of intensity (pressure) at reference range compared with a reference level; in air, the reference pressure is 20 µPa and the reference range is 1 m, while for underwater sound, the reference is 1 µPa and the reference range is also at 1 m

Deep-scattering layer—a layer of dense aggregation of fishes, squid, and other species found at depth that migrate vertically in the water column each day; the layer of organisms moves toward the surface at night to feed and returns to depth at dawn

Deepwater—the area of the ocean that is past the continental shelf break, deeper than 100 to 200 m of water

Delayed implantation—in mammals it is the suspended development of an embryo between shortly after conception and subsequent attachment (implantation) to the uterine wall

Delimitation—fixing a boundary

Delphinus—it is the genus of oceanic dolphins consisting of short-beaked and long-beaked common dolphins, which are similar in appearance

Demersal—applied to fish that live close to the seafloor, such as cod and hake

Demography—birth and death rates that determine a population's dynamics; abundance, age, and sex structure of the population and reproductive status and life cycle of individuals

Density—physical property measured by mass per unit volume; in biology, the number of organisms per unit of distance

Dermochelyidae—the family of sea turtles that includes only one species, the leatherback turtle

Desiccation—removal of water, dehydration; the process of drying

Detritus—fragmented particulate organic matter derived from the decomposition of plant and animal remains

Developmental habitat—an environment crucial to the growth of late-stage juvenile animals; for some sea turtles, this environment can be a shallow, sheltered habitat where forage items such as seagrasses, sponges, mollusks, and crustaceans are abundant

Diatoms—microscopic algae (Bacillariophyceae) in which the cell wall (frustule) is composed of silica and consists of two major valves and girdle bands; unicellular, colonial, or filamentous; important components of freshwater and marine habitats as members of both planktonic and benthic communities; comprised of two major types based on symmetry: pennate – bilateral, centric – radial; forms the primary food base for marine ecosystems; may produce harmful algal blooms in marine habitats (domoic acid producing *psuedo-nitzschia*)

Diel—refers to 24-hour activity cycle based on daily periods of light and dark

Dimorphic—having two different forms

Dinoflagellates—microscopic single-celled plant of the Class Pyrrhophyceae that has two flagella, one propelling water to the rear and providing forward motion, attached just behind the center of the body and directly posteriorly, the other causing the body to rotate and move forwards, forming a transverse ring or spiral of several turns around the center of the body; some are naked, others are covered with a membrane or plates of cellulose; often abundant; dense growths may produce luminescent bays and harmful algal bloom in freshwater and marine habitats (*Alexandria*)

Dispersal—spreading of individuals throughout suitable habitat within or outside the population range. In a more restricted sense, the movement of young animals away from their point of origin to locations where they will live at maturity

Display—any behavior that conveys information, usually to members of the same species or to predators; often used during mating or territory defense

Dissolved organic matter (DOM)—is dissolved and colloidal organic material that passes through a filter with a mesh size of between ~0.1 and 1 microns; dissolved organic carbon is the carbon component of the DOM

Diurnal—active or occurring during daylight hours; having a daily cycle

Dominant species—species most prevalent in a particular community, or at a given period

Dorsal—relating to the upper surface of an animal

Downwelling—downward movement or sinking of surface water towards the ocean bottom; may be caused by convergent currents or density differences

Drift net—a monofilament gillnet set at or near the surface that stretches up to 60 km or more in length, used passively (drifts) to entangle fish or invertebrates, which also catches a large number of non-target species, including marine mammals and sea turtles

Drive fishery—small cetaceans (such as pilot whales) are maneuvered into a confining situation where they are either entrapped or immediately driven ashore and killed

Echinoderms—phylum of marine invertebrates having bilateral symmetry in larval forms and usually a five-sided radial symmetry as adults, a calcareous endoskeleton, and a water vascular system (e.g., sea cucumbers, sea urchins)

Echinoids—group (class) of echinoderms including sea urchins, heart urchins, sand dollars, etc. that are spiny and globular to disc-like in shape

Echiuroids—unsegmented marine worms with one or more pairs of bristles; live in sand or rock crevices intertidally or in shallow water

Echolocation—the production of high-frequency sound waves and reception of echoes to locate objects and investigate the surrounding environment

Ecosystem—a system of ecological relationships in a local environment comprising both organisms and their nonliving environment, intimately linked by a variety of biological, chemical, and physical processes

Eddy—the circular movement of water

Eelgrass—vascular flowering plants of the Genus *Zostera* that are adapted to living under water while rooted in shallow sediments of bays and estuaries

El Niño—periodic movement of warmer than usual water in the southeastern Pacific Ocean towards the west coasts of the Americas; typically occurs in December or January and is the result of the Southern Oscillation

El Niño/Southern Oscillation (ENSO)—the climatic phenomenon that causes changes in wind and current patterns (reversal of the Pacific equatorial currents) that leads to changed ocean temperatures and weather patterns over vast distances; leads to the disruption of coastal upwelling and die-offs of plankton, fish, sea birds, and marine mammals

Embayment—an indentation in the shoreline that forms a bay

Encrusting—forming or resembling a crust

Endangered species (ESA)—any animal or plant species in danger of extinction throughout all or a significant portion of its range; the authority to list a species is shared by the USFWS (plants and animals on land) and NMFS (most mairine species) under provisions of the Endangered Species Act

Endangered species (IUCN Red List)—a species that is considered to be facing a very high risk of extinction in the wild

Endemic—occurring in a specific area

Endemic species—species native and confined to a certain region and having restricted distribution (i.e., a species unique to a place, found naturally nowhere else

Energy flux density—the average rate of sound energy flow per area for one period

Entrainment—the process of picking up and carrying along

Environmental impact statement (EIS)—a detailed written statement that helps public officials make decisions that are based on understanding of environmental consequences and to take actions that protect, restore, and enhance the environment

Epibenthic—refers to organisms living on the ocean floor

Epicontinental waters—shallow waters which occupy wide portions of continental shelf

Epifauna—animals living on the surface of the ocean floor; any encrusting fauna

Epipelagic—the oceanic zone from the surface to 200 m

Equatorial—of or existing at or near the geographic equator

Equidistant line or equidistance—a median line, every point of which is the same distance from the nearest points on the baselines of two countries

Estuary—a semi-enclosed body of water where freshwater mixes with saltwater; often an area of high biological productivity and important as nursery areas for many marine species

Euphausiids—known as krill, these are pelagic shrimp-like crustaceans

Euphotic zone—the uppermost area of the ocean (up to 150 m) that is sufficiently illuminated to permit photosynthesis by phytoplankton, algae, and submerged aquatic vegetation

Eurybathic—an organism that can tolerate of a wide range in depth

Eurythermal—an organism that can tolerate a wide range of temperatures

Eutrophication—the process by which nutrient-rich water promotes a rapid growth of algae and phytoplankton, which reduces the water's dissolved oxygen content

Exclusive Economic Zone (EEZ)—all waters from the low-tide line outwards to 200 NM (except for those that are close together, i.e., Mediterranean countries) in which the inner boundary of that zone is a line coterminous with the seaward boundary of each of the coastal states; the country has the power to manage all natural resources

Existence value—value that individuals may attach to the mere knowledge of the existence of something, as opposed to having direct use of that thing; synonymous with non-use value

Expected occurrence—an area encompassing the expected distribution of a protected species that is indicative of where one would expect to encounter that species; based primarily on habitat preferences, life history, and documented occurrence records

Extent—coordinate pairs that define the rectangular boundary (xmin, ymin and xmax, ymax) of a data source and in which all the coordinates for that data source fall

Extirpated—species that no longer exists in the wild

Extralimital—outside the normal limits of an animal's distributional range; in the case of marine mammals, 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

Extrapolate—to estimate a value that falls outside a range of known values

Extreme high tide—flooding associated with extremely large tides and during storm surges or wind-driven tidal inundations

Falcate—sickle-shaped and curved (refers to the dorsal fin of some cetaceans)

False crawl—an abandoned sea turtle nesting attempt or simply a U-shaped crawl from the ocean up the beach, and then back to the water

Fathom—a marine unit of measure of water depth equaling 1.83 m

Fauna—animal life of a region

Fecundity—the potential of an organism to produce offspring (measured as a number of gametes)

Fish aggregating device (FAD)—single or multiple floating structures that are connected to the ocean floor by ballast or anchors; used to attract fish

Fishery—one or more stocks of fish that can be treated as a unit for purposes of conservation and management and that are identified on the basis of geographical, scientific, technical, recreational and economic characteristics, and any fishing for such stocks

Fissiped—refers to animals in the Order Carnivora other than the pinnipeds (for example, otters)

Fjord—a deep, steep-walled, U-shaped valley formed by erosion by a glacier and submerged with seawater

Flank—side of the body; used mainly to refer to the side of the posterior half of the body

Flatfish—members of the fish order Heterosomata which swims or lies on one side of its body; sides are greatly flattened and compressed; mainly marine animals (e.g., flounders, soles)

Flipper—the flattened forelimb of a marine mammal

Flora—all the plant species of a given area

Flotsam—floating refuse or debris; parts of a wrecked ship and goods lost in a shipwreck

Flukes—the horizontally spread tail of a cetacean or dugong

Forage—the act of searching for food or provisions

Fore reef—area from the seaward edge of the reef crest that slopes into deeper water to the landward edge of the bank/shelf platform. Features not forming an emergent reef crest but still having a seaward-facing slope that is significantly greater than the slope of the bank/shelf are also designated as fore reef

Fore-arc—referring to the region ahead of the island arc (the convex side of the arc)

Fringing reefs—reefs made of corals that grow on hard surfaces of rocky shores below the lowest tide mark. These reefs follow shorelines at a close distance

Front or frontal—see ocean front

Fundamental frequency—the lowest frequency of a harmonic series; measured in the Hz (cycles per second)

Fusiform—spindle-shaped or torpedo-shaped and tapering at one or both ends

Gadids—members of the Family Gadidae which includes Pacific cod and hake

Galatheid crabs—deep sea scavenging crabs found in abundance around hydrothermal vents, cold seeps, and whale falls

Gape—the mouth in cetaceans, usually referring to the junction of upper and lower lips

Gastropods—class of symmetrical, univalve mollusks that have a true head, an unsegmented body, and a broad, flat foot

Genera—one of taxonomic or scientific classifications of plants and animals

Gestation period—period of development of an embryo within the uterus of a viviparous animal from conception to birth

Gillnet—a type of fishing gear made of rectangular mesh panels that are set more or less vertically in the water so that fish swimming into it are entangled by their gills; they can be set to fish at the surface, midwater, or on the bottom of the water column

Gorgonians—coral of the Class Anthozoa, subclass Octocorallia, Order Gorgonacea; this order of corals includes sea rods, sea whips, feather plumes, and sea fans

Grapsoid—crabs pertaining to the genus Grapsus or of the family Grapsidae

Great whales—typically refers to all the baleen whales plus the sperm whale

Green algae—division of algae (Chlorophyta) consisting of plankton and benthic forms occurring widespread in marine and freshwater habitats; marine species are primarily macroscopic forms frequently attached to moist rocks, woods, pilings, or larger algae or grow on sandy bottoms on shells in quiet estuaries; consist of motile and nonmotile types; may be unicellular, colonial, filamentous, membranous (e.g., sea lettuce), and tubular

Gregarious—used to describe animals that form social groups

Gyre—circular movement of waters, larger than an eddy; usually applied to oceanic systems

Habitat—the living place of an organism or community of organisms that is characterized by its physical or living properties

Habitat preference—the choice by an organism of a particular habitat in preference to others

Halophyte—a plant that grows in soils that have a high content of various salts

Hard coral—see scleractinian

Hardbottom—a substrate formed by the deposition of calcium carbonate by reef building corals and other organisms, bedrock or volcanic rock usually of minimal relief, or rocky outcroppings and talus

Hardbottom community—area of bottom habitat with three-dimensional character providing physically stable shelter and substrate for large populations of sessile or attached invertebrates and fishes

Harem—a group of females whose breeding is controlled by a single male who seeks to prevent other males from breeding with them

Haru Ischiban—first strong southerly wind that signals the onset of spring

Hatchling—a newly hatched bird, amphibian, fish, or reptile

Haulout—periodic and purposeful process by which pinnipeds or sea turtles crawl or pull themselves out of the water onto land (e.g., intertidal rock outcrops, sandbars, shoals, mudflats, or sandy beaches)

Herbivore—an animal that eats plants as its main source of energy

Herbivorous—feeding on plants; phytophagous; protozoans that feed on bacteria and/or algae

Hermaphroditic—having both sexes in the same individual, either at the same time or at different times

Hermatypic coral—reef-building coral containing symbiotic, unicellular zooxanthallae in their endodermal tissue; usually colonial, may be solitary, found in shallow, warm, sunlit waters

High tide—the highest level to which the tide rises within the daily tidal cycle

Himeumigame—Japanese for olive ridley turtle

Holdfast—the algal (seaweed) equivalent of roots that attaches the organism to a surface or the seafloor

Hydric soil—soils that are saturated or flooded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation

Hydrographic—used with reference to the structure and movement of bodies of water, particularly currents and water masses

Hydrography—the science of measuring and describing the surface waters of the Earth

Hydroids—class of solitary or colonial coelenterates that have a hollow cylindrical body closed at one end with a mouth surrounded by tentacles at the other end

Hydrophone—transducer for detecting underwater sound pressures; an underwater microphone

Hydrophyte—a damp-loving plant that grows only under water or in very moist soil

Hydrothermal vent—location on the ocean floor in which water percolates down through fractures in recently formed ocean floor, is heated by underlying magma, and surfaces through chimneys. Hydrothermal vents are usually located near the axis of spreading on ocean ridges and rises

Hydrozoans—delicate marine animals usually in clusters or colonies of the Phylum Coelenterata; individual polyps are encased in gelatinous cups and often secrete coral as supporting structures; highly branched polyp or hydroid stage of many members is important component of fouling

Hypersaline—having more salt than normal sea water

Ice floe—a large mass of sea ice (pack ice) kept in motion by winds, currents, and wave action

Ichthyofauna—all fish that live in a particular area

Ichthyoplankton—fish eggs and larvae drifting in the water column

Immature—not fully grown or developed; not yet capable of reproducing

Incidental fisheries bycatch—the catch of additional species, such as fishes, turtles, or marine mammals, that are not targeted by a fishery but are harvested in addition to the target or sought after species

Incubation—the act of keeping an egg warm so that development is possible

Indigenous species—a species native to a place or biota

Indo-Pacific—widespread species with western limit west of the Andamans and eastern limit east of non-marginal areas of the Pacific Plate

Infauna—organisms that live buried in the soft substrate (sand or mud)

Infrasonic—sound at frequencies too low to be audible to humans, generally below 20 Hz

Inshore—lying close to the shore or coast

Insular—pertaining to or situated on an island

International Union for Conservation of Nature (IUCN) Red List—system for classifying species at high risk of extinction, a list of animal species and subspecies thought to be threatened with extinction and those which are known or thought to have become extinct in the wild

Inter-nesting interval—the amount of time between successive sea turtle nesting events during the nesting season

Interstitial—pertaining to, or occurring within, the pore spaces (interstices) between sediment particles

Intertidal—marine or estuarine environment that lies between the area of shore exposed between high and low tide

Islet—a small island

Isobath—bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isopods—shrimp-like animals of the Order Isopoda that have their body flattened dorso-ventrally

Isotherm—contour of equal temperature; usually shown as a line linking points of the same temperature

Juvenile—mostly similar in form to adult but not yet sexually mature; a smaller replica of the adult

Kelp—usually large blade-shaped or vinelike brown algae of the Order Laminariales that typically grows on rock or stony bottoms (i.e., giant kelp, bull kelp, etc.)

Kelp holdfast—a branched, modified stem that attaches kelp to rocks or other hard substrata

Kogia—the genus comprised of the pygmy sperm whale (*Kogia breviceps)* and dwarf sperm whale (*Kogia sima*)

Krill—known as euphasiids, these are pelagic shrimp-like crustaceans

Kuroshio—the fast-flowing western boundary current of the North Pacific subtropical gyre

Kuroshio current—fast ocean current flowing northeastward from Taiwan to Ryukya Islands and close to coast of Japan to about 150° East

La Niña—when ocean temperatures in the eastern equatorial Pacific are unusually cold; it is essentially the opposite of the El Niño phenomenon; La Niña sometimes is referred to as the cold phase of an El Niño Southern Oscillation event (ENSO)

Labroids—coral reef fishes comprising the families of parrotfishes, damselfishes, and wrasses

Lactation—secretion or formation of milk by the mammary glands for the purpose of nursing offspring

Lagoon—a shallow stretch of seawater partly or completely separated from the open ocean by an elongated, narrow strip of land such as a reef or barrier island

Lagoon reefs—area enclosed by the low tide line to the inner edge of the atoll reef flat; often contains numerous patch reefs

Lair—a resting place used by an animal; often for giving birth, nursing young, or hibernating; den

Lancetfish—large elongate scaleless oceanic fish with sharp teeth and a long sail-like dorsal fin of the Family Alepisauridae

Lanternfish—small, usually deep sea fish with many luminescent spots on their bodies of the Family Myctophidae

Larval—young fish between time of hatching and attainment of juvenile characteristics

Leads—long narrow channels of open water in the sea ice which form between pack ice and the shore

Least Concern species (IUCN Red List)—a species that does no qualify for Critically Endangered, Endangered, Vulnerable, or Near Threatened status since it is widespread and abundant

Lee—the side (as of a ship) that is sheltered from the wind

Lithified—turned to stone

Littoral—the zone or division of the ocean bottom that lies between the high and low tide lines; intertidal

Live bottom community—a concentration of benthic invertebrates and demersal fishes that is associated with a region of vertical relief and structural complexity that can be organic (e.g., coral skeletons) and inorganic (e.g., rocks) in origin; such oasis-like communities are often surrounded by expanses of bottom with little relief or structure

Live rock—any natural, hard substrate (including dead coral or rock) to which is attached, or which supports, any living life-form associated with coral reefs

Longline—a type of fishing gear using a buoyed line onto which are attached numerous branch lines each terminating in a baited hook; longlines may extend for tens of kilometers and are usually left to drift in surface waters or near the seafloor

Lost year—the early juvenile stage (first years of life) of most sea turtle species that is spent far offshore; few turtles are observed during this time

Low/unknown occurrence—an area where the likelihood of encountering a species is rare or not known

Low tide—the lowest level to which the tide ebbs within the daily tidal cycle

Macroalga—classification of multicellular algae consisting of red, green, or brown species that are defined according to the size of the plant where the body of the plant is large enough to be observable to the human eye and project more than one centimeter above the substratum

Macrobenthic—organisms that live on the bottom of a water body (or in the sediment) on the surface of bedforms (e.g. rock, coral or sediment-epibenthos) or within sedimentary deposits (infauna), that are >50 cm in length

Macrofauna—animals larger than 500 µm

Macroflora—Aquatic plants large enough to be seen with the unaided eye. The most common macrophytes are rooted vascular plants that are usually arranged in zones in aquatic ecosystems and restricted by light and sediment deposition along the shoreline

Macrophyte—Aquatic plants large enough to be seen with the unaided eye. The most common macrophytes are rooted vascular plants that are usually arranged in zones in aquatic ecosystems and restricted by light and sediment deposition along the shoreline

Macroplankton—large planktonic organisms, 2 to 20 cm in size

Macroscopic algae—large algae, commonly referred to as seaweed

Mangrove—a variety of salt-tolerant trees and shrubs that inhabit the intertidal zones of tropical and subtropical regions; tropical equivalent of salt marshes

Masking—obscuring of sounds of interest by interfering sounds, generally at similar frequencies

Maximum sustained (sustainable) yield (MSY)—the maximum harvest that can be sustained year after year, derived from population models

Mean—(arithmetic) average

Mean high tide—the average of all the high tides as calculated over a long period of time

Mean higher high tide—the arithmetic average of the elevations of the higher high waters of a mixed tide over a specific 19 year period. For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19 year interval

Mean higher high water (MHHW)—average height of all daily higher high waters recorder over 19 year period, or computed equivalent period

Median—(arithmetic) the middle number in a set of data when it is calculated from lowest to highest; it is an indicator of central location in a dataset

Medusa—free-swimming, sexually mature form of coelenterates; umbrella- or bell-shaped; swims by pulsations of its body; tentacles and sense organs are located at edge of bell

Melon—a fatty cushion forming a bulbous “forehead” in toothed whales; may act to focus sound for echolocation

Mesopelagic—ocean zone of intermediate depths from about 200 to 2,000 m below the surface, where light penetration drops rapidly and ceases

Mesoplodon—a genus of beaked whales, which includes the Blainville’s beaked whale, Ginkgo-toothed beaked whale, Hubbs’ beaked whale, Perrin’s beaked whale, and pygmy beaked whale

Metabolism—all biochemical reactions that take place in an organism

Metadata—information about geospatial data (such as GIS shapefile or coverage file) that describes the source of the data or information, the creation date, the data format, the projection, the scale, the accuracy, and the reliability of the GIS file with regard to some standard

Metazoan—an organism composed of many cells

Microhabitat—a smaller part of a habitat that has some internal interactions allowing it to function self-sufficiently within a generally larger habitat

Microphytic—microscopic plant life (e.g., cyanobacteria, phytoplankton, and picoplankton)

Microplankton—small planktonic organisms, 20 to 200 µm in diameter

Microzooplankton—single cell animals that drift with or are carried with the motion of the currents

Migration—periodic movement between one habitat and one or more other habitats involving either the entire or significant component of an animal population; this adaptation allows an animal to monopolize areas where favorable environmental conditions exist for feeding, breeding, and/or other phases of the animals' life history

Mollusk—largely aquatic phylum of bilaterally symmetrical, unsegmented invertebrates consisting of snails, squids, octopuses, clams, and others

Molt—for pinnipeds, this refers to shedding the fur; belugas are the only cetacean known to do this–the top layer of skin is shed all at one time of the year versus other cetaceans which continuously are sloughing skin

Morids—of or belonging to the family Moridae, which includes the codlings and deepsea codfishes

Morphology—the form and structure of an organism considered as a whole; appearance

Mudflat—relatively flat, muddy regions found in intertidal areas that are submerged by the rise of the tide

Myctophids—family (Myctophidae) of small oceanic fishes which live between 2,000 to 4,000 m; characteristically have numerous small photophores on side of the body; contribute to sound-scattering layers in the ocean

Mysids—small shrimp-like crustaceans

Mysticeti—suborder of cetaceans comprised of the baleen whales

Nasal septum—the wall of flexible cartilage dividing the nasal cavity into halves

Nautical mile (NM)—a distance unit used in the marine environment that is equal to one minute of latitude or 1.85 km

Nautilus—small cephalopod mollusk that is common fossil; found in Pacific and Indian Oceans, pearly or chambered; has many small arms and lives in outermost chamber of beautiful spiral, chamber shell

Near Threatened species (IUCN Red List)—a species that does not qualify for Critically Endangered, Endangered, or Vulnerable status, but is close to qualifying for or is likely to qualify for one of those categories in the near future

Nearshore—an indefinite zone that extends seaward from the shoreline

Nektonic—pertaining to marine swimming animals

Neonate—a newborn

Neritic—pertaining to that part of the continental self between low tide and depths of about 183 m including both bottom and water

Neritic zone—the shallow portion of pelagic ocean waters; ocean waters that lie over the continental shelf, usually no deeper than 200 m

Nocturnal—applied to events that occur during nighttime hours

North Pacific—the part of the Pacific Ocean found north of the Equator

Not expected occurrence—an area within the operating area where a species is not expected to be encountered

Nudibranch—member of the mollusk Class Gastropoda that has no protective covering as an adult; carries on respiration by gills or other projections on the dorsal surface (sea slug)

Nursery habitat—an environment crucial for the development of early-stage animals; for some sea turtles, this environment is often an open-ocean area characterized by the presence of *Sargassum* rafts and/or ocean current convergence fronts

Occurrence record—a marine mammal or sea turtle sighting (aerial or shipboard survey), stranding, incidental fisheries bycatch, nesting, haulout, or tagging data record for which location information is available. An occurrence record, especially sighting occurrence records, may represent the occurrence of one or multiple animals of a particular species; for instance, one occurrence record from a marine mammal sighting survey may indicate that 34 short-finned pilot whales were observed at a location

Oceania—the group of islands in the south Pacific including Melanesia, Micronesia, and Polynesia

Oceanic zone—the deepwater portion of pelagic ocean waters; ocean waters beyond the continental shelf or that are deeper than the depth of water overlying the continental shelf break (typically 100 to 200 m deep)

Oceanography—the scientific study of the oceans, including the chemistry, biology, geology, and physics of the ocean environment

Octave band—the frequency band whose upper limit in Hz is twice the lower limit

Octocorals—erect, non-crusting group of soft corals whose polyps are always formed into colonies; each polyp having eight pinnate (side-branching) tentacles

Odontoceti—the suborder of cetaceans comprised of toothed whales (e.g., beaked whales, dolphins, porpoises, sperm whale)

Offshore—open, ocean waters over the continental slope and beyond that are deeper than 200 m; water seaward of the continental shelf break

Olfaction—the sense of smell or the process of smelling

Oligotrophic—refers to a body of water which is poor in dissolved nutrients and usually rich in dissolved oxygen, resulting in low primary production

Omnivore—an animal that feeds on both plant and animal tissue

Oophagy—first young to hatch in each of the two oviducts proceed to eat the other embryos in the oviduct with them

Ophuiroid—brittle stars and basket stars, the ophiuroids generally have five long slender, whip-like arms which may reach up to 60 centimeters (2 feet) in length on the largest specimens

Opportunistic—used to describe organisms that take advantage of all feeding opportunities and do not prey on a few specific items

Opportunists—having the ability to exploit newly available habitats or resources

Optimum sustainable population—with respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element

Osagame—Japanese for leatherback turtle

Otariids—the eared seals (sea lions and fur seals), which use their foreflippers for propulsion; from the Family Otariidae

Outer reef slope—portion of the seaward reef that slopes into deep water

Overfishing/Overfished—fishing at a rate or level that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield on a continuing basis

Overwinter—staying the winter in one area

Overwintering—to remain alive through the winter

Ovoviviparous—giving birth to live young which have developed from eggs that hatched within the mother's body

Pacific Decadal Oscillation (PDO)—long-lived El Niño-like pattern of Pacific climate variability marked by widespread variations in Pacific Basin and North American climate

Pacific Ocean—a major ocean area contained in a basin extending approximately from 70° west longitude (Cape Horn) to 147° east longitude. The separation of the Pacific Ocean from the Atlantic Ocean is a line marking the shortest distance between Cape Horn and the South Shetland Islands. The Pacific and Indian Oceans are separated by a line running through the Malay Peninsula, Sumatra, Java, Timor, Cape Londonderry (Australia), Tasmania, and the 147° east longitude to Antarctica

Pack ice—sea ice, especially that which is unattached to land and usually moving and shift to same extent

Parturition—act of giving birth

Passive margin—the margin of a continent that is not significantly deformed by tectonic processes because it is the trailing edge of a continent. It does not directly collide with other tectonic plates. The Atlantic coast of North America is an example

Patch reef—a coral boulder or a clump of corals unattached to a major reef structure

Pectoral fin—flipper; flattened fore-limb of a cetacean (supported by bone); for fishes, this fin is part of pair, which is supported by the pectoral girdle and usually located just behind the gill opening

Pelagic—open ocean; the primary division or zone in the open ocean that encompasses the entire water column and is subdivided into the neritic (shallow) and oceanic (deep) zones

Phaeophyte—brown algae

Phocids—all of the "true" seals (i.e., "earless" species); from the Family Phocidae. Generally used to refer to all recent pinnipeds that are more closely related to Phoca than to otariids or the walrus

Photic zone—the uppermost zone in the water where sunlight permits photosynthesis

Photo-identification—the use of photographs to identify animals individually; for example, dorsal fin shape and markings for dolphins and the underside of flukes for humpback whales

Photosynthesis—the autotrophic process in which solar energy is converted into organic matter (cellular energy) by synthesizing water and carbon dioxide with chlorophyll; plants, algae, and phytoplankton synthesize organic compounds via this process

Physiography—physical geography of the ocean bottom and continental margins

Phytoplankton—microscopic, photosynthetic plants and plant-like protists (algae) of the epi-pelagic and neritic zones that are the base of offshore food webs on which ultimately most shellfish, fish, birds, and marine mammals depend; drift with currents, but usually have some ability to control their level in the water column

Picoplankton—small plankton within the size ranging 0.2 to 2.0 µm in size; composed primarily of bacteria

Pinnacles—sharp pyramidal or cone-shaped rock partly or completely covered by water

Pinnipeds—seals, sea lions, fur seals, and walruses

Piscivorous—a carnivorous animal that eats flesh

Planktivore—an animal that eats phytoplankton and/or zooplankton

Plankton—organisms that drift in the water column or on the water's surface, with no means of propelling or moving themselves

Planktonic—free-floating

Poaching—stealing

Polar—in latitudes near one of the poles (North or South), typified by cold and ice-infested waters

Polychaete—class of soft-bodied, metamerically segmented coelomate worms; marine; may be free-swimming, errant, burrowing or tube dwelling

Polygon—area represented by a two-dimensional feature

Population—a group of individuals of the same species occupying the same area

Porifera—phylum of simple multicellular animals, called sponges; enclosed in a single central cavity or penetrated by numerous interconnected cavities; filter feeder, sessile; may be marine or freshwater

Posterior—situated near or toward the back of an animal's body

Practical salinity unit (psu)—the currently used dimensionless unit for salinity, replacing parts per thousand (ppt)

Predation—an interspecific interaction where one animal species (predator) feeds on another animal or pant species (prey) while the prey is alive or after killing it. The relationship tends to be positive (increasing) for the predator population and negative (decreasing) for the prey population

Prefecture—a self-governing body

Prey—animal hunted or caught for food

Primary producer—an autotroph or organism able to utilize inorganic sources of carbon and nitrogen as starting materials for biosynthesis; uses either solar or chemical energy

Primary production—organic matter synthesized by organisms from inorganic substances

Proboscis—a flexible, elongated snout of certain animals

Pup—a young animal of various species, especially young pinnipeds

Pupping—the process of giving birth by pinnipeds

Purse seine—a large commercial fishing net pulled by two boats, with ends that are pulled together around a shoal of fish so that the net forms a pouch or "purse"

Pyrosome—blue-green bioluminescent, pelagic, tunicates that form thimbled-shaped colonies of the Genus *Pyrosoma*

Range—the maximum extent of geographic area used by a species

Rare—in the case of marine mammals and sea turtles, a species that occurs in an area sporadically

Recreational fishing—fishing primarily for sport or pleasure

Red algae—division of algae (Rhodophyta) consisting of large multicellular, structurally complex photosynthetic organisms that grow attached to rocks or other substrates; largely marine; some forms instrumental in formation of coral reefs by precipitating calcium carbonate; form large rocky masses

Reef drop-off—outer reef slopes that are nearly vertical to slightly undercut

Reef flat—shallow (semi-exposed) area between the shoreline intertidal zone and the reef crest of a fringing reef. This zone is protected from the high-energy waves commonly experienced on the shelf and reef crest

Reef front—the fore reef area including the buttress reef, the reef terrace, reef escarpment, and reef slope

Reef passes—channels that connect the lagoon to the outer reef slope

Reef slope—zone of the fore reef occurring below the reef escarpment which is the steeply-sloped transition between the fore reef terrace and the fore reef slope. The fore reef slope is steeply sloped and occurs in water depths of 55 m to 60 m

Reef top—area comprising the reef flat and reef crest

Regular—in the case of marine mammals and sea turtles, a species that occurs as a regular or normal part of the fauna of the area, regardless of how abundant or common it is

Relief—the inequalities (elevations and depressions) of the sea bottom

Remigration interval—the amount of time between successive sea turtle nesting seasons

Rhodophyte—red algae

Robust—powerfully built

Rookery—an animal's breeding ground; it is the specific beach on which they nest (sea turtle) or pup (pinniped)

Rorqual—any of six species of baleen whales (the minke, blue, humpback, fin, Bryde's, or sei whale) belonging to the Family Balaenopteridae; characterized by a variable number of pleats that run longitudinally from the chin to near the umbilicus; the pleats expand during feeding to increase the capacity of the mouth

Rostrum—the snout or beak of a cetacean; in fish, a forward projection of the snout

Rugosity—an important coral reef parameter that describes the amount of "wrinkling" or roughness of the reef profile. It is an index of substrate complexity. Areas of high complexity are likely to provide more cover for reef fishes and more places of attachment for algae, corals and various sessile invertebrates

Saddle—a light-colored patch behind the dorsal fin of some cetaceans

Sagittal crest—prominence on top of he cranium, causing a noticeably raised forehead on males of some otariid pinniped species

Salinity—the concentration of salt in water, measured in practical salinity units (psu)

Salp—barrel-shaped tunicate without an exoskeleton that forms asexual polymorphic colonies that are found in the upper levels of most oceans

Salt marsh—coastal ecosystem that is inundated by seawater for some period of time; plants in this ecosystem have special adaptations to survive in the presence of high salinities

Sand flat—A flat expanse of sand on the coast or in an estuary

Sargassum—a genus of brown algae commonly found in temperate and tropical waters

Scleractinian—hard or stony corals known as true corals that dominate reef ecosystems; they have a compact calcareous skeleton and polyps with no siphonoglyphs (grooves)

Scombrids—family of mackerels, tunas, and bonitos that are generally predators of the open ocean who are capable of considerable speed

Scorpaenids—of or belonging to the suborder Scorpaenoidei, which includes the scorpion fishes and rockfishes

Scutes—long, thickened scales that cover underlying bony plates of carapace and plastron of sea turtles that are used for protection

Scyphozoans—any of various marine coelenterates of the Class Scyphozoa, which includes large jellyfishes, characterized by the absence of a velum and by a polyp stage that is very small or lacking entirely

Sea anemones—large, heavy, complex polyps that belong to the cnidarian Class Anthozoa

Sea cucumbers—echinoderm having a flexible sausage-shaped body with tentacles surrounding the mouth and tube feet; free-living feeder

Sea surface temperatures (SST)—the temperature of the layer of seawater (approximately 0.5 m deep) nearest the atmosphere

Sea whips—erect colony of marine animals of the phylum Cnidaria with whip-like branches; skeleton consists of a horny axis, overlaid with small calcareous bodies called spicules

Seagrass—submerged aquatic vegetation that form extensive underwater meadows (or beds) found in shallow-water depths and various temperatures and salinity ranges

Seamount—an undersea mountain that rises steeply from the ocean floor to an altitude greater than 1,000 meters above the ocean basin

Seaweed—any macroscopic marine alga or sea grass

Secondary production—organic material produced by processing organic material other than that from primary production; consumers

Sediment—solid fragmented material, either mineral or organic, that is deposited by ice, water, or air

Sessile—used to describe an animal that is attached to something rather than free moving

Sestonophages—organisms that utilize suspended particulate matter in the water column for food (e.g., mollusks); sessile sestonophages: attached to a substratum; not free to move about (e.g., oyster); mobile sestonophages: moving or capable of moving readily (e.g., amphipods).

Set gillnets—gillnets that are anchored to the seafloor and may be fished on the ocean bottom or floating above the anchors; used to catch California halibut, sharks, white seabass, barracuda, white croaker, flying fish, and rockfish

Sexual maturity—the state in which an animal is physiologically capapble of reproducing

Sexually dimorphic—differences in the appearance of the sexes of a species; size differences are a primary difference where males are generally larger than females; other differences may be in body shape and color

Shallow water—water that is between the shore and the continental shelf break or shallower than 200 m

Shapefile—vector data storage format used to store the location, shape, and attributes of geographic features; a shapefile must be one and only one of three possible feature classes: lines, points, and polygons

Shelf break—region where the slope of the seabed rapidly changes from gently sloping to steeply sloping and the continental shelf gives way to the continental slope; the world-wide average water depth at which the shelf break is found is 155 m, but on average, the shelf break usually occurs between 100 to 200 m water depth

Shelf break (continental)—region where the slope of the seabed rapidly changes from gently sloping to steeply sloping and the continental shelf gives way to the continental slope; the world-wide average water depth at which the shelf break is found is 155 m, but on average, the shelf break usually occurs between 100 to 200 m water depth

Shelf break region—the geographic area surrounding the continental shelf break and including both the outer continental shelf and upper continental slope

Sirenia—the order of marine mammals that consists of manatees and the dugong

Site fidelity—the tendency to return to the same site repeatedly

Softbottom—as substrate comprised of soft sedimentary material such as sand, silt, or mud

Soft corals—class of corals (Anthozoa) characterized by having retractable polyps with eight, branching tentacles (i.e., sea anemones); usually attached to rocks

Source level—the acoustic pressure that would be measured at a standard distance (usually 1 m) from a point source radiating the same amount of sound as the actual source

South Pacific—the part of the Pacific Ocean found south of the Equator

Species diversity—the number of different species in a given area

Species of concern—species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act

Species—a population or series of populations of organisms that can interbreed freely with each other but not with members of the other species

Sponges—any of numerous primitive, chiefly marine animals of the Phylum Porifera, characteristically having a porous skeleton composed of fibrous material or siliceous or calcareous spicules and often forming irregularly shaped colonies attached to an underwater surface

Standard deviation (S.D.)—a statistical measure of the amount by which a set of values differs from the arithmetical mean; simply, how widely values are dispersed from the mean

Stenella—in the Pacific, it is the genus of oceanic dolphins consisting of striped, pantropical spotted, and spinner dolphins, which are similar in appearance

Stenellid—refers to dolphins of the Genus *Stenella*

Stock structure—the genetic diversity of a stock

Stock—a genetically separate population of a species (biological stock), or a discrete population subject to management (management stock)

Stomatopods—group of predatory marine crustaceans that comprises the mantis shrimp, elongate, flattened and shrimp-like or lobster-like organisms with enlarged anterior pincers whose outer joints fold back against the basal joints in the praying mantis

Stony corals—see scleractinian

Stranding—the act where marine mammals or sea turtles accidentally come ashore, either alive or dead

Strategic stock—any marine mammal stock: (1) from which the level of direct human-caused mortality exceeds the potential biological removal level; (2) which is declining and likely to be listed as threatened under the Endangered Species Act; or (3) which is listed as threatened or endangered under the Endangered Species Act or as depleted under the Marine Mammal Protection Act

Subadult—maturing individuals that are not yet sexually mature

Subarctic—pertaining to regions adjacent to the Arctic Circle

Subduction—a process by which one tectonic plate descends beneath another. The surface expression of such a process may by an island-arc system or a folded mountain range

Sublittoral—benthic region extending from mean low waters to a depth of about 200 meters

Submarine canyon—narrow, deep depression or steep-sided valley cut in the continental shelf or slope formed by river of glacial erosion before the shelf was submerged

Submarine ridge—a ridge of submarine mountains where two massive tectonic plates are moving apart

Subnivean lair—a lair dug into the ice

Subpopulations—an identifiable fraction or subdivision of a population

Subsistence fishing—fishing primarily to obtain for personal use rather than for sale or recreation

Substrate—the material to which an organism is attached or in which it grows and lives; also, the underlying layer or substance

Subtidal—marine or estuarine environment that lies below mean low-water; always submerged in a tidally-influenced area

Subtropical—the regions lying between the tropical and temperate latitudes

Suction feeding—capture of prey using suction, generally with the tongue employed as a piston to create a vacuum pressure

Surf line—point offshore where waves and swells are affected by the underwater surface and become breakers

Surf zone—area between outermost breaker and limit of wave uprush

Suspension feeder—an animal that eats by filtering out tiny particles or organic material suspended in the water

Symbiont—the smaller participant in a symbiotic relationship; living in or on the host

Sympatric—species or subspecies occurring together; having overlapping areas of distribution

Sympatry—co-occurrence of two or more species in the same immediate habitat

Syngnathids—family of fish containing seahorses and pipefishes

Taimai—Japanese for hawksbill turtle

Talus—weathered rock which has fallen from and accumulated at the bottom of a cliff

Taxa (taxon)—a defined unit (e.g., species, genus, or family) in the classification of living organisms

Taxonomy—the study of the rules, principles, and practice of classification, especially of living organisms

Tectonic plate—an area of the earth's crust which moves during geological time resulting in continental drift and other major changes in the topography of the surface of the globe

Temperate—between subpolar and subtropical regions, where the mean annual temperature ranges between 50 and 55°F (10 to 13°C)

Temporary threshold shift (TTS)—a temporary impairment in hearing ability caused by exposure to strong sounds

Terrigenous—derived from land or a continent

Territory—an area occupied exclusively by one animal and defended by aggressive behavior or displays

Thermocline—a relatively narrow boundary layer of water where temperature decreases rapidly with depth; little water or solute exchange occurs across the thermocline which is maintained by solar heating of the upper water layers

Thermoregulatory—an organism's ability to maintain a specific body temperature regardless of the environmental temperature

Threatened species (ESA)—any plant or animal species likely to become endangered within the foreseeable future throughout all or a part of its range; the authority to designate a species as threatened is shared by the U.S. Fish and Wildlife Service (terrestrial species, sea turtles on land, manatees) and National Marine Fisheries Service (most marine species) under provisions of the Endangered Species Act

Tidal flat—a marshy or muddy land area covered and uncovered by the rise and fall of the tide

Tidepools—pool of waters remaining on beach or ref after recession of tide

Topography—physical features of the ocean floor, such as mounds or ridges

Transition Zone—an area of mixing between the cold, low-salinity, highly productive subarctic water and the warmer, more saline and less productive subtropical water

Transoceanic—on or from the other side of the ocean

Trans-Pacific—spanning or crossing the Pacific Ocean

Triads—group of three

Trophic level—a step in the transfer of food or energy within a chain

Tropical cyclone—a warm core low pressure system which develops over tropical, and sometimes subtropical, waters, and has an organized circulation. Depending on sustained surface winds, the system is classified as a tropical disturbance, a tropical depression, a tropical storm, or a hurricane or typhoon

Tropical—the geographic region found in the low latitudes (30° north of the equator to 30° south of the equator) characterized by a warm climate

Tsunami—series of waves of extremely long wave length and long period generated in a body of water by an impulsive disturbance caused by an earthquake, a submarine landslide, or a submarine volcanic eruption. Tsunamis are not caused by or related to tides and therefore "tidal wave" is a misnomer

Tunicates—any of various chordate marine animals of the subphylum Tunicata or Urochordata having a cylindrical or globular body enclosed in a tough outer covering (i.e., sea squirts and salps)

Tursiops—the genus of bottlenose dolphins comprised of the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)

Typhoon—a tropical cyclone with sustained winds of 74 miles per hour (65 knots) or greater in the western North Pacific Ocean. This same tropical cyclone is known as a hurricane in the eastern North Pacific and North Atlantic Ocean, and as a cyclone in the Indian Ocean

Upwelling—upward movement or rising of deep, usually nutrient- and oxygen-rich, water to the surface; may be caused by wind-forcing, divergent currents, or density differences

Uro-genital area—portion of ventral surface around and near the excretory and genital orifices

Vagrant—a wanderer, in the same sense of an animal moving outside the usual limits of distribution for its species or population

Ventral—relating to the underside (or belly side) of an animal

Vertebrates—animals with a backbone

Vestimentiferan—any of various marine tubeworms, including the giant tubeworms, of the phylum Vestimentifera, that lack a digestive system, depend on chemoautotrophic bacteria for nutrients, and inhabit areas close to deep sea hydrothermal vents or areas of cold water seeps on continental margins

Vulnerable species (IUCN Red List)—a species that is considered to be facing a high risk of extinction in the wild

Water column—a vertical column of seawater extending from the surface to the sea bottom

Water mass—a body of water that can be identified by a specific temperature or salinity

Weaning—the end of the lactation period; the process of changing from milk to a solid diet in juvenile mammals

West Pacific—that part of the Pacific Ocean found west of the 180° longitude line

Wetland—an area inundated by water (either freshwater or saltwater) frequently enough to support vegetation that requires saturated soil conditions for growth and reproduction; generally includes swamps, marshes, springs, seeps, or wet meadows

Whale lice—amphipod crustaceans of the Family Cyanidae; adapted for living in crevices and other secure places on the skin of cetaceans (for example, gray whales), on which whale lice largely feed

Whistle—a narrow band frequency sound produced by some toothed whales and used for communication; they typically have energy below 20 kHz

Young-of-the-year (YOY)—a juvenile fish less than 1 year old

Zonation—the occurrence of single species or groups of species in recognizable bands that might delineate a range of water depth or a range of height in the intertidal zone

Zoobenthos—animals living in or on the sea bed

Zooplankton—diverse group of non-photosynthesizing organisms that drift freely in the water or its surface; zooplankton are composed of a wide range of invertebrates, including larval forms of fish and shellfish

Zooxanthallae—diverse group of non-photosynthesizing organisms that drift freely in the water or its surface; zooplankton are composed of a wide range of invertebrates, including larval forms of fish and shellfish

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A-26	Occurrence of the striped dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.
A-27	Occurrence of the short-beaked common dolphin in the Japan and Okinawa Complexes OPAREA and vicinity.
A-28	Occurrence of the long-beaked common dolphin in the Japan and Okinawa Complexes OPAREA and vicinity.
A-29	Occurrence of the Pacific white-sided dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.
A-30	Occurrence of the northern right whale dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.
A-31	Occurrence of the Risso's dolphin in the Japan and Okinawa Complexes OPAREA and vicinity.
A-32	Occurrence of the melon-headed whale in the Japan and Okinawa Complexes OPAREA and vicinity.
A-33	Occurrence of the Fraser's dolphin in the Japan and Okinawa Complexes OPAREA and vicinity.
A-34	Occurrence of the pygmy killer whale in the Japan and Okinawa Complexes Oparea and vicinity.
A-35	Occurrence of the false killer whale in the Japan and Okinawa Complexes OPAREA and vicinity.
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A-37	Occurrence of the short finned pilot whale in the Japan and Okinawa Complexes OPAREA and vicinity.
A-38	Occurrence of the harbor porpoise in the Japan and Okinawa Complexes OPAREA and vicinity.
A-39	Occurrence of the Dall's porpoise in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.
A-40	Occurrence of the finless porpoise in the Japan and Okinawa Complexes OPAREA and vicinity.
A-41	Occurrence of the spotted seal in the Japan and Okinawa Complexes OPAREA and vicinity.
A-42	Occurrence of the northern fur seal in the Japan and Okinawa Complexes OPAREA and vicinity.

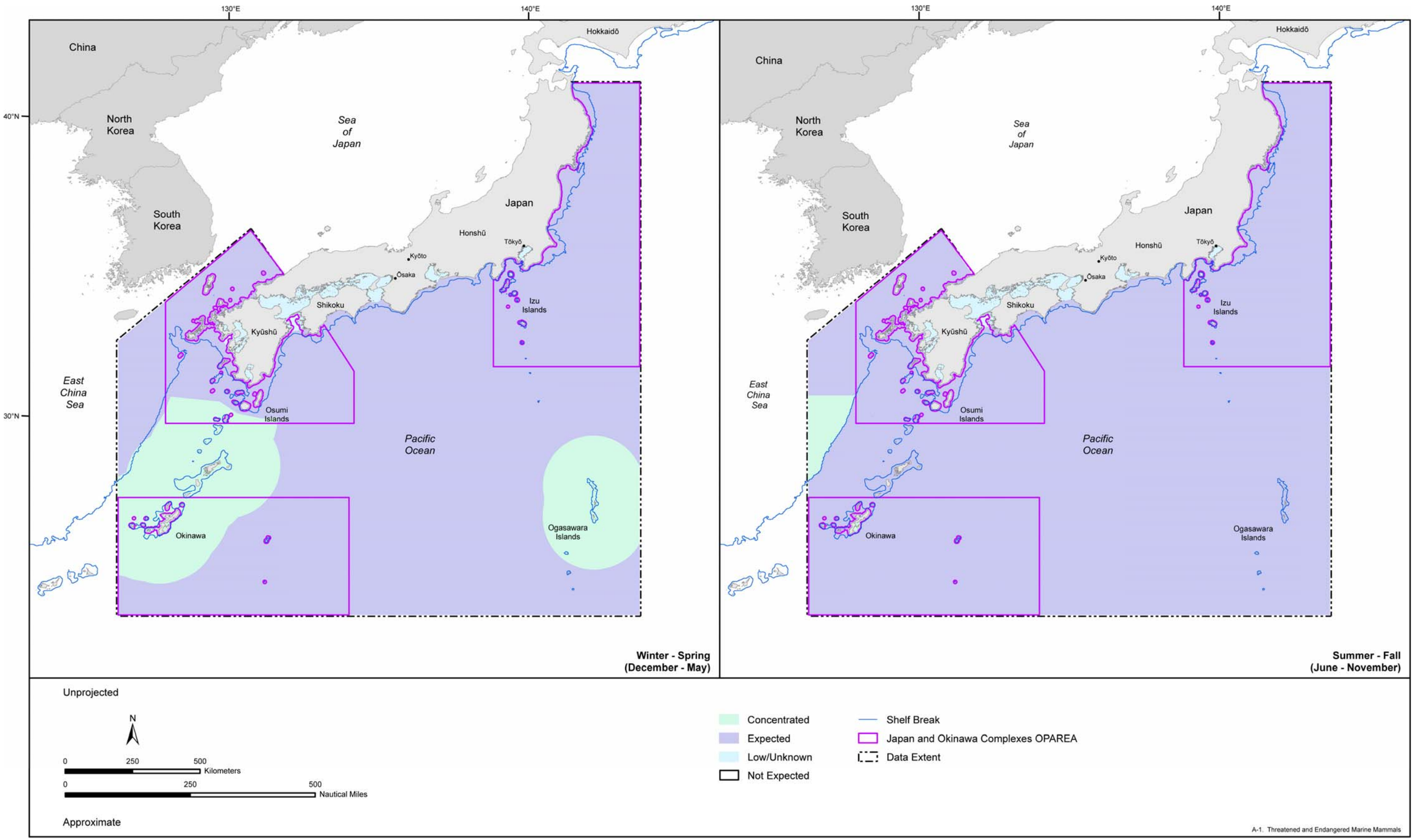

Figure A-1. Occurrence of threatened and endangered marine mammals in the Japan and Okinawa Complexes OPAREA during winter/spring and summer/fall.

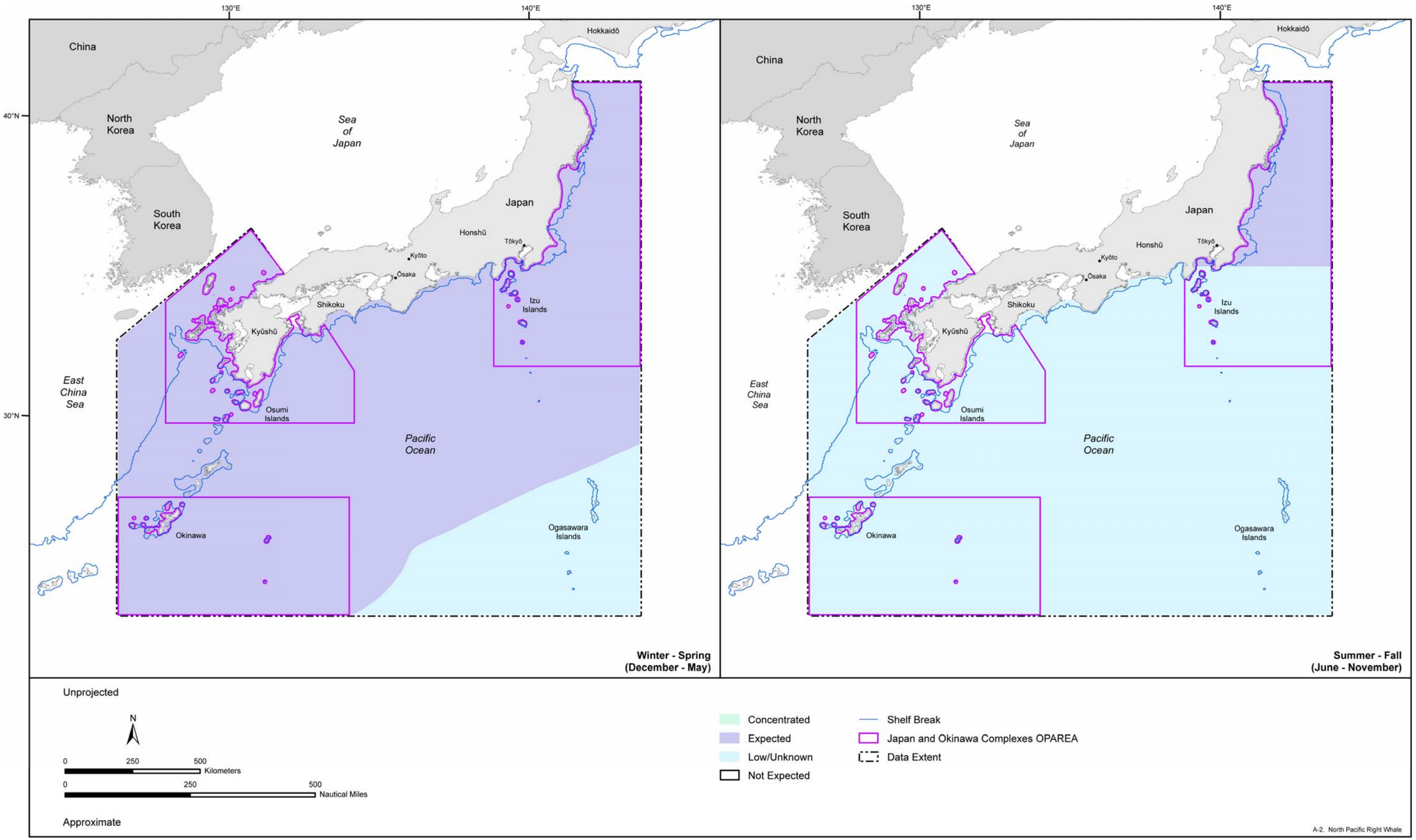

Figure A-2. Occurrence of the North Pacific right whale in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

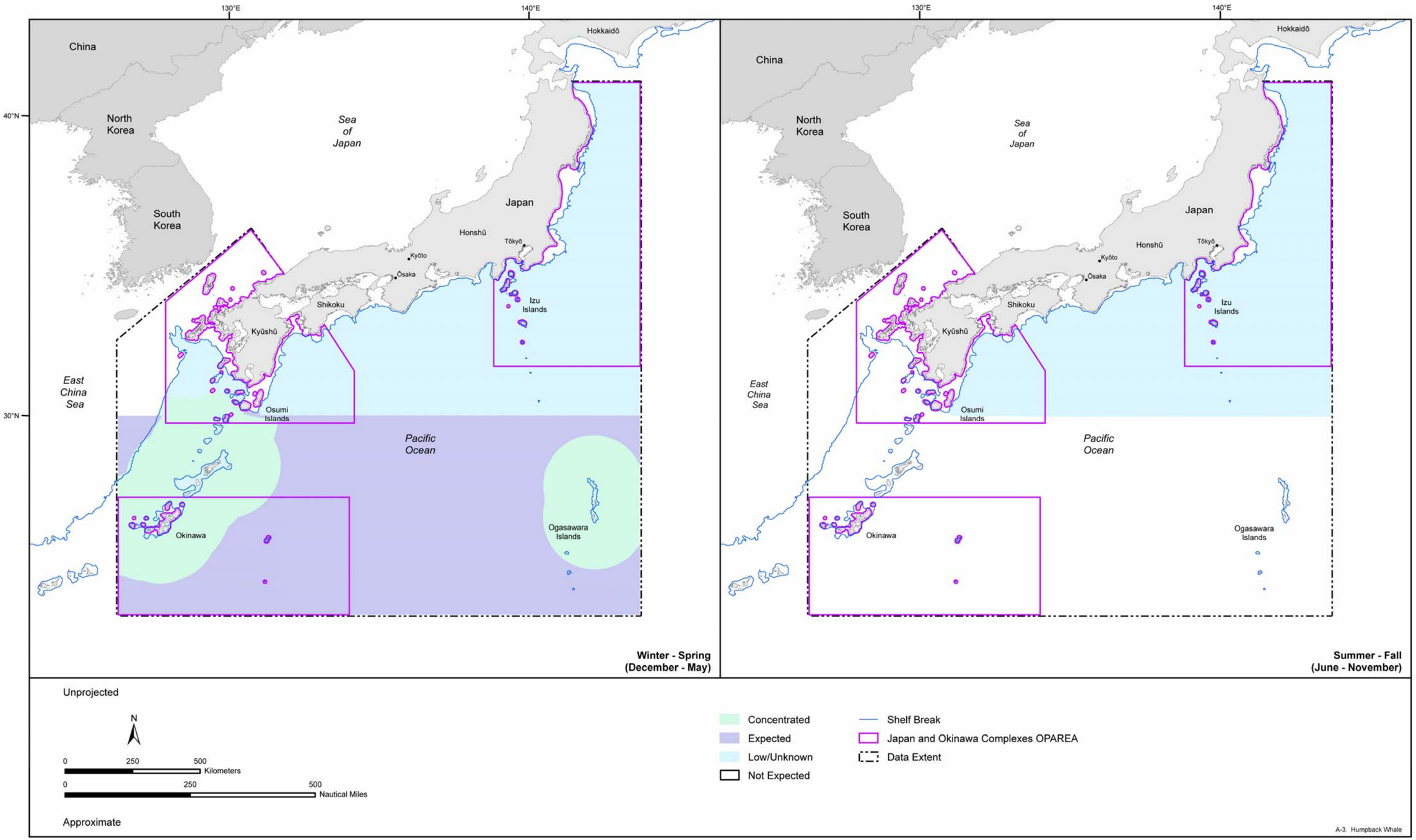

Figure A-3. Occurrence of the humpback whale in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

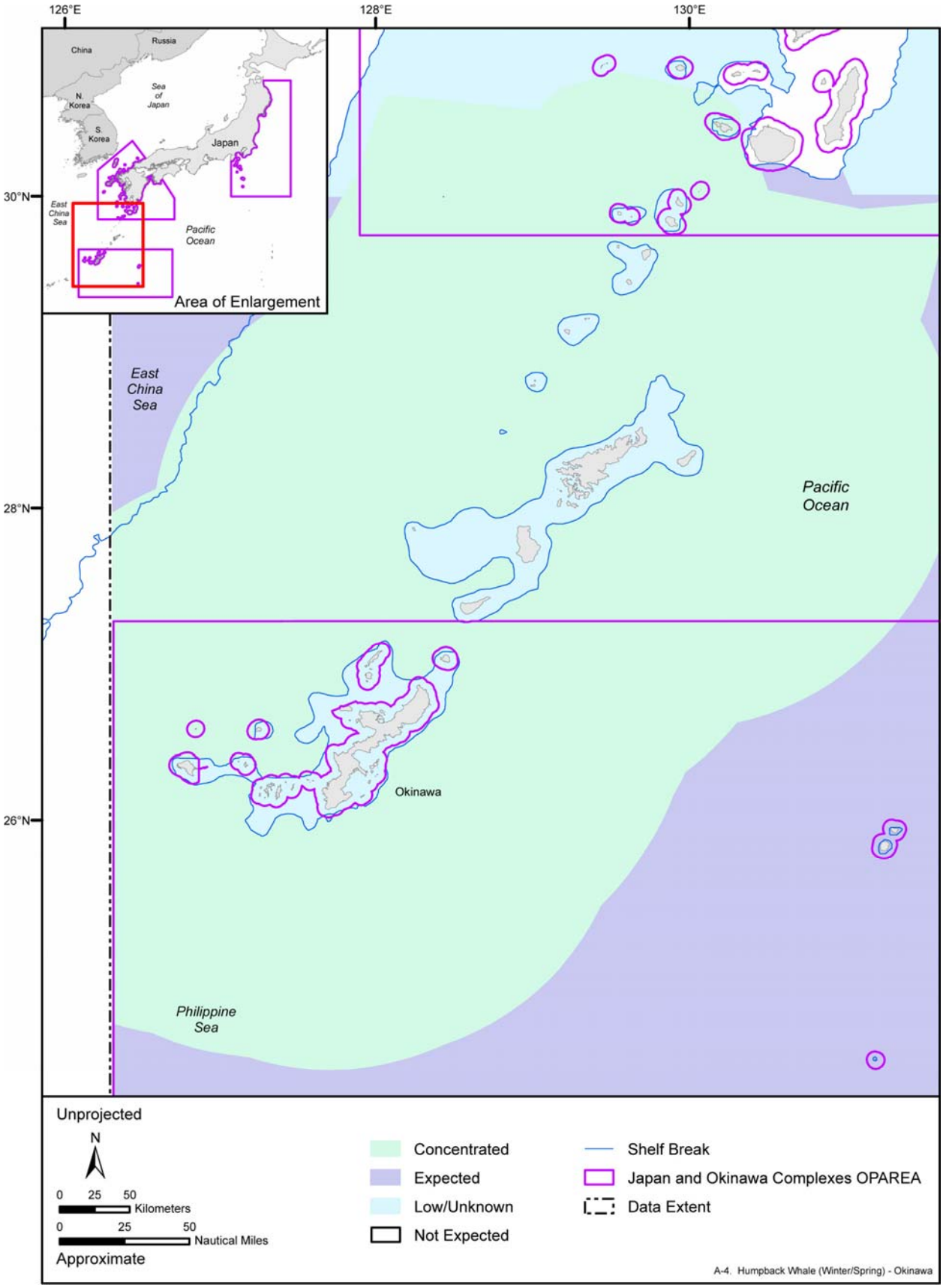

Figure A-4. Occurrence of the humpback whale in the Okinawa study area and vicinity during winter/spring.

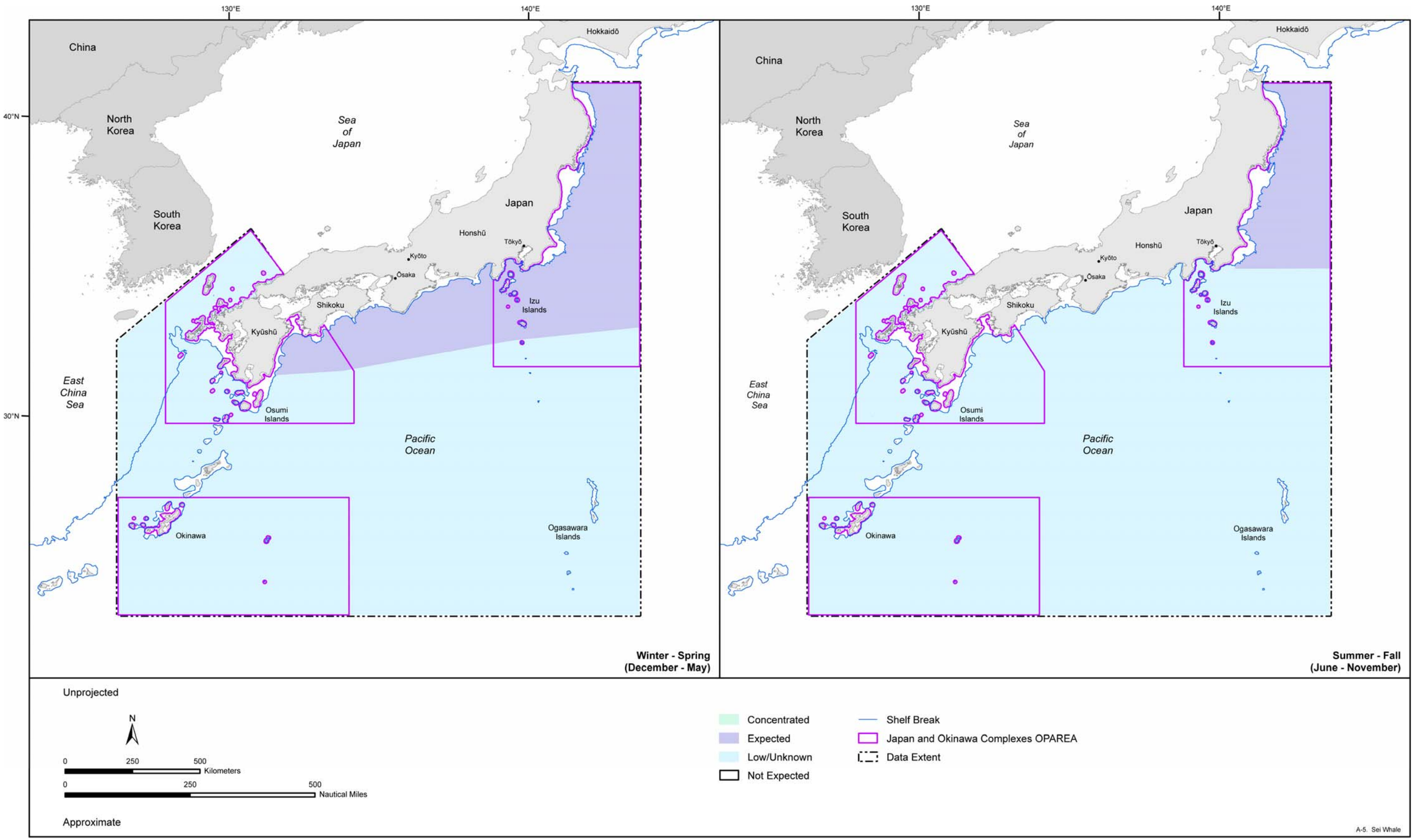

Figure A-5. Occurrence of the sei whale in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

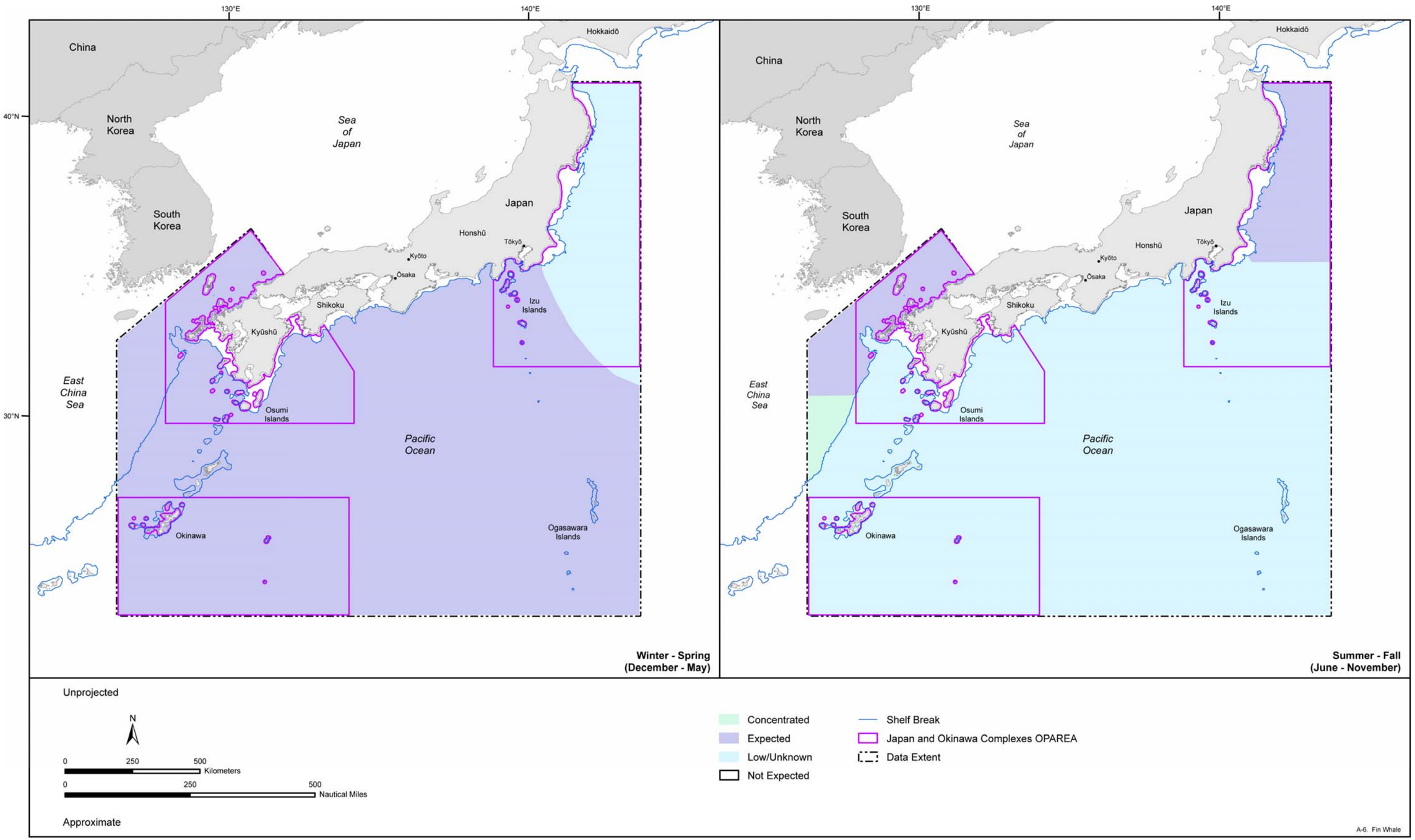

Figure A-6. Occurrence of the fin whale in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

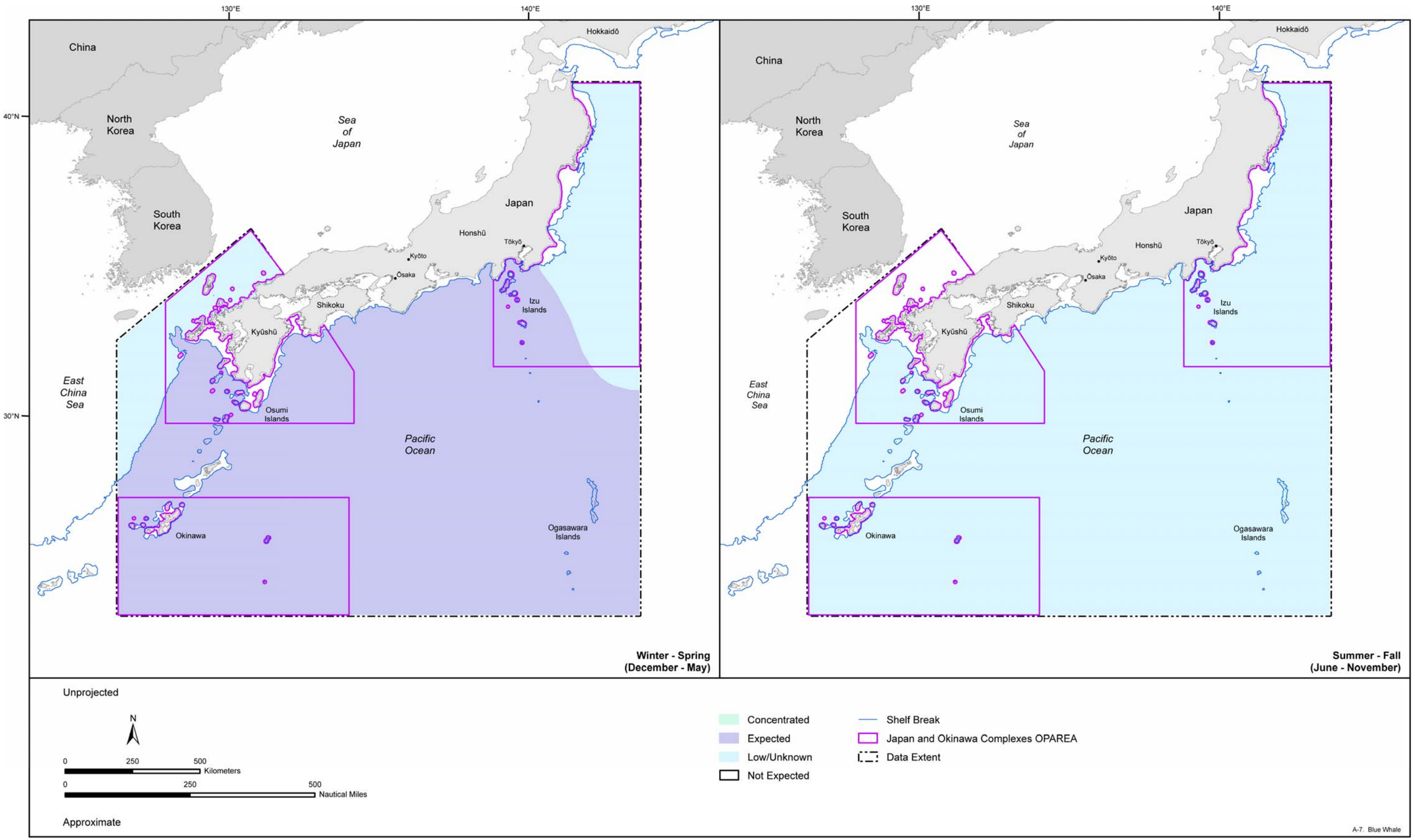

Figure A-7. Occurrence of the blue whale in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

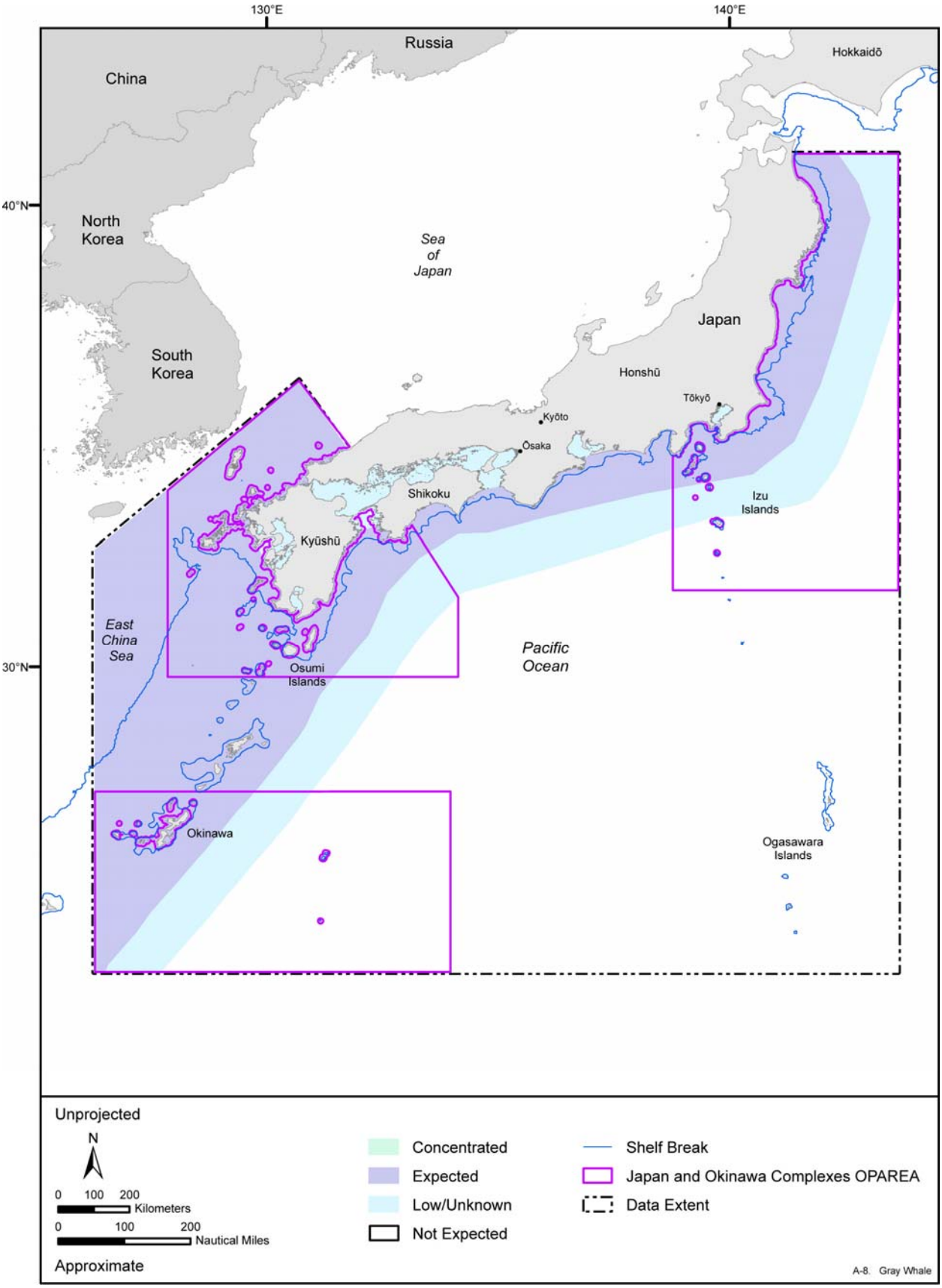

Figure A-8. Occurrence of the gray whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

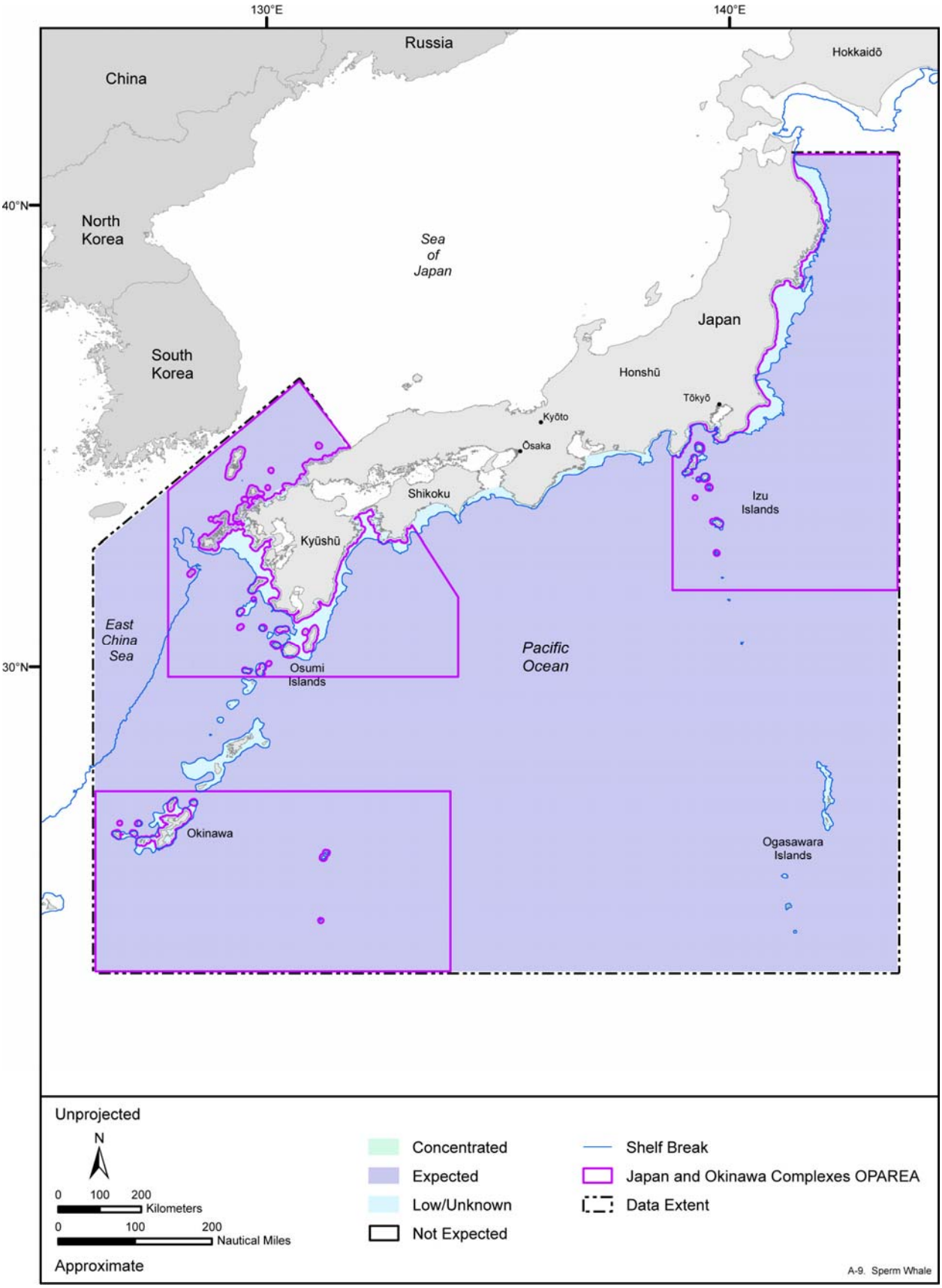

Figure A-9. Occurrence of the sperm whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

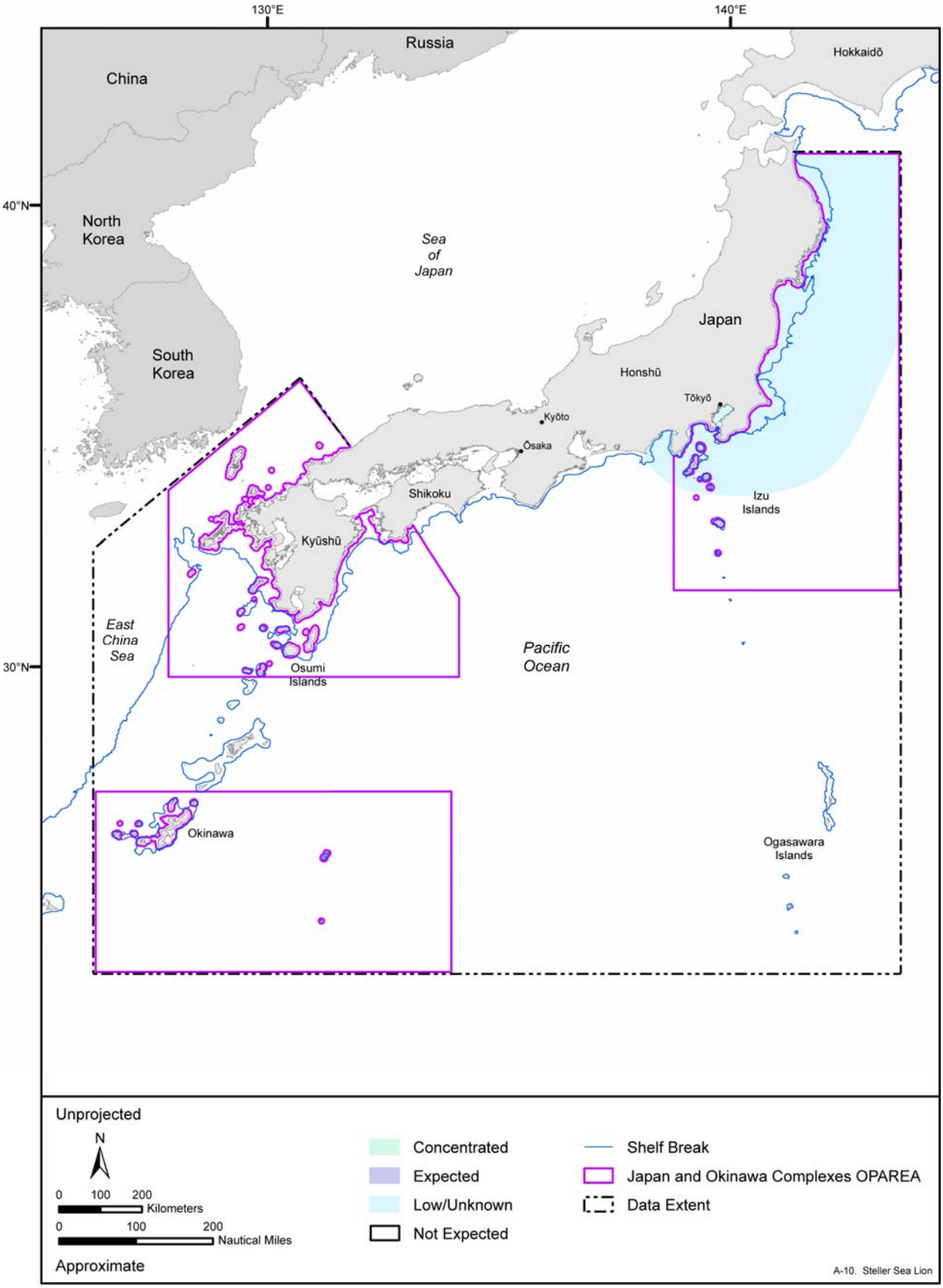

Figure A-10. Occurrence of the Steller sea lion in Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

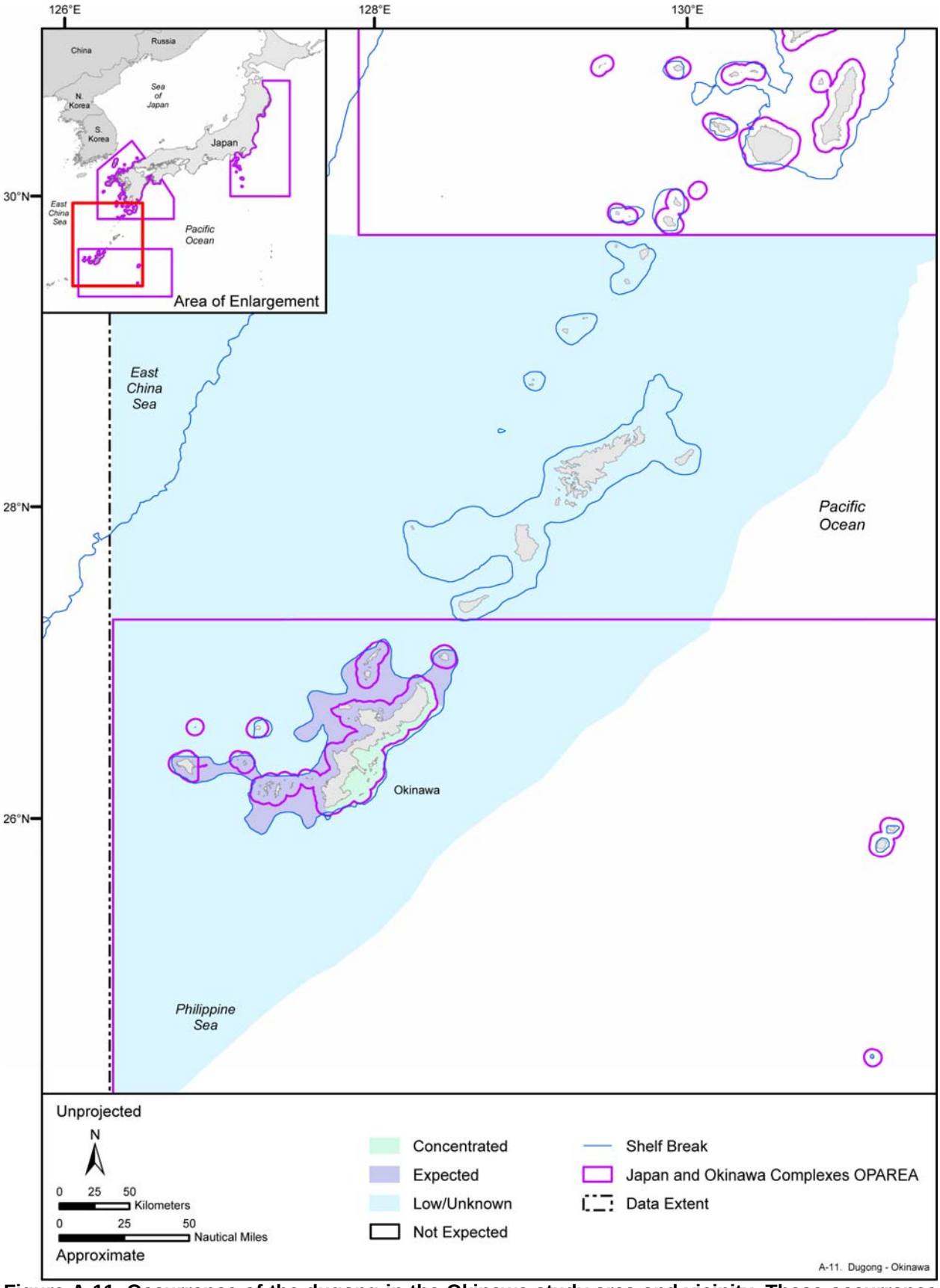

Figure A-11. Occurrence of the dugong in the Okinawa study area and vicinity. These occurrence patterns are applicable throughout the year.

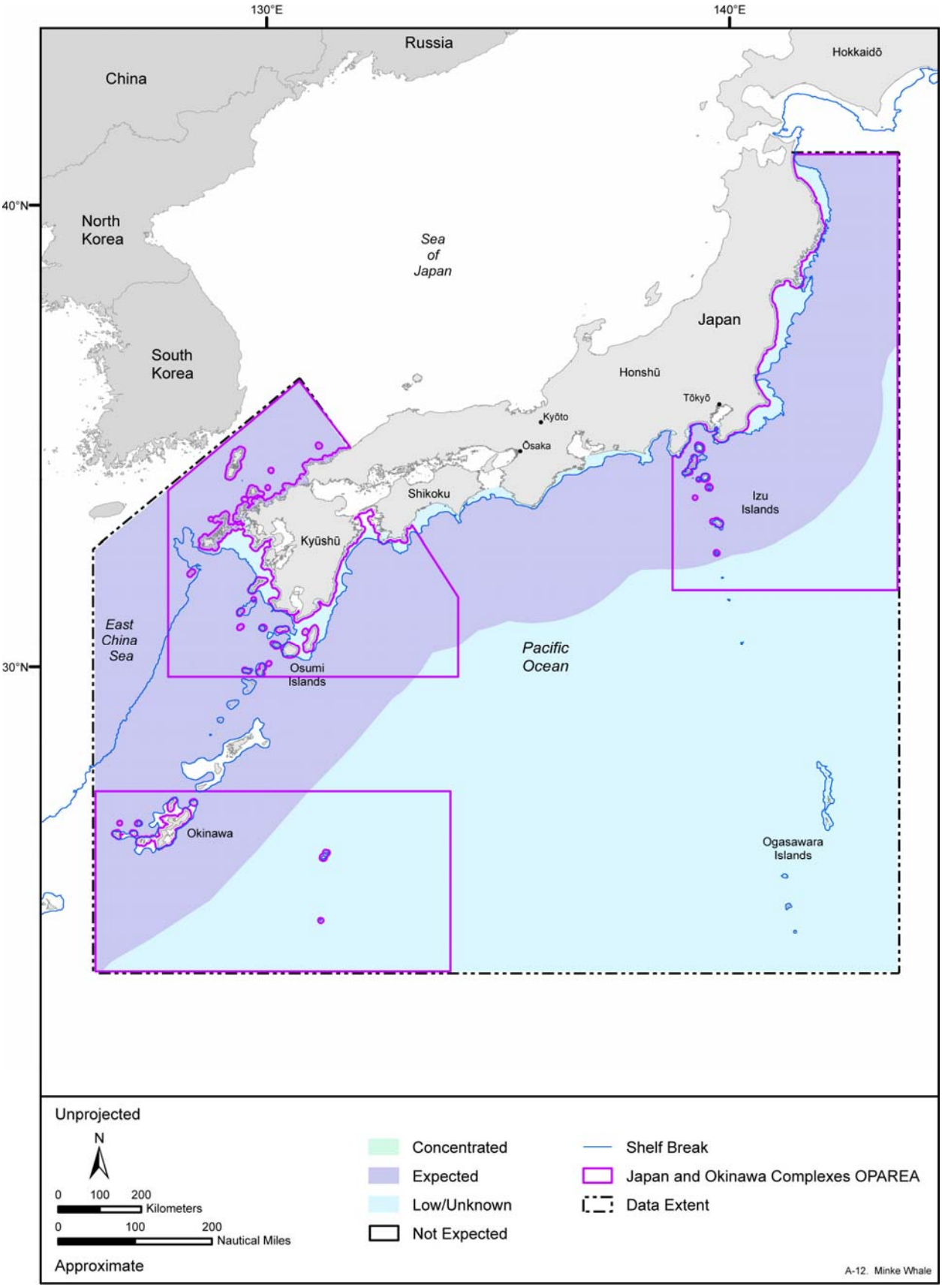

Figure A-12. Occurrence of the minke whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

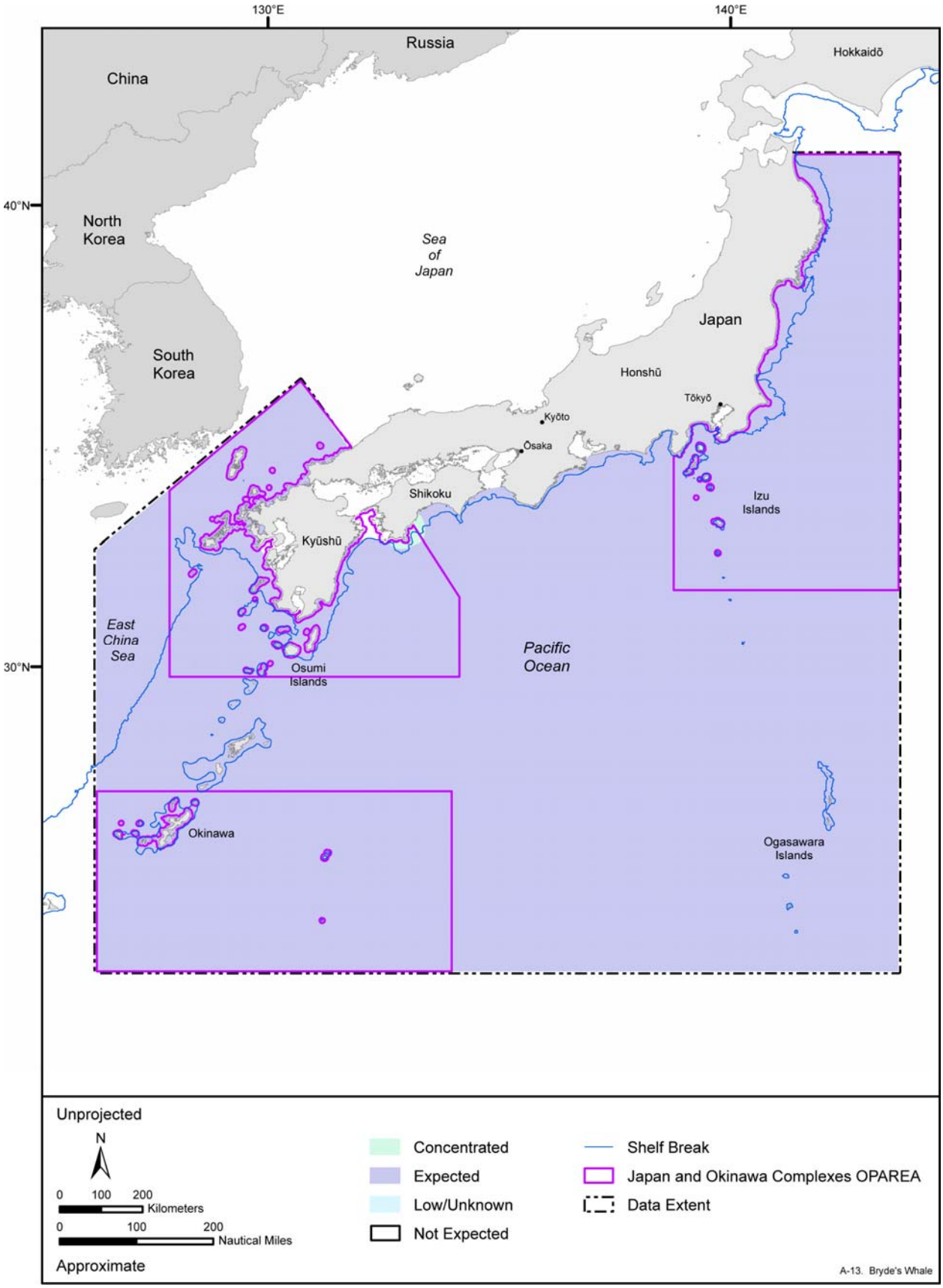

Figure A-13. Occurrence of the Bryde's whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

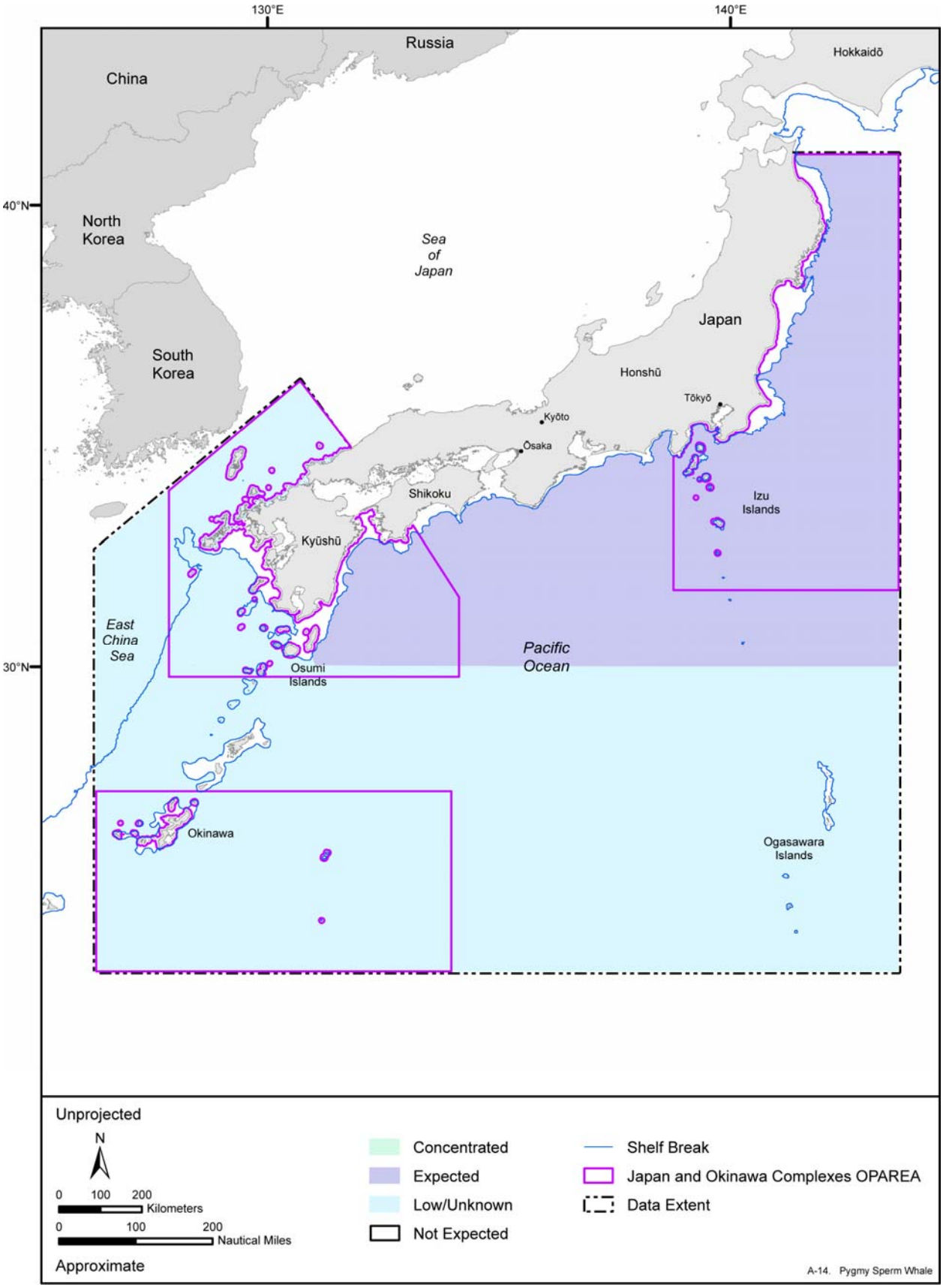

Figure A-14. Occurrence of the pygmy sperm whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

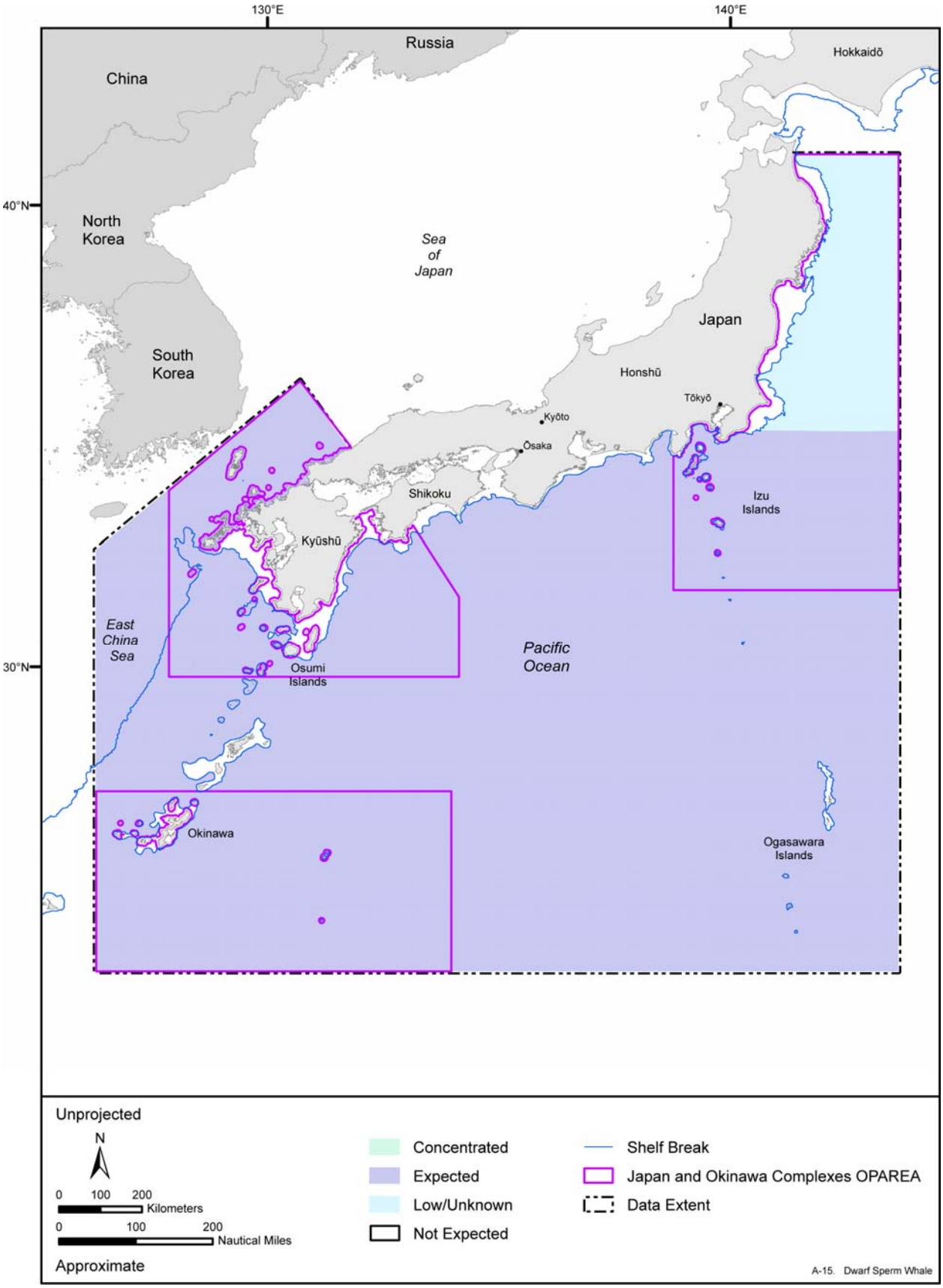

Figure A-15. Occurrence of the dwarf sperm whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

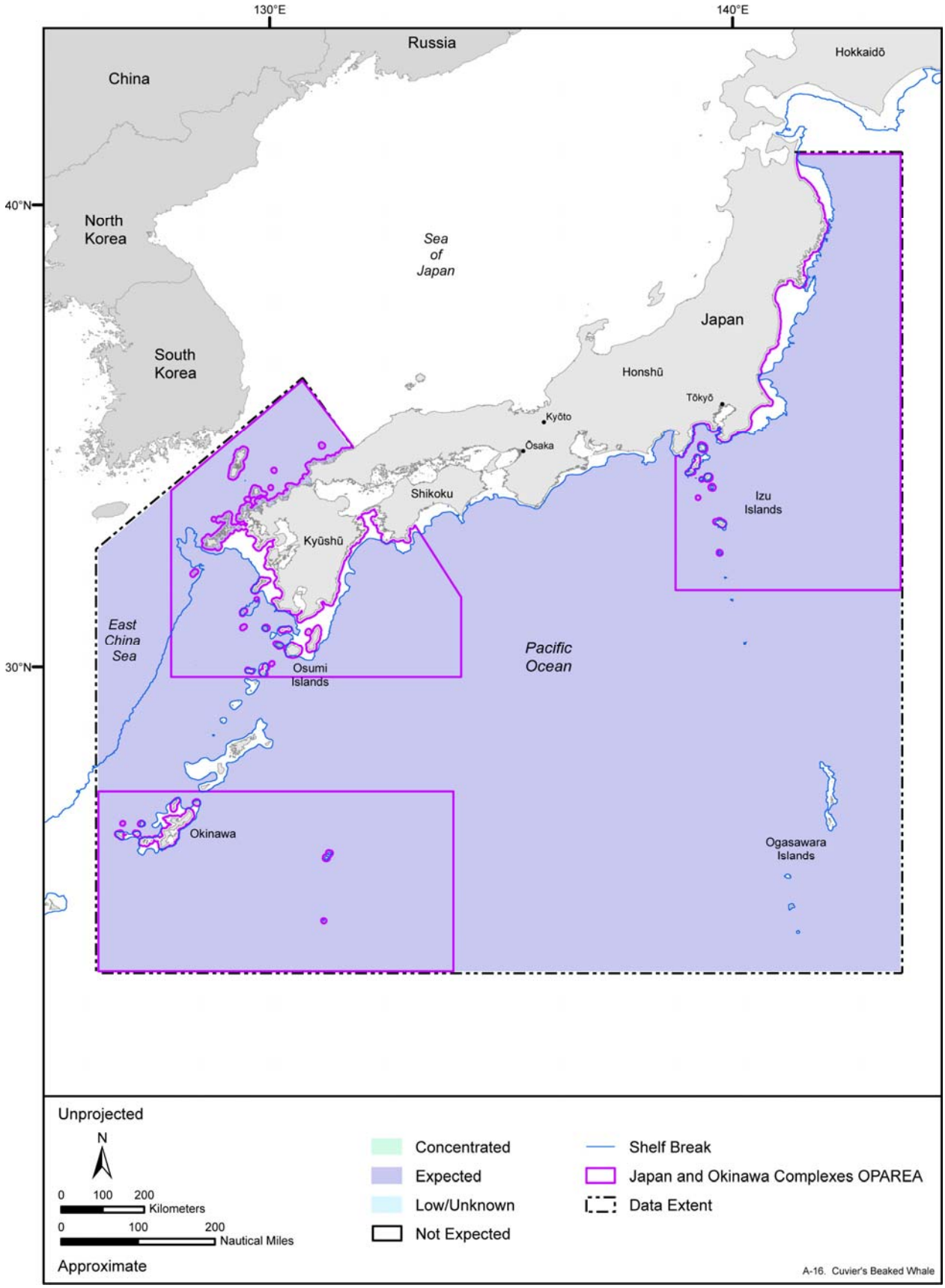

Figure A-16. Occurrence of the Cuvier's beaked whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

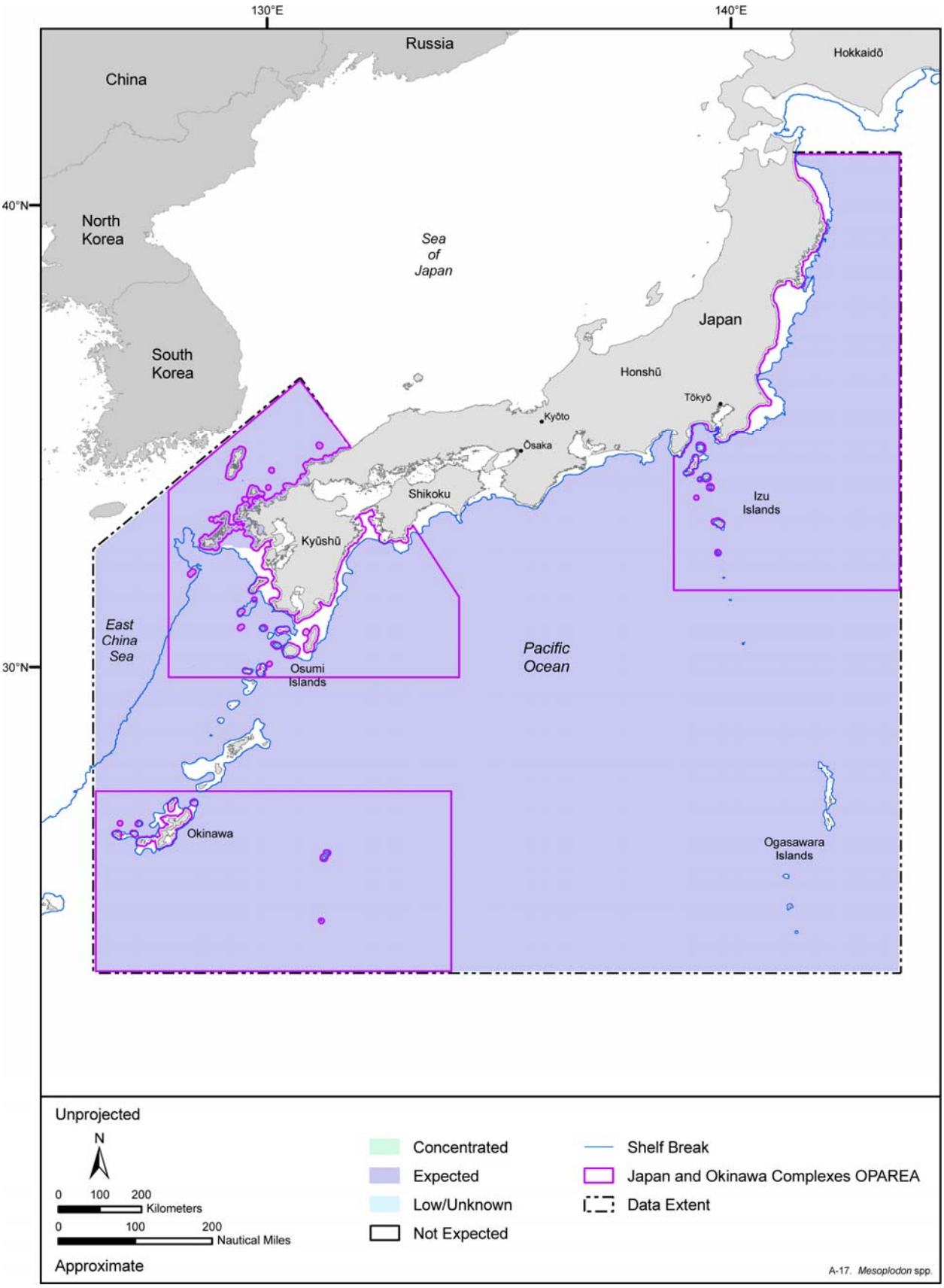

Figure A-17. Occurrence of the *Mesoplodon* spp. in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

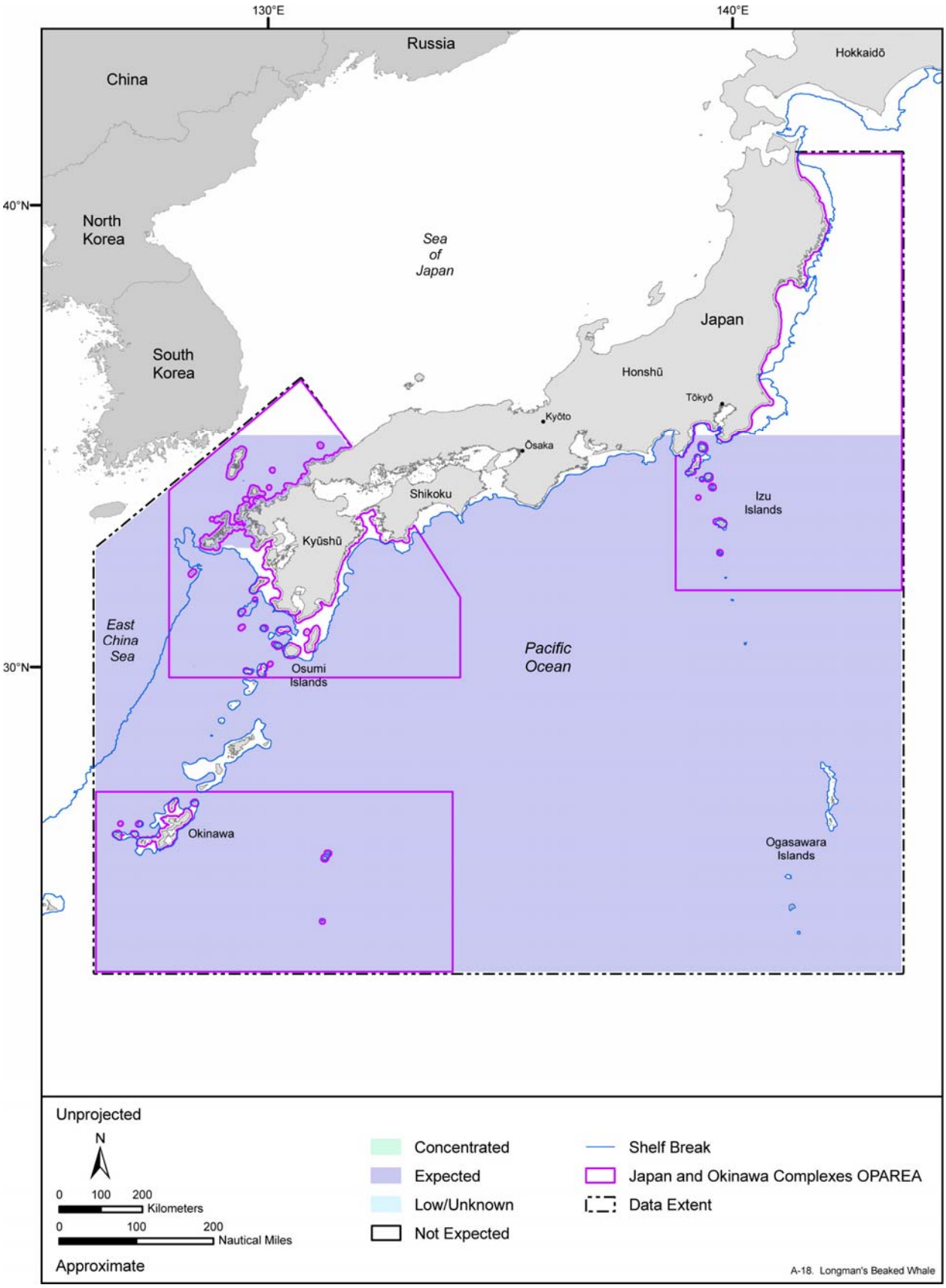

Figure A-18. Occurrence of the Longman's beaked whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

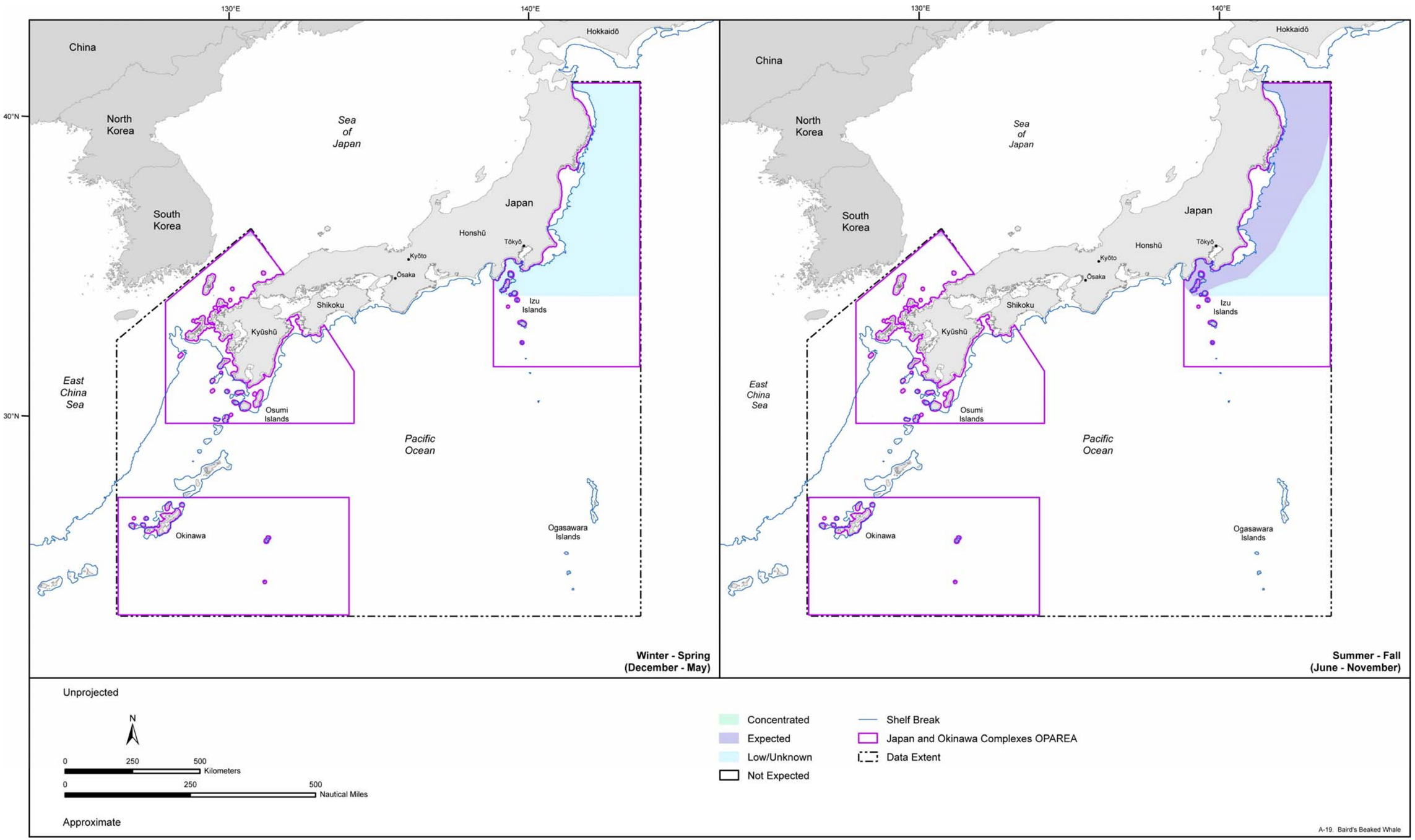

Figure A-19. Occurrence of the Baird's beaked whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

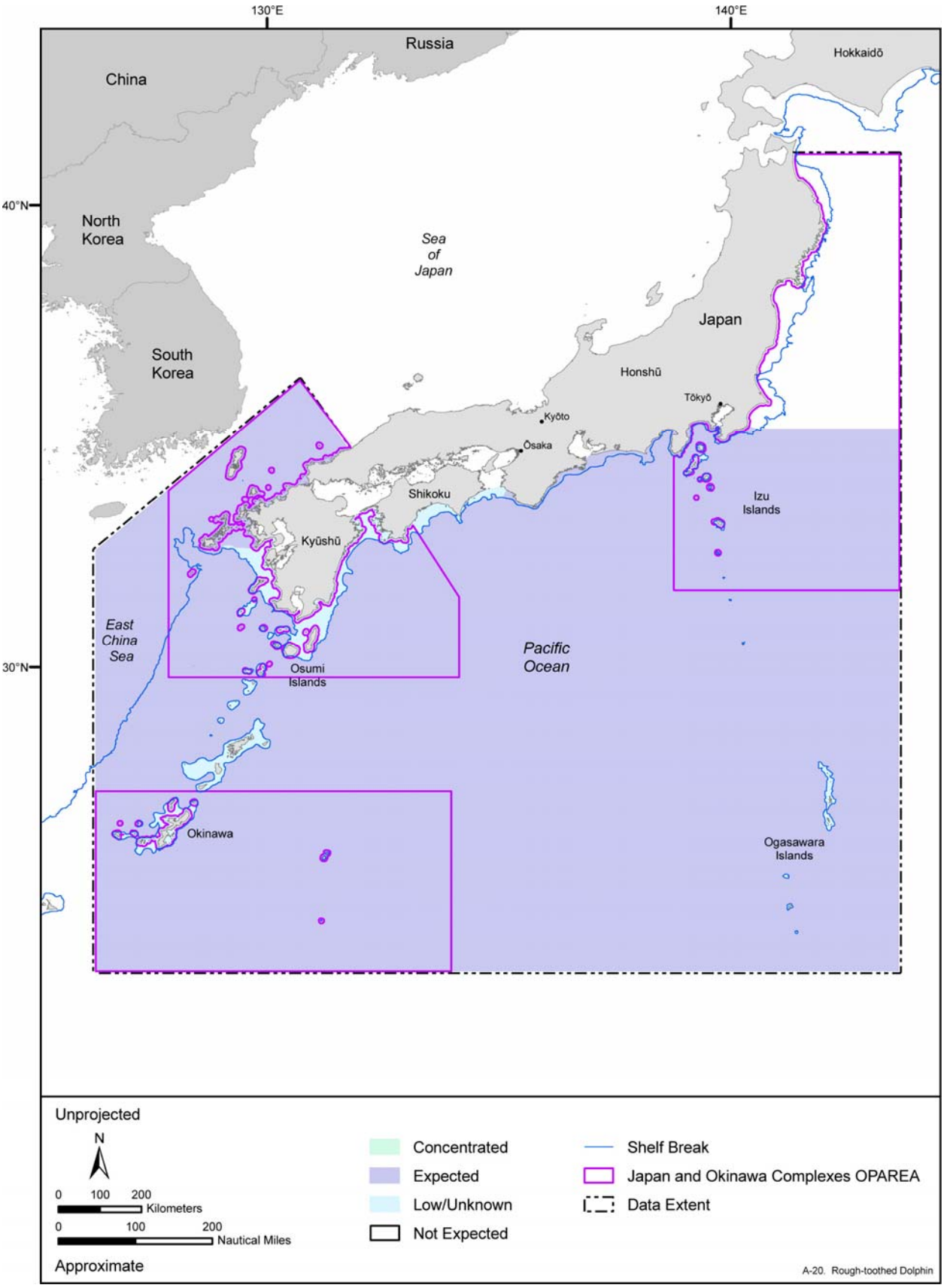

Figure A-20. Occurrence of the rough-toothed dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

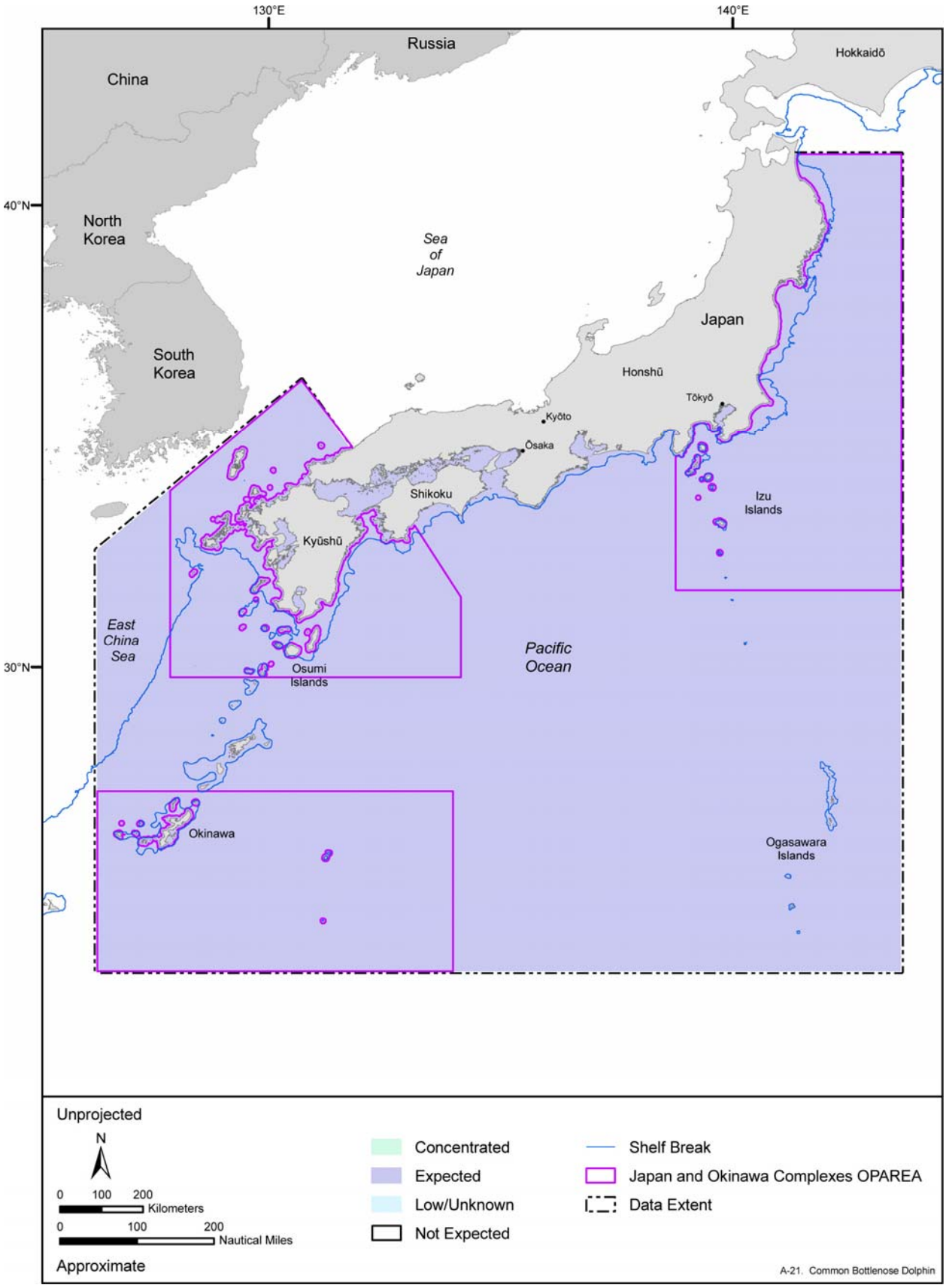

Figure A-21. Occurrence of the common bottlenose dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

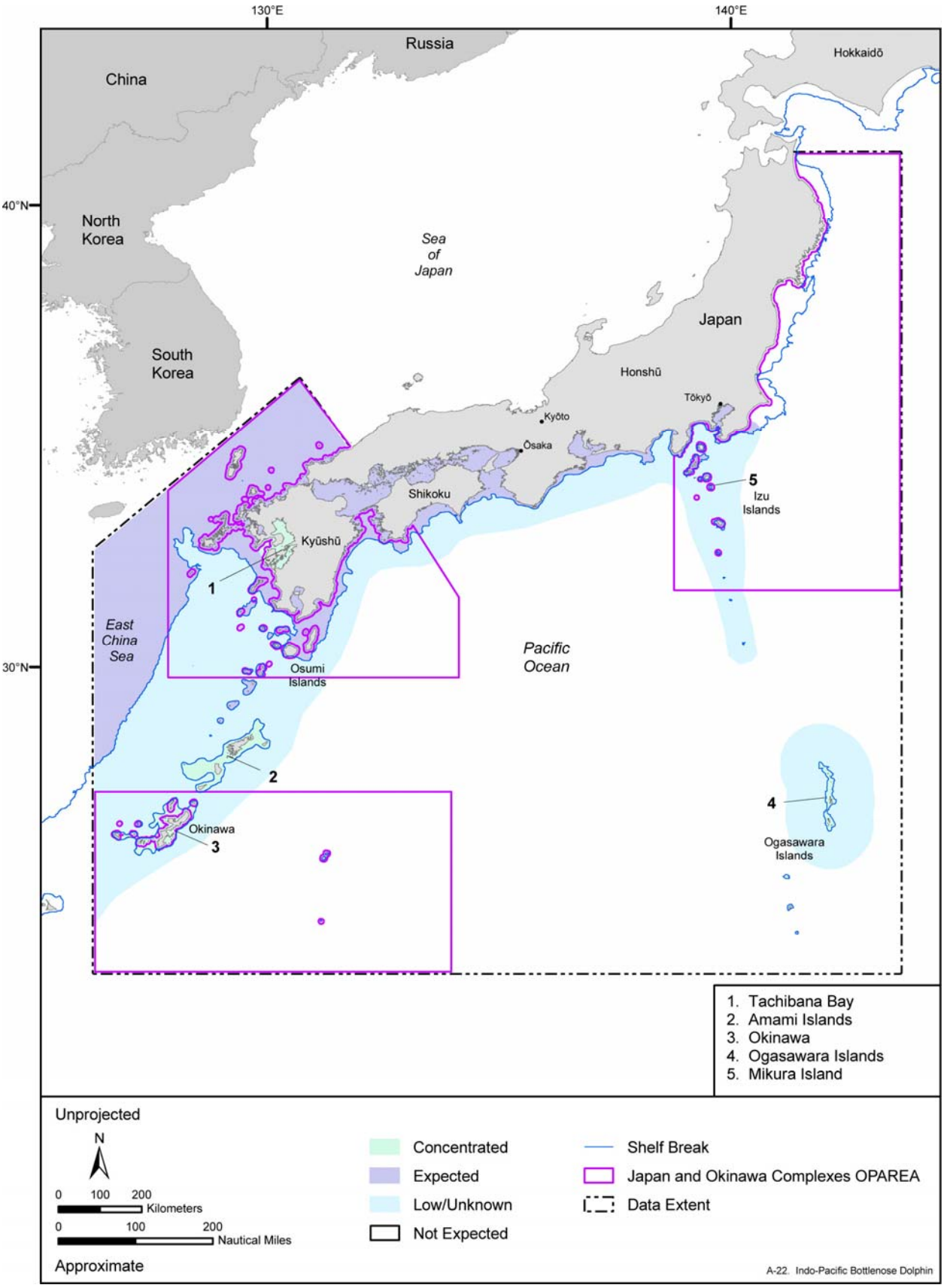

Figure A-22. Occurrence of the Indo-Pacific bottlenose dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

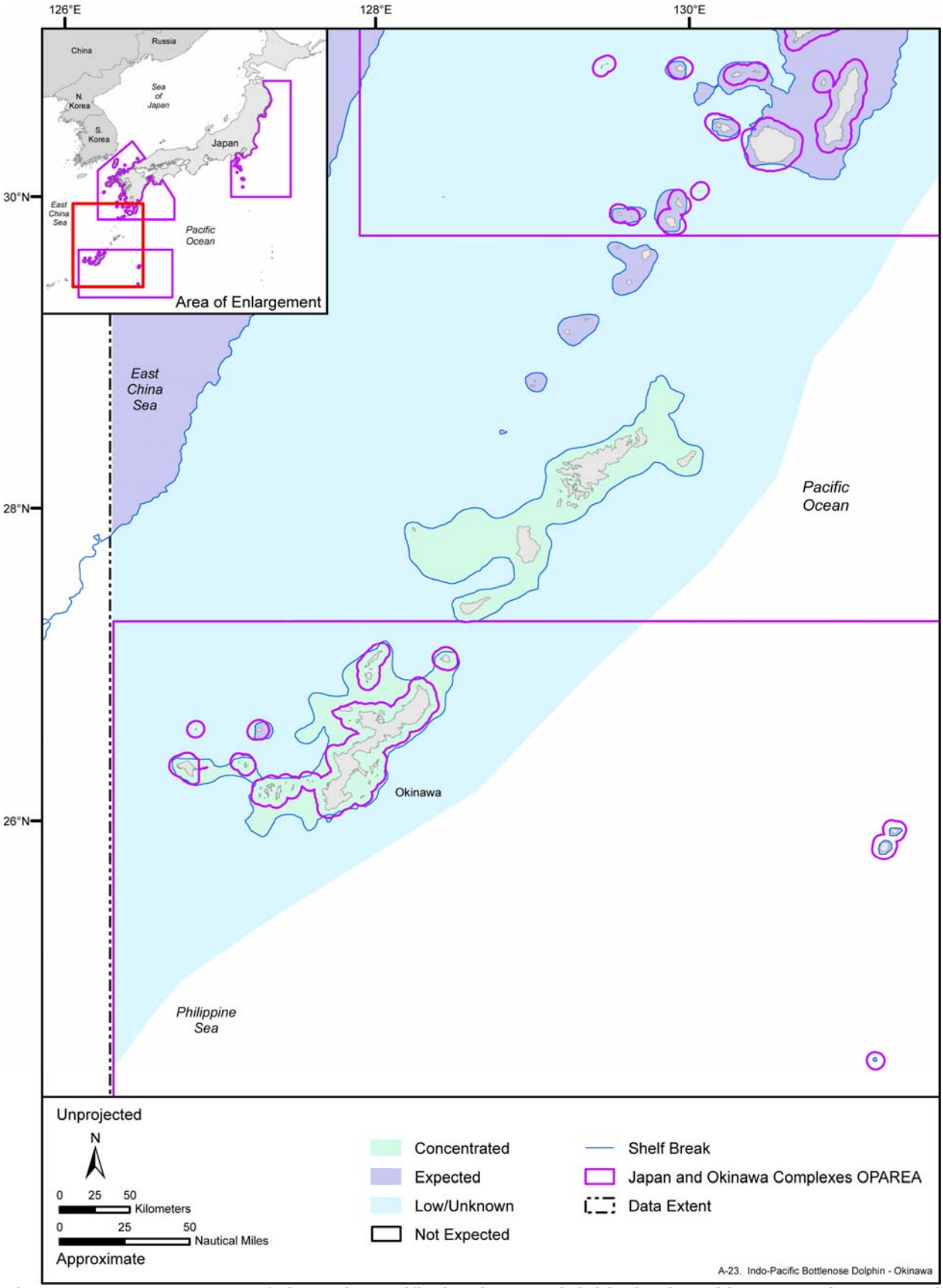

Figure A-23. Occurrence of the Indo-Pacific bottlenose dolphin in the Okinawa study area and vicinity. These occurrence patterns are applicable throughout the year.

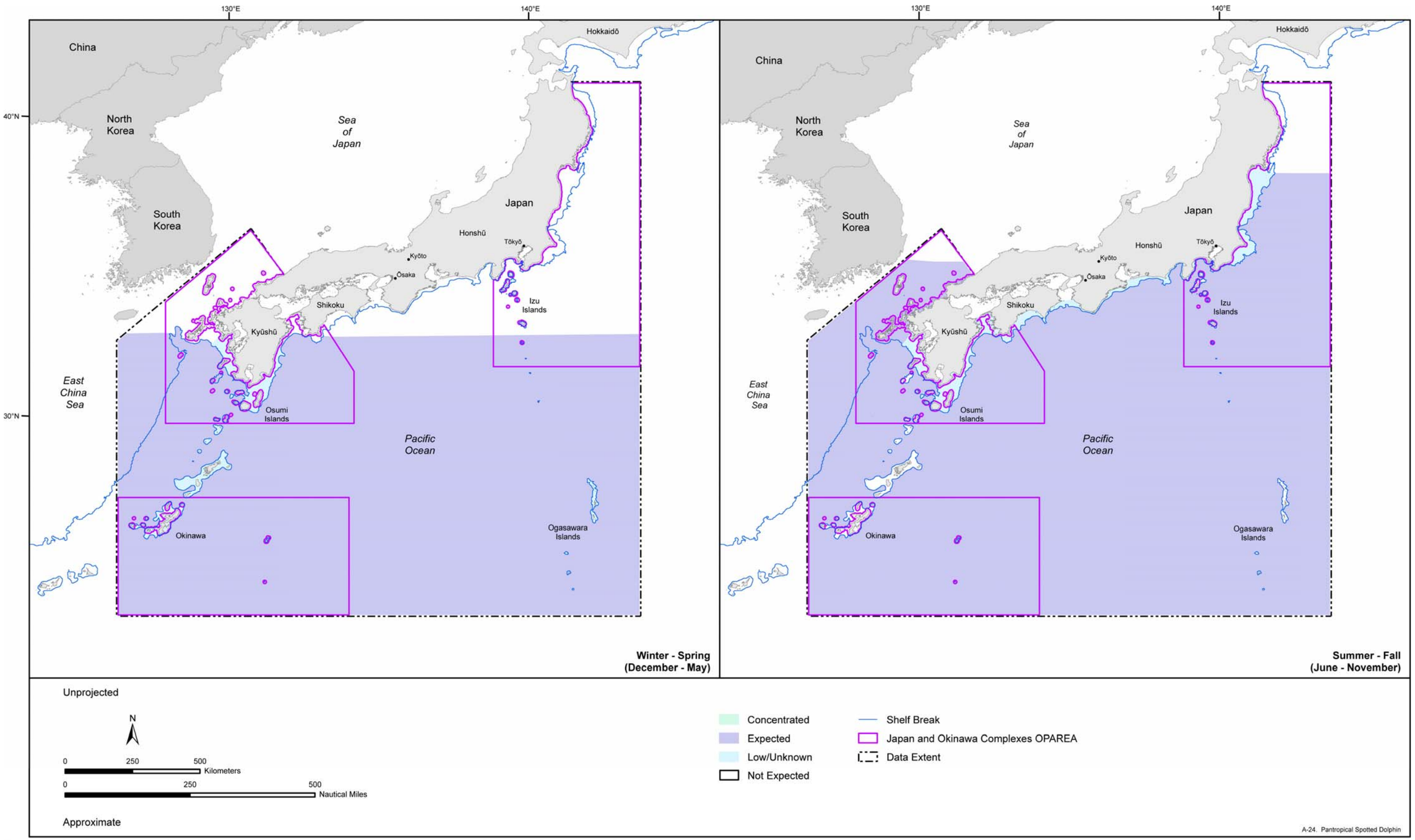

Figure A-24. Occurrence of the Pantropical spotted dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

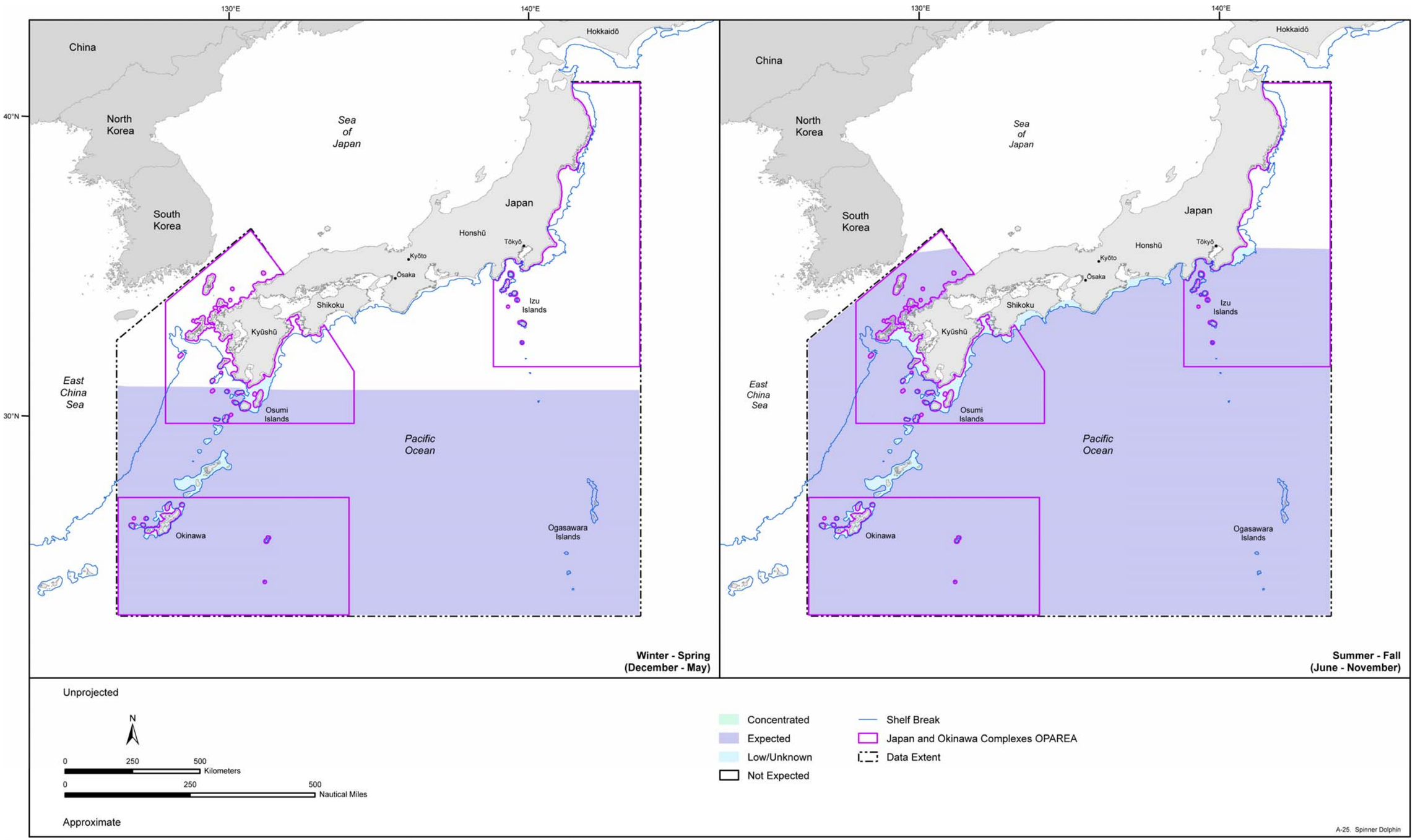

Figure A-25. Occurrence of the spinner dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

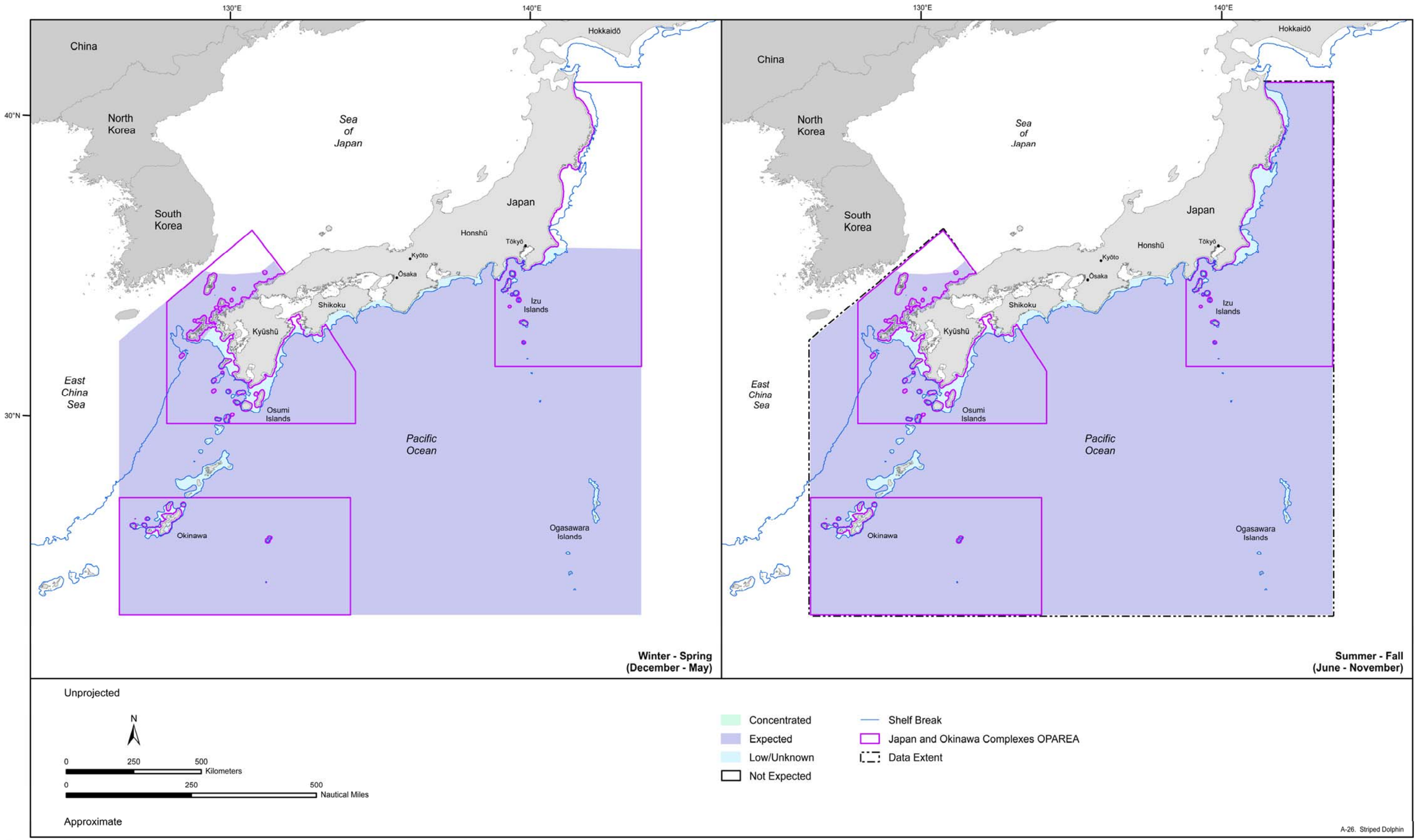

Figure A-26. Occurrence of the striped dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

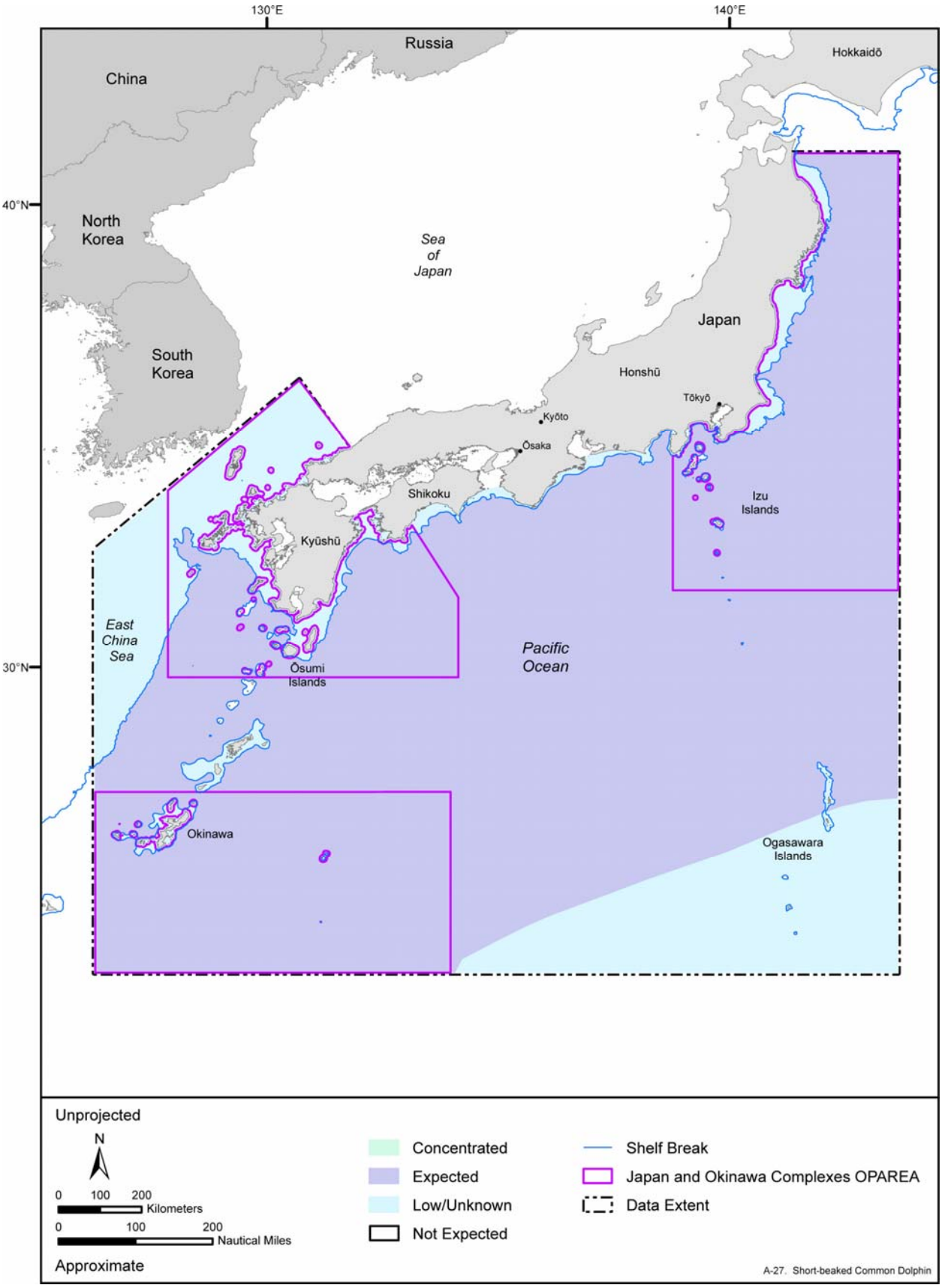

Figure A-27. Occurrence of the short-beaked common dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

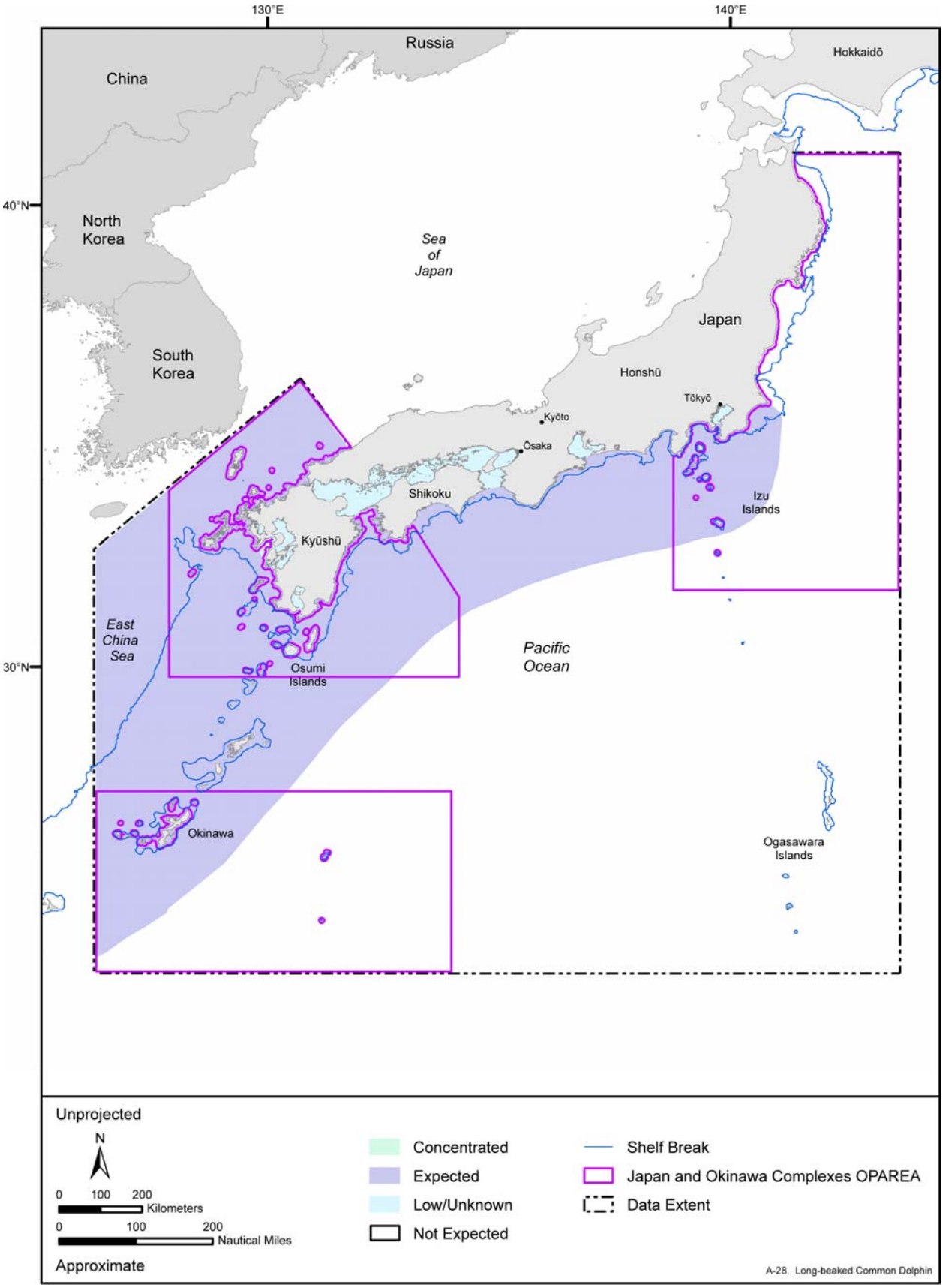

Figure A-28. Occurrence of the long-beaked common dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

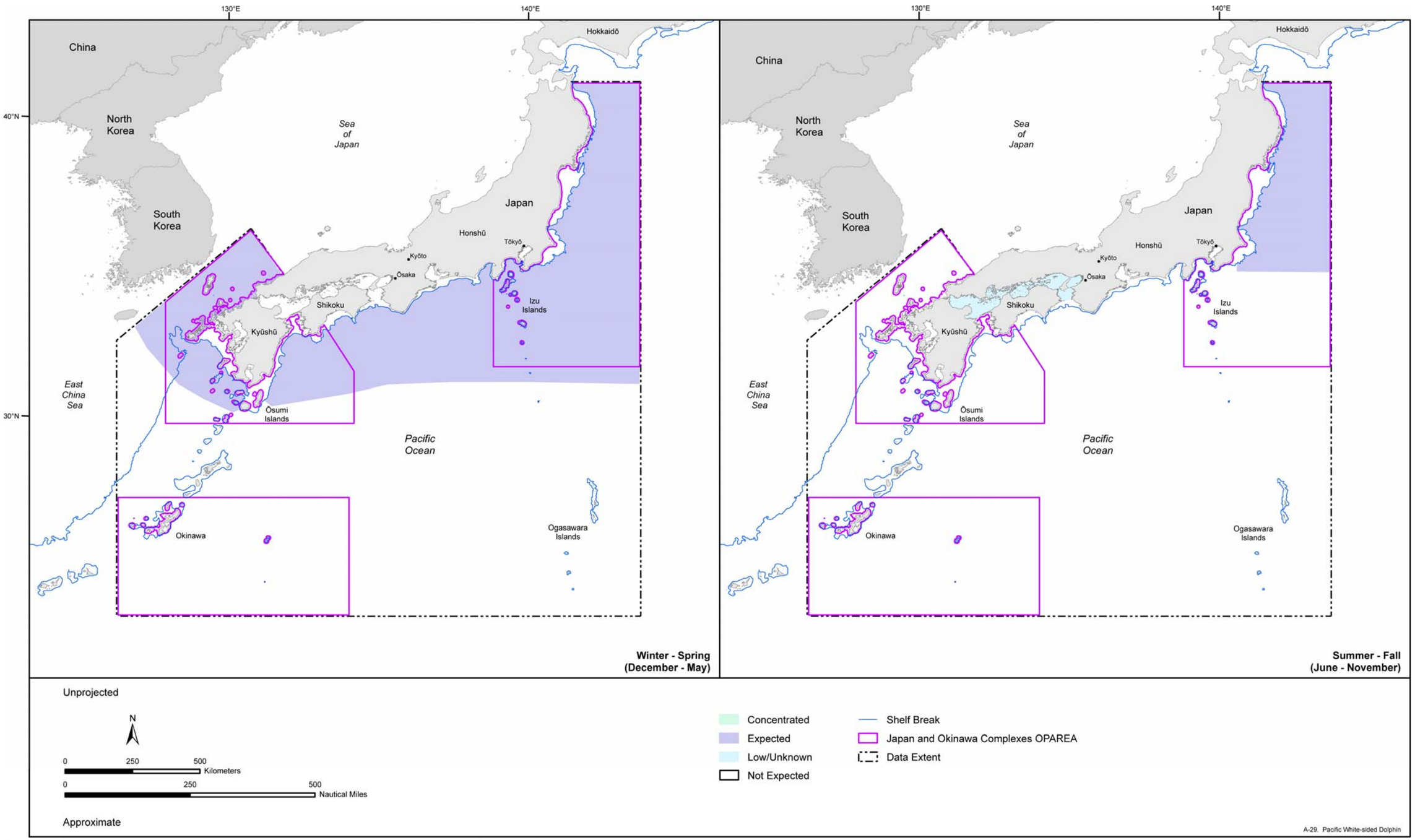

Figure A-29. Occurrence of the Pacific white-sided dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

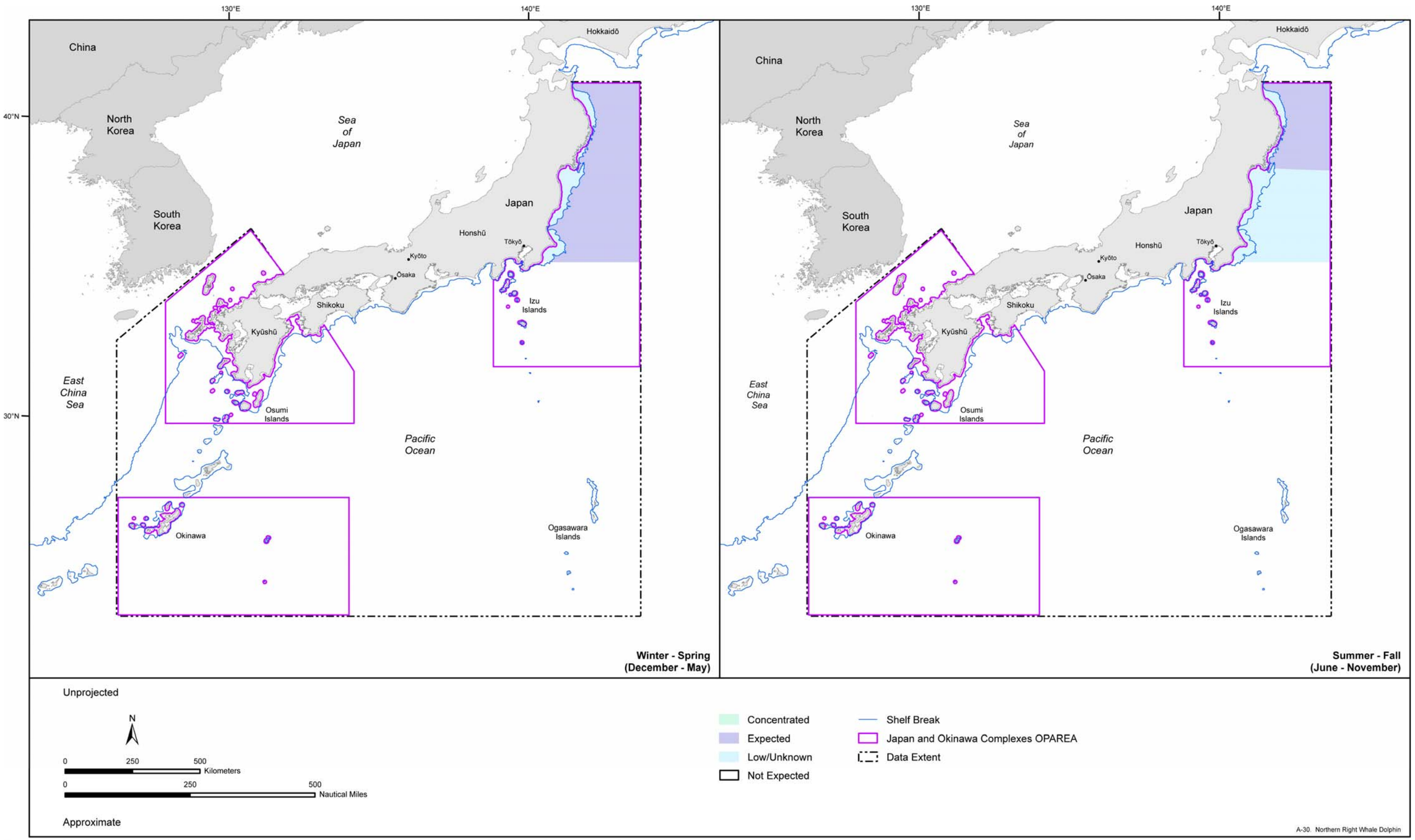

Figure A-30. Occurrence of the northern right whale dolphin in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

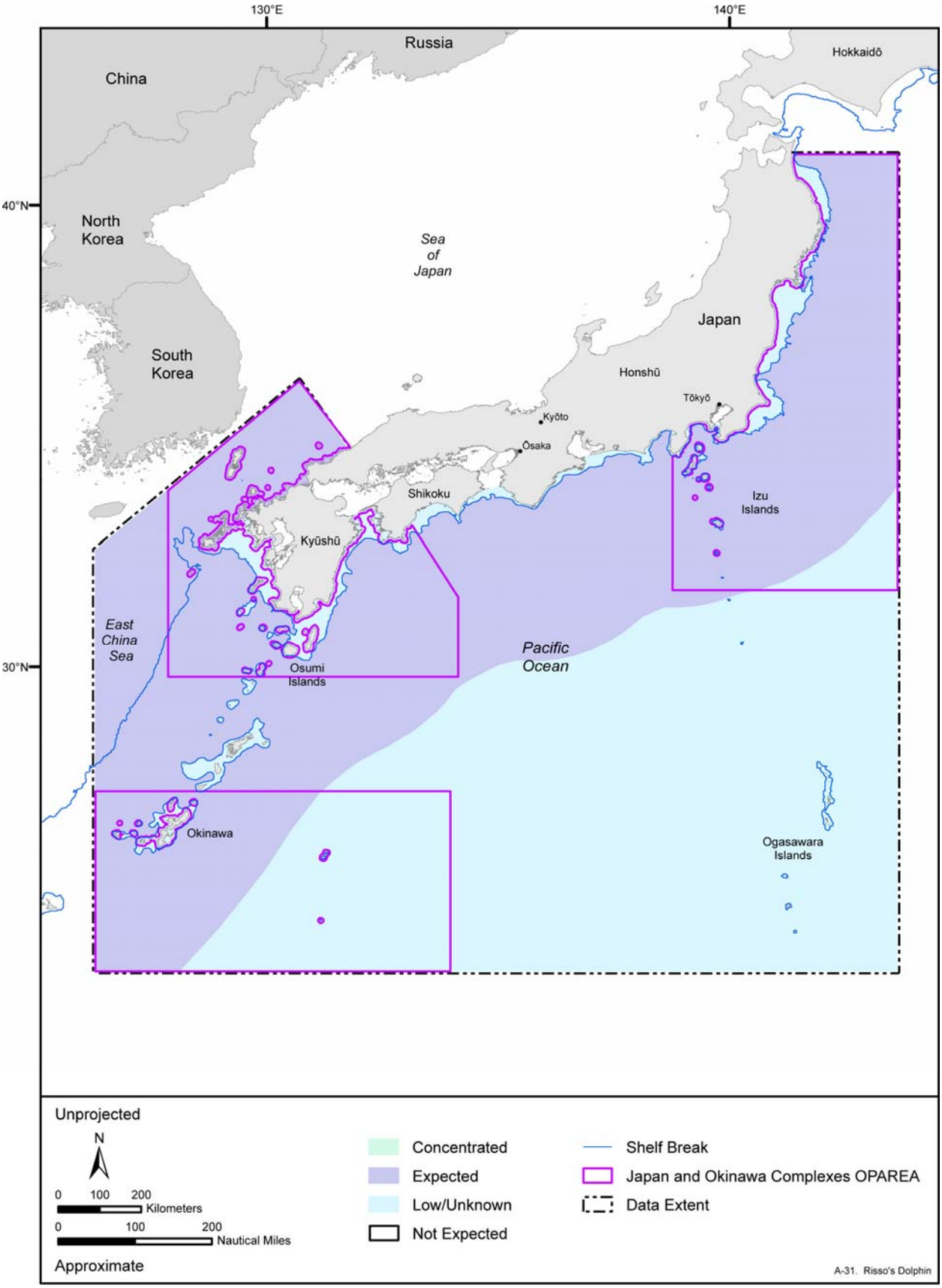

Figure A-31. Occurrence of the Risso's dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

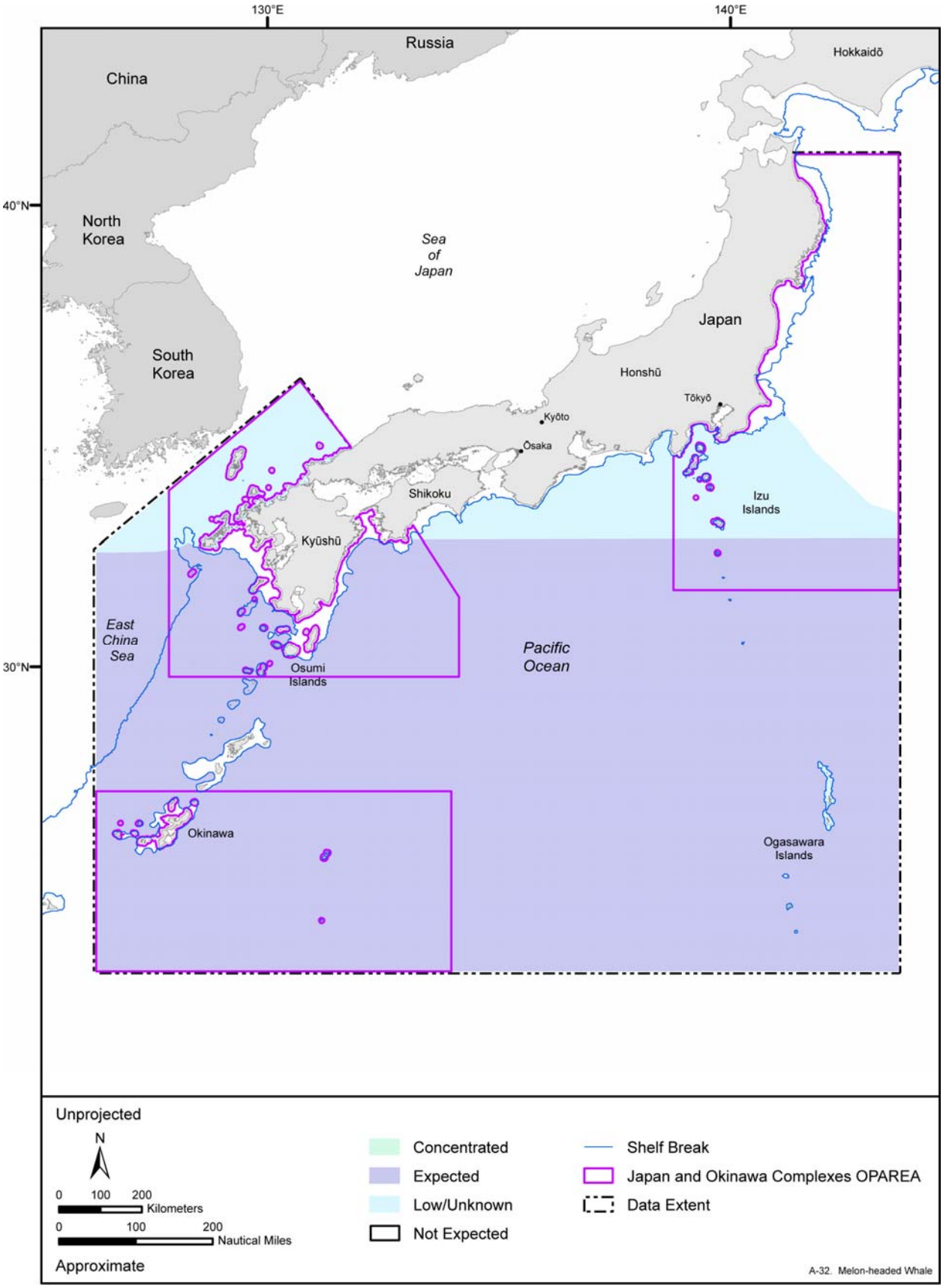

Figure A-32. Occurrence of the melon-headed whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

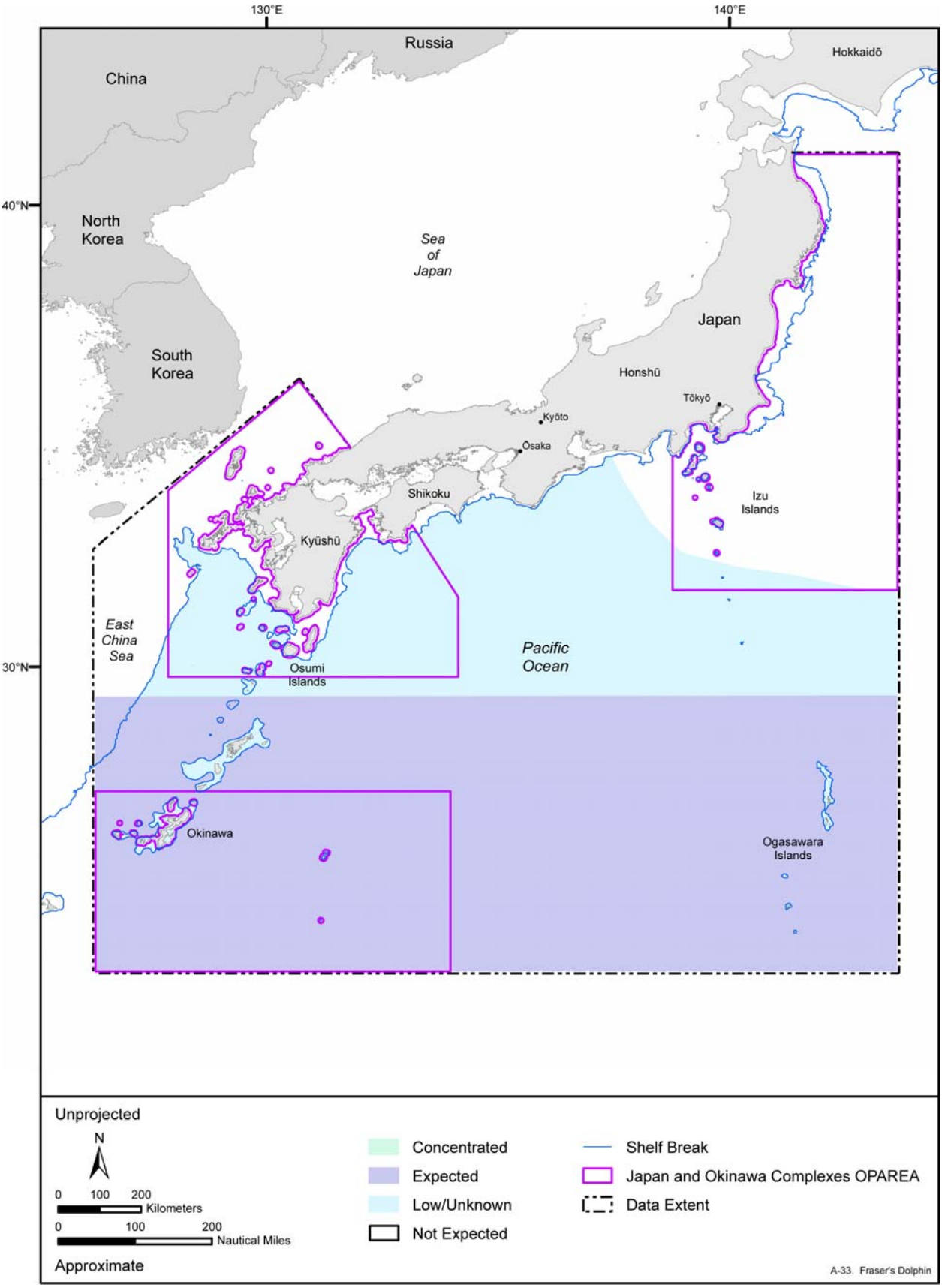

Figure A-33. Occurrence of the Fraser's dolphin in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

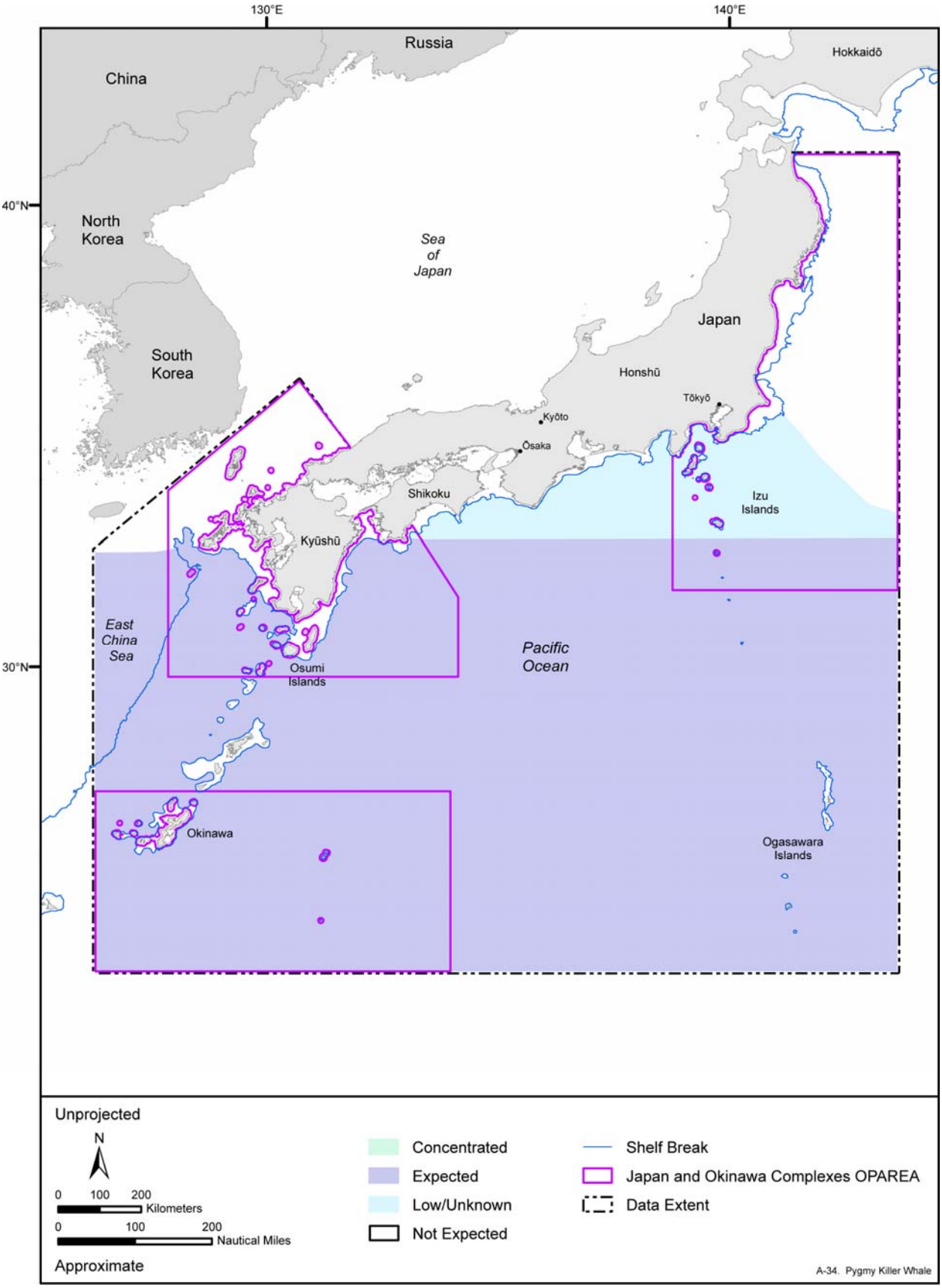

Figure A-34. Occurrence of the pygmy killer whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

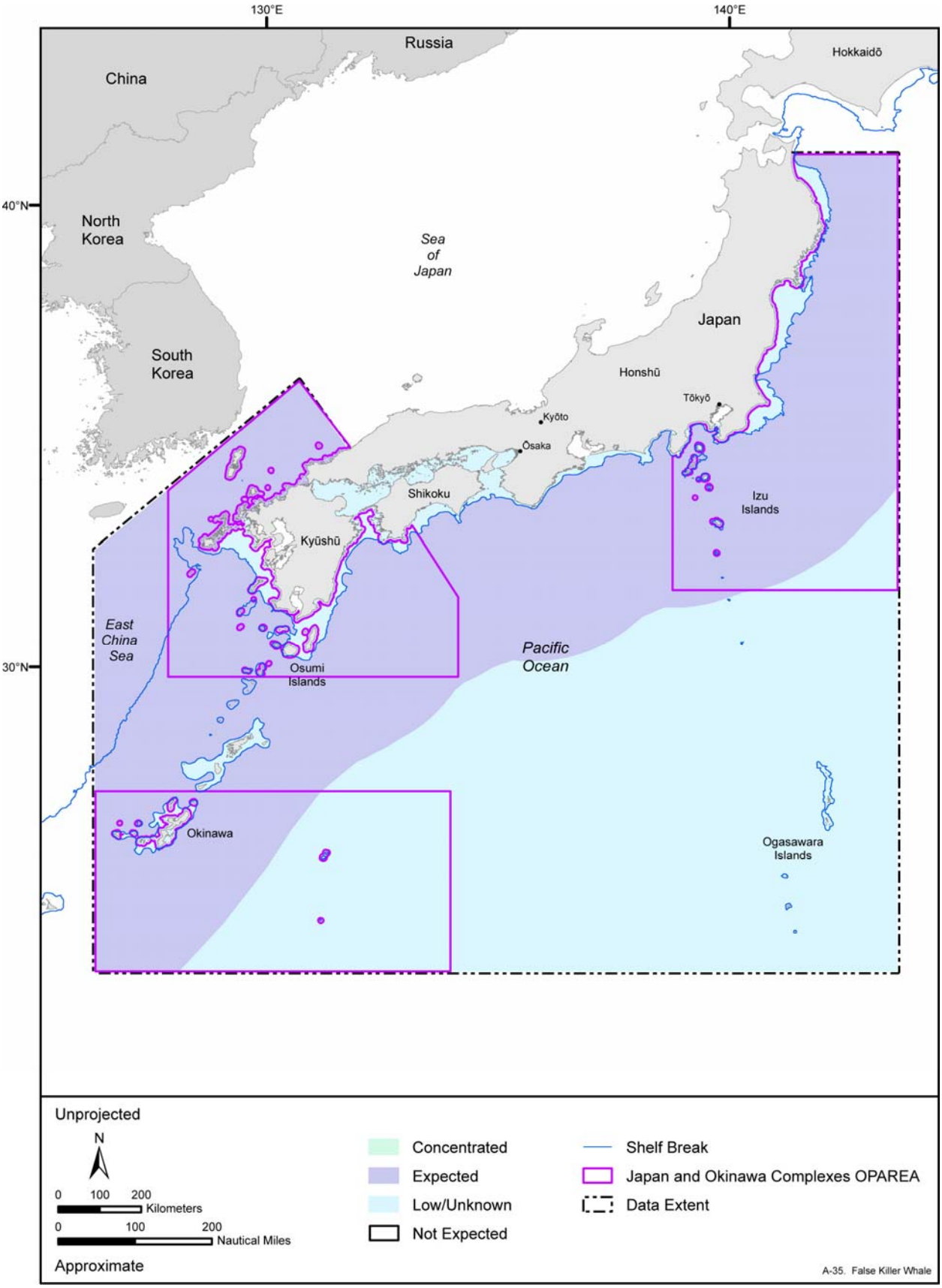

Figure A-35. Occurrence of the false killer whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

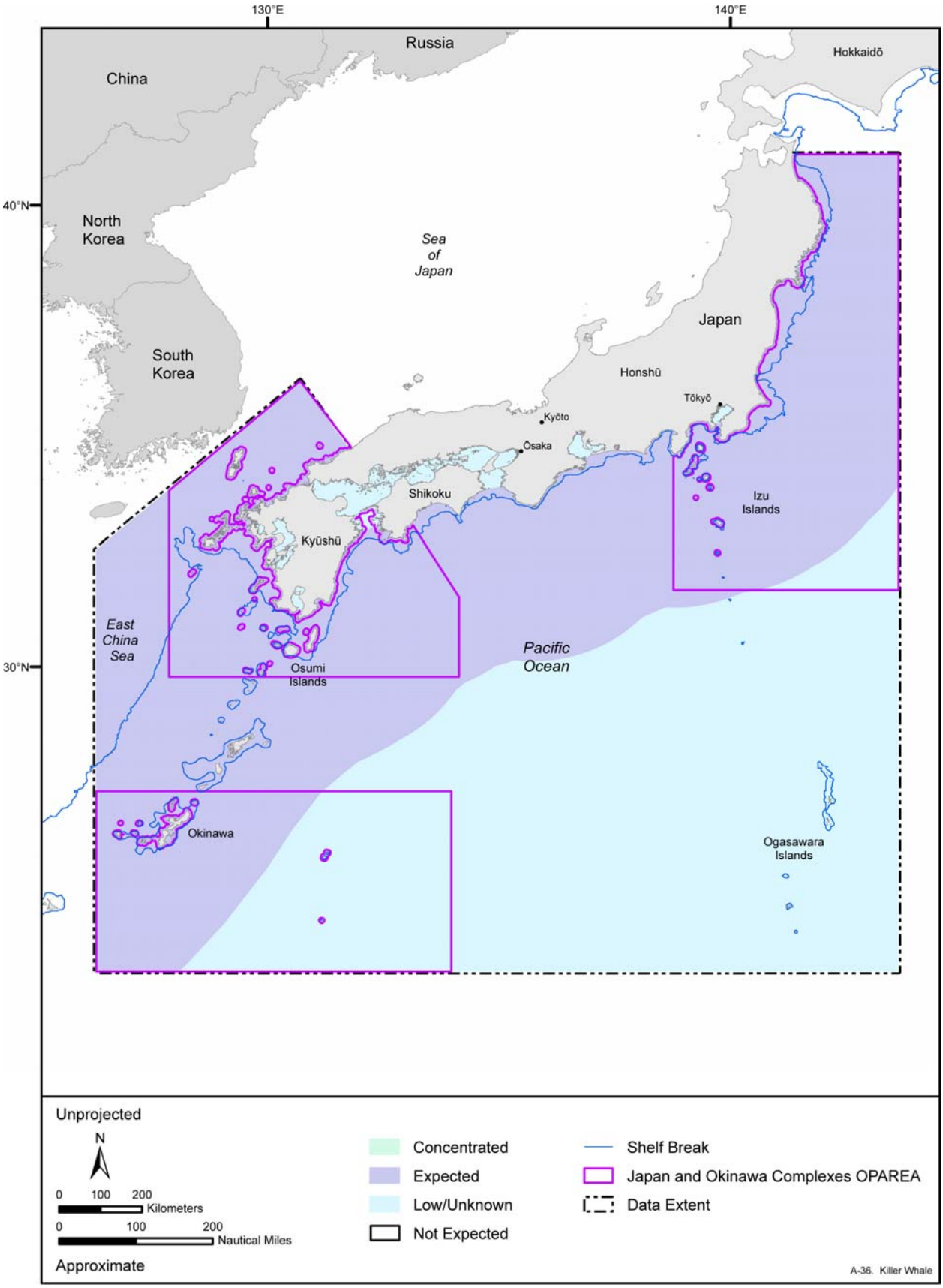

Figure A-36. Occurrence of the killer whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

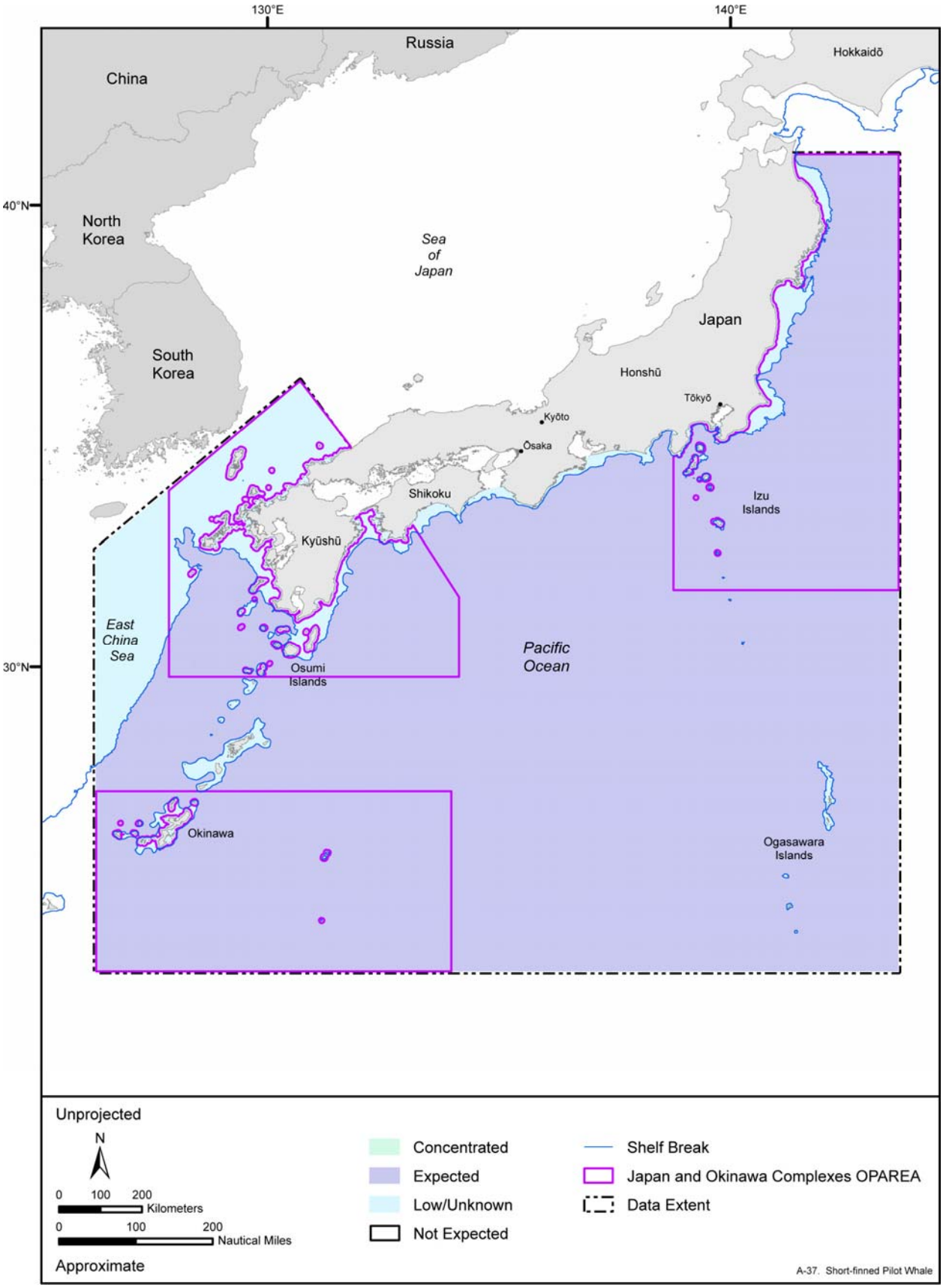

Figure A-37. Occurrence of the short-finned pilot whale in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

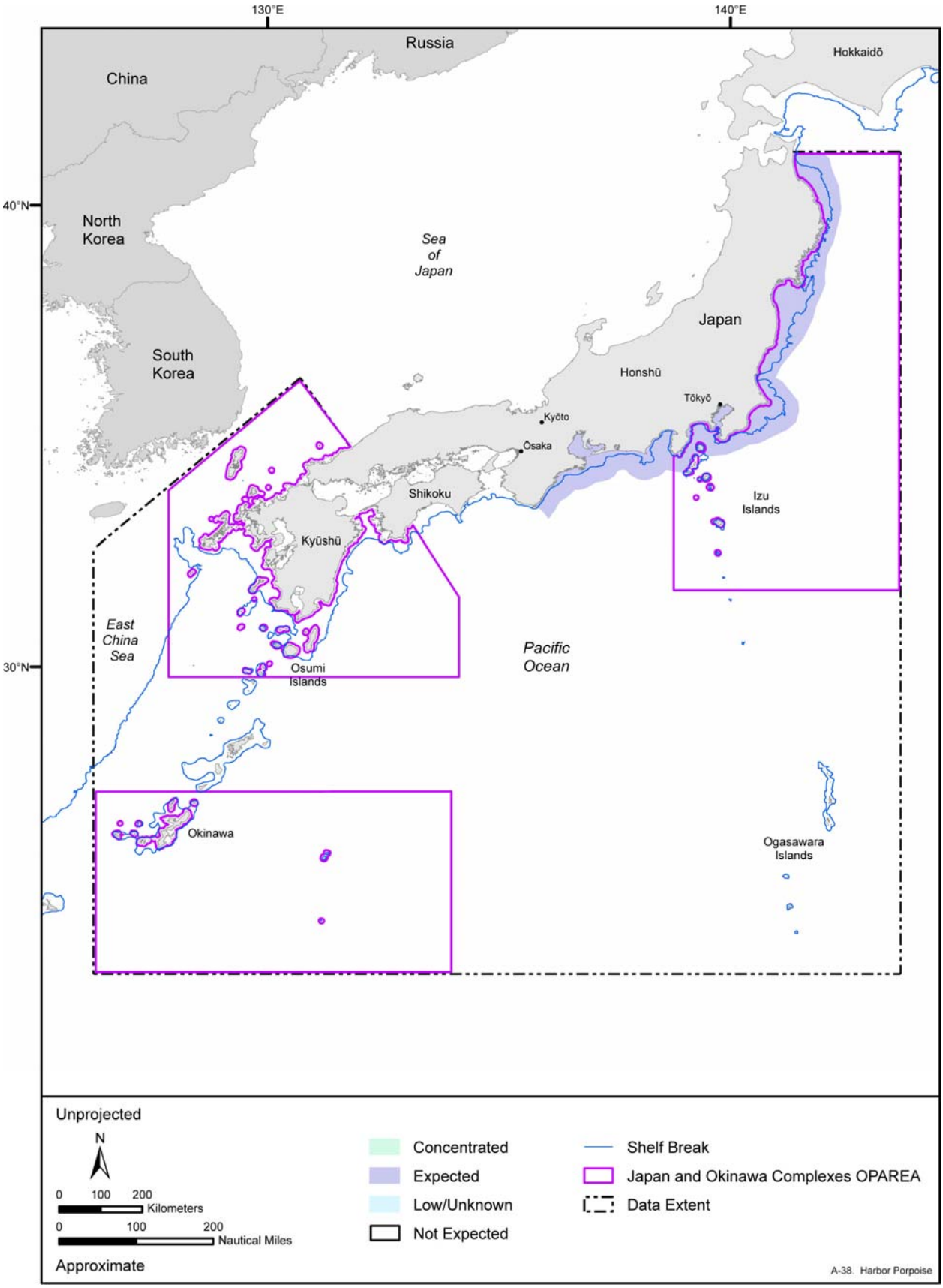

Figure A-38. Occurrence of the harbor porpoise in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

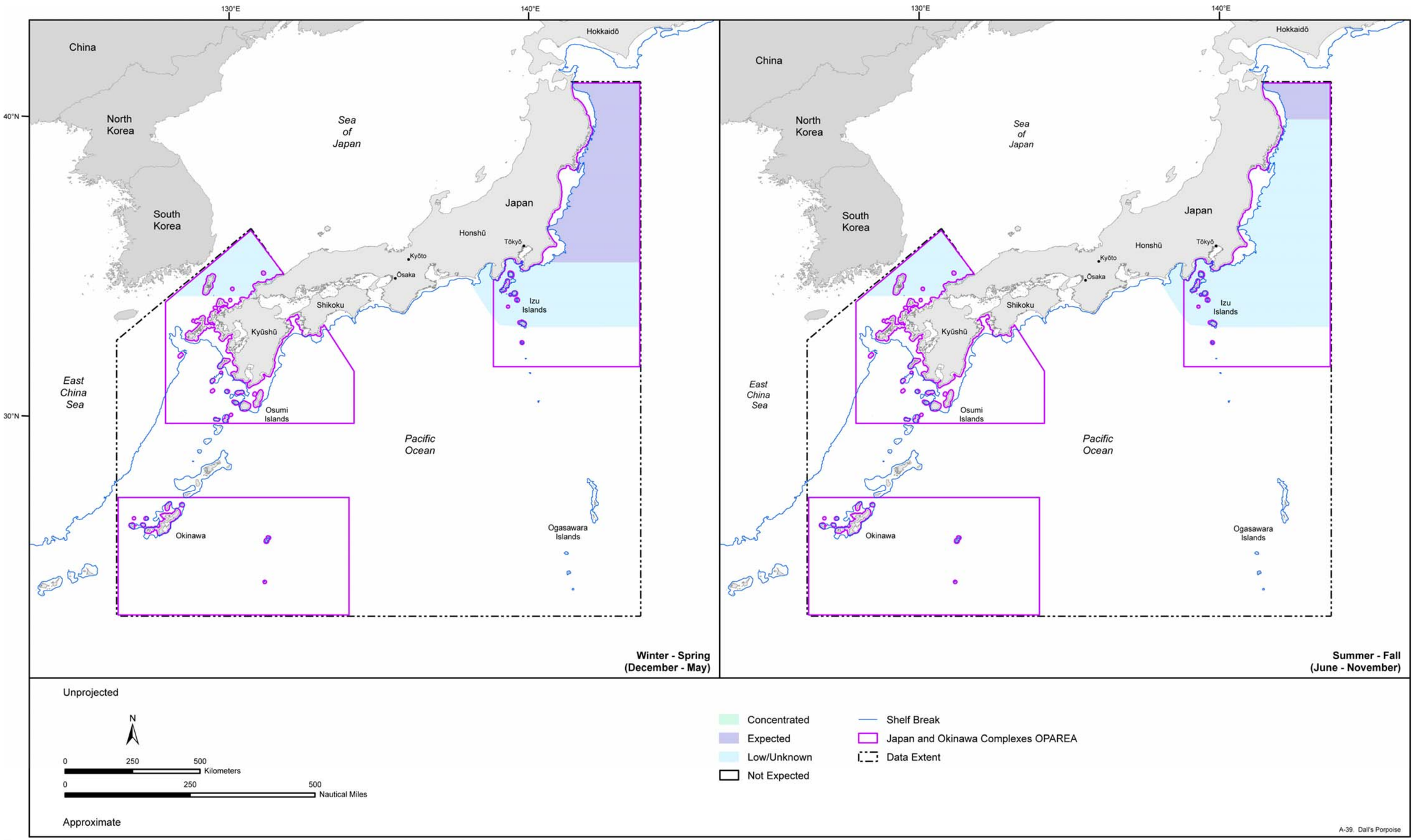

Figure A-39. Occurrence of the Dall's porpoise in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

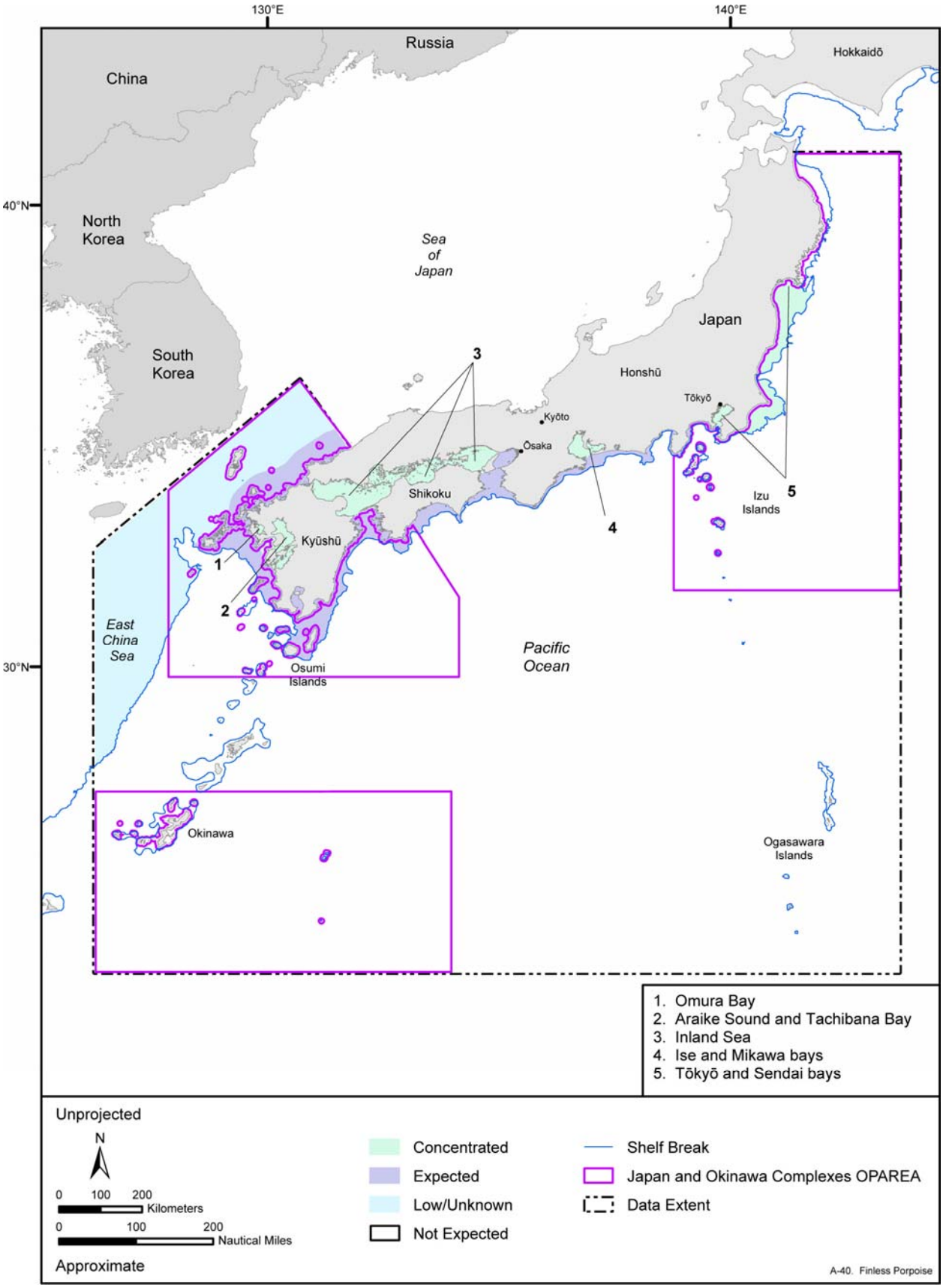

Figure A-40. Occurrence of the finless porpoise in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

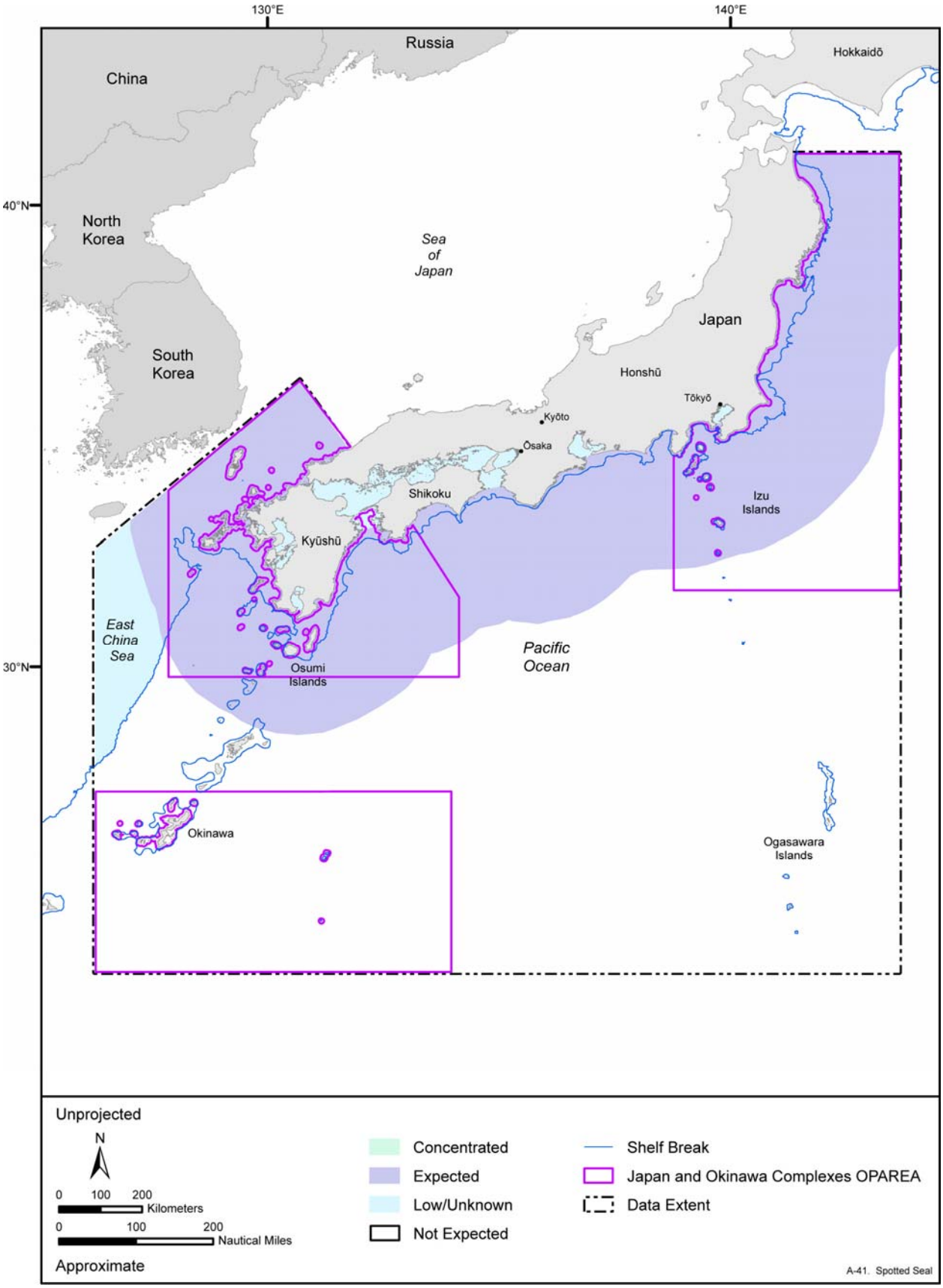

Figure A-41. Occurrence of the spotted seal in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

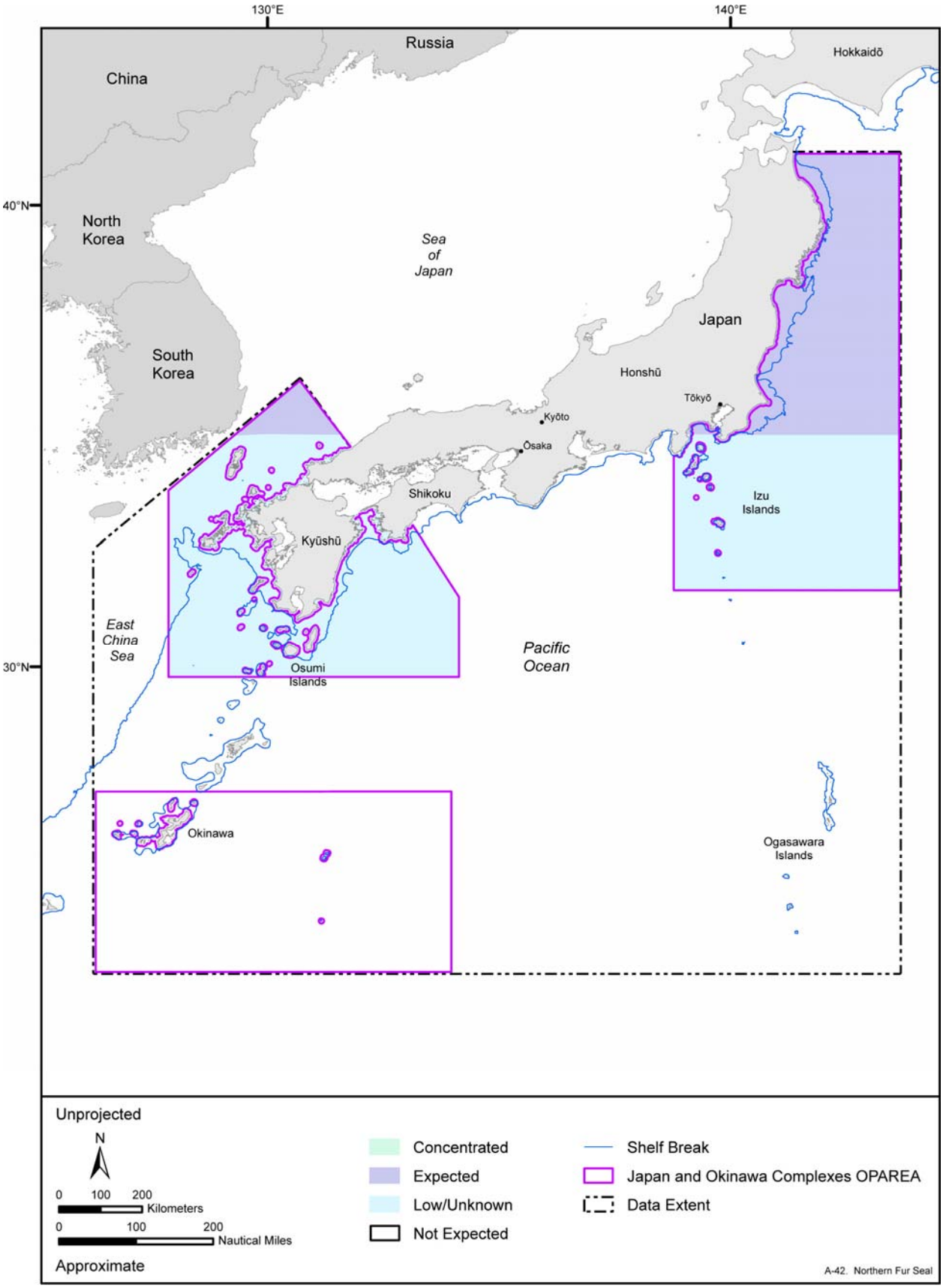

Figure A-42. Occurrence of the northern fur seal in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

APPENDIX B: SEA TURTLES

LIST OF FIGURES

Figure	Title
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B-2	Occurrence of the green turtle in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.
B-3	Occurrence of the hawksbill turtle in the Japan and Okinawa Complexes OPAREA and vicinity.
B-4	Occurrence of the loggerhead turtle in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.
B-5	Occurrence of the olive ridley turtle in the Japan and Okinawa Complexes OPAREA and vicinity.
B-6	Occurrence of the leatherback turtle in the Japan and Okinawa Complexes OPAREA and vicinity.

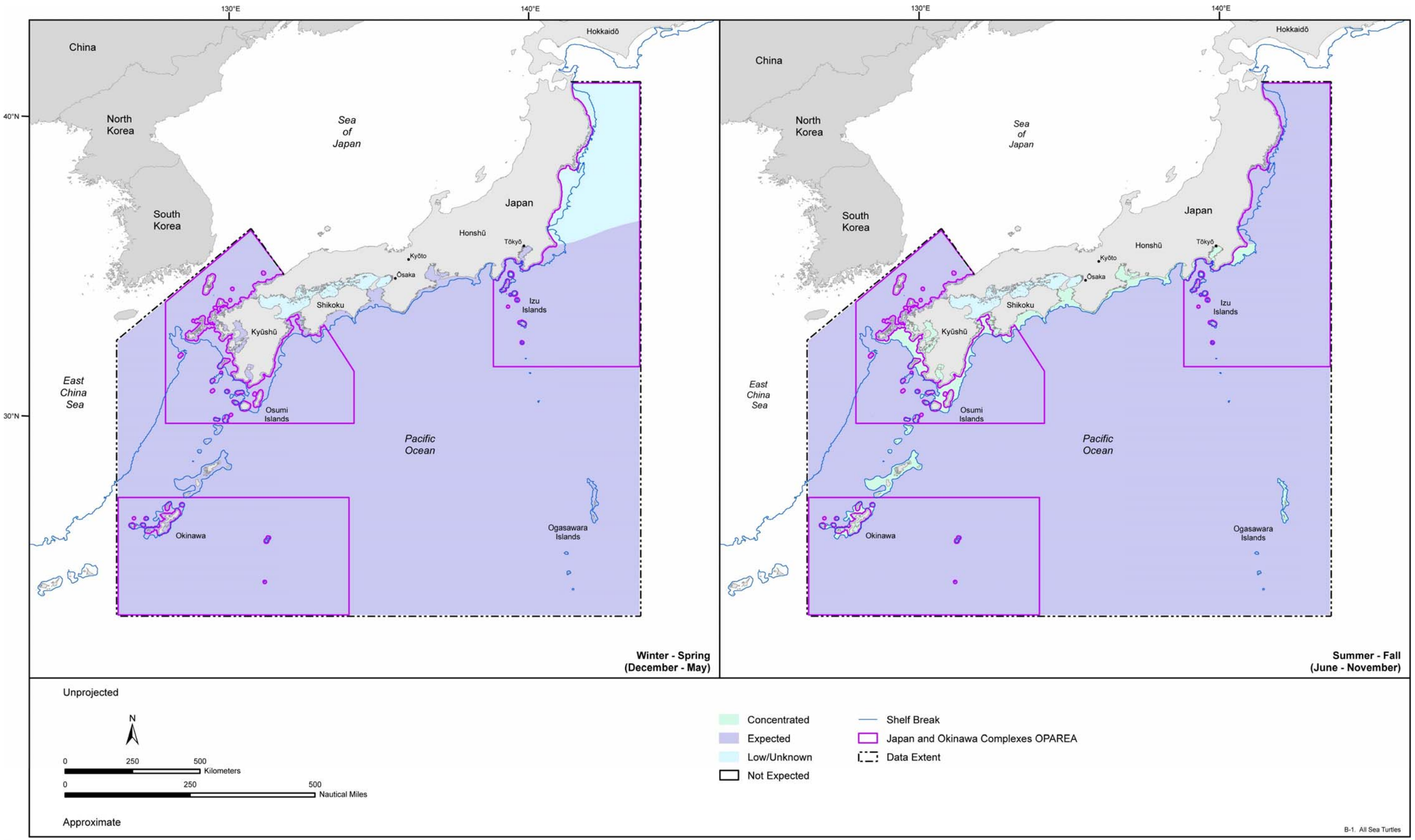

Figure B-1. Occurrence of all sea turtles in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

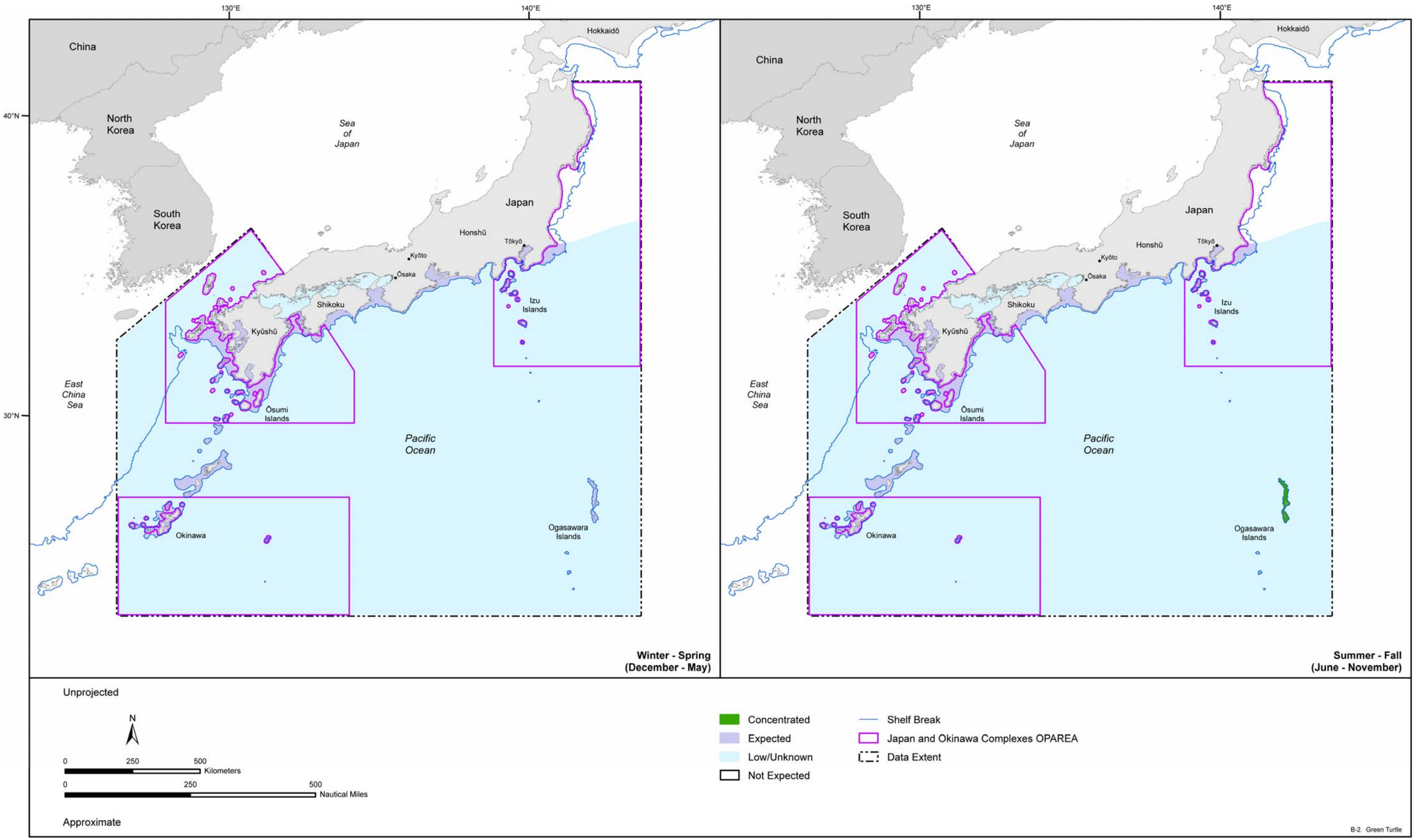

Figure B-2. Occurrence of the green turtle in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

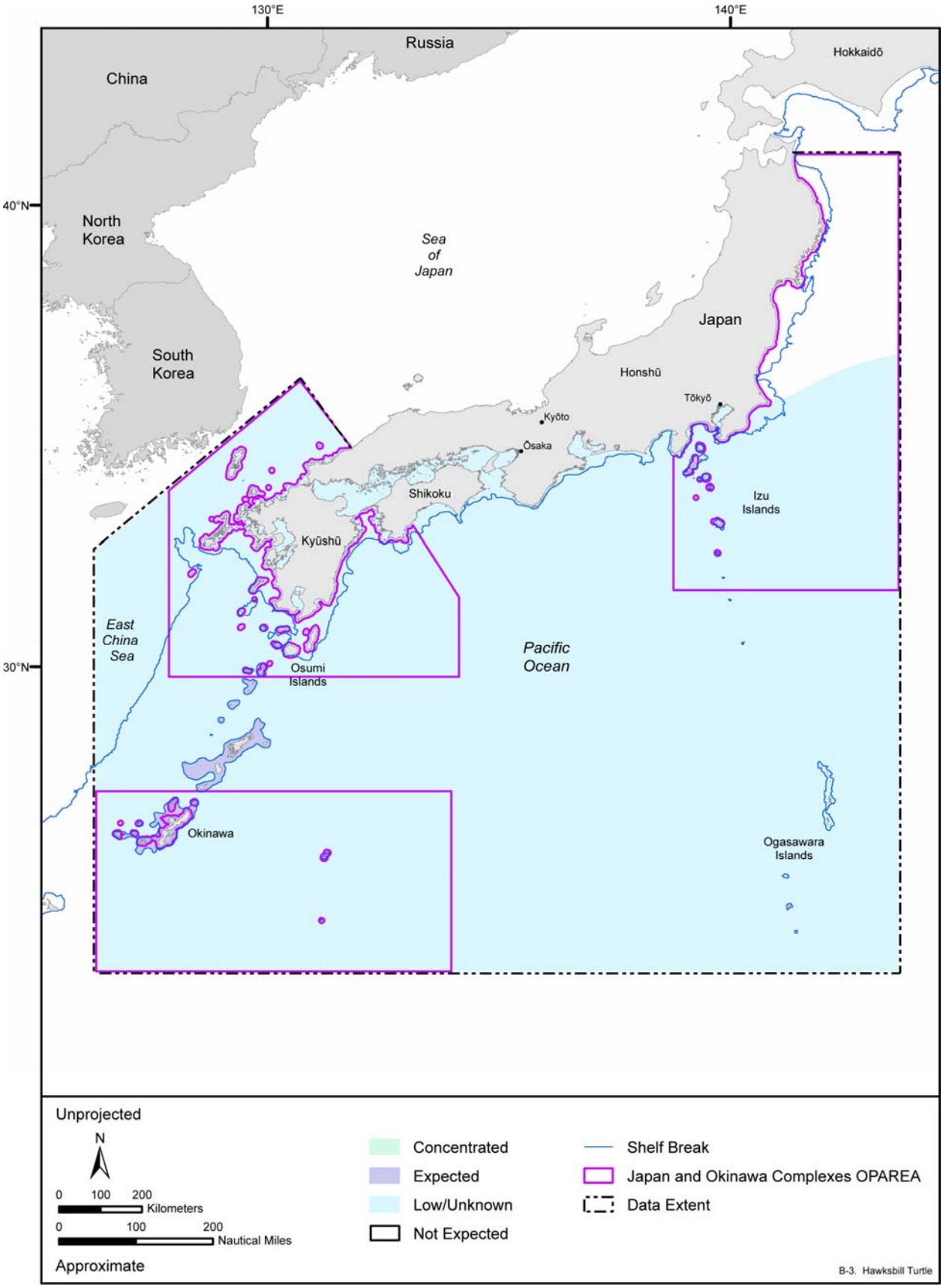

Figure B-3. Occurrence of the hawksbill turtle in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

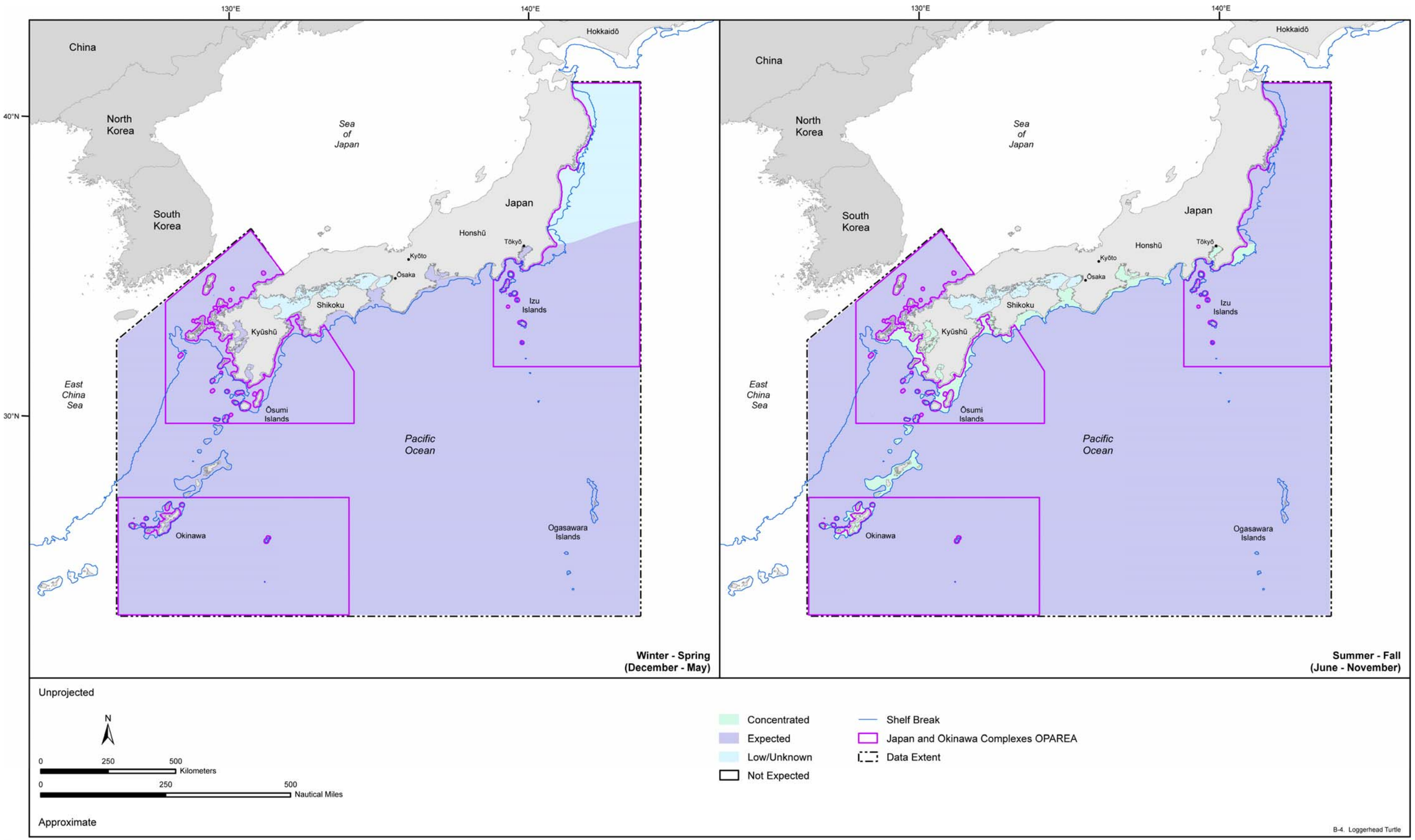

Figure B-4. Occurrence of the loggerhead turtle in the Japan and Okinawa Complexes OPAREA and vicinity during winter/spring and summer/fall.

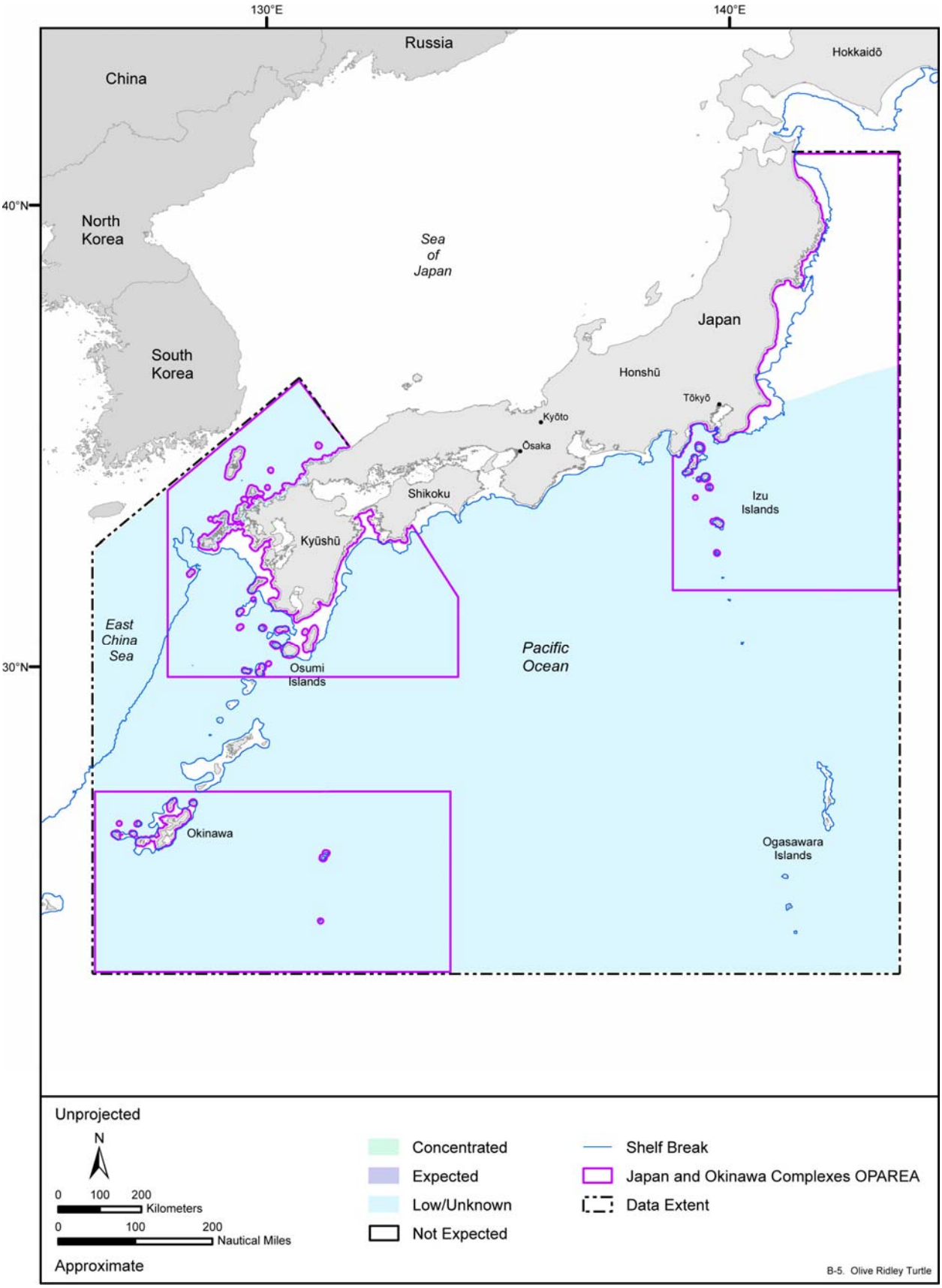

Figure B-5. Occurrence of the olive ridley turtle in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.

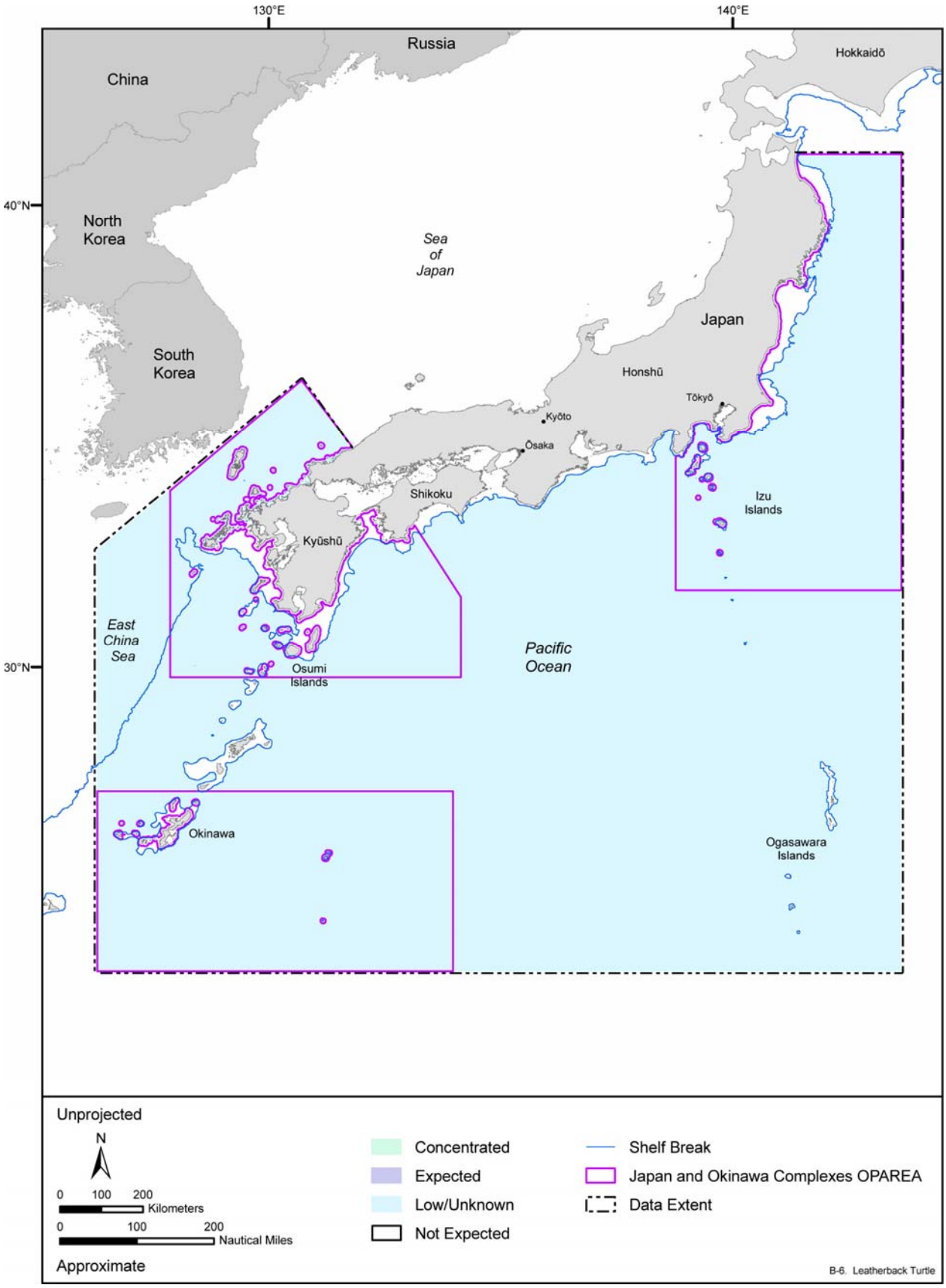

Figure B-6. Occurrence of the leatherback turtle in the Japan and Okinawa Complexes OPAREA and vicinity. These occurrence patterns are applicable throughout the year.