Marine Resources Assessment for the Pacific Northwest Operating Area

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FINAL REPORT
SEPTEMBER 2006

PREPARED FOR: DEPARTMENT OF THE NAVY, COMMANDER, U.S. PACIFIC FLEET

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STATEMENT OF PURPOSE

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

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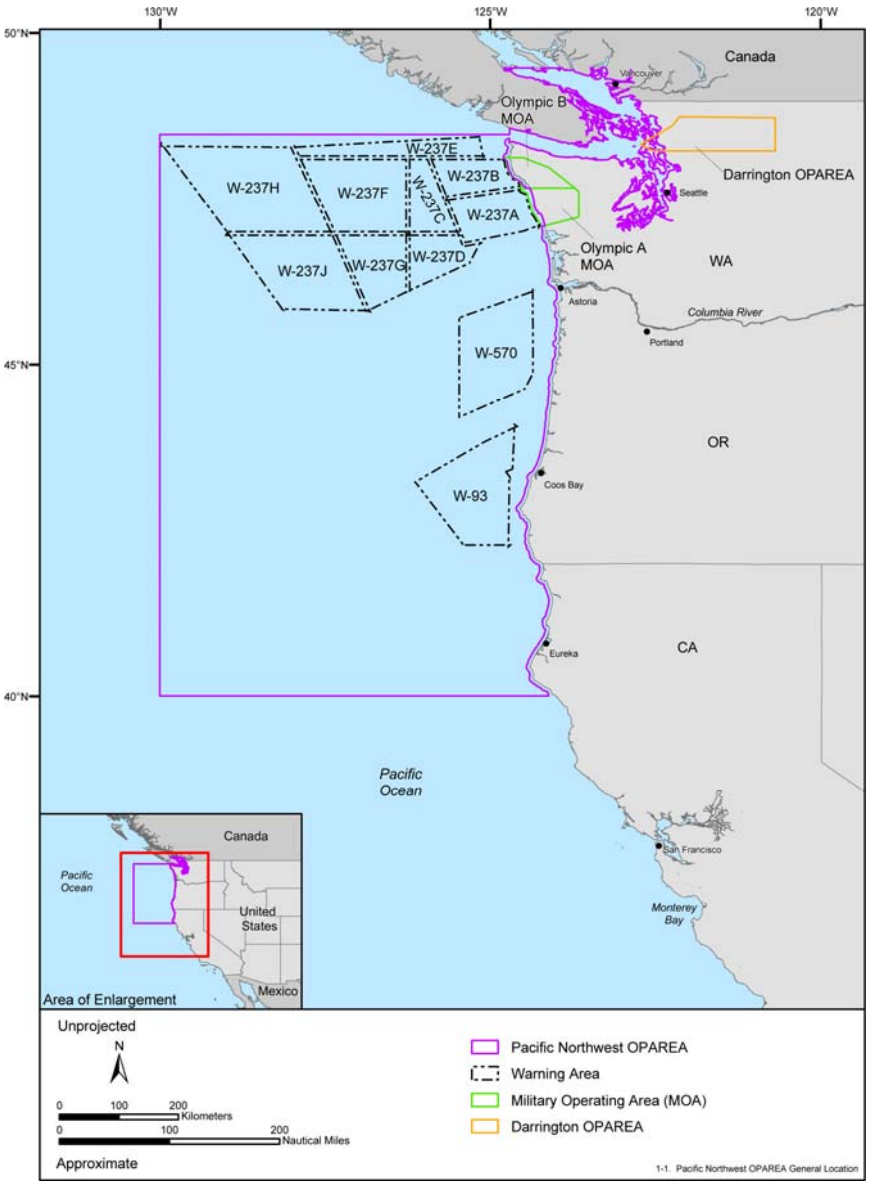
EXECUTIVE SUMMARY

The Department of the Navy (DoN) is committed to demonstrating environmental stewardship while executing its national defense mission. The U.S. Navy (Navy) is responsible for compliance with a suite of federal environmental and natural resources laws and regulations that apply to the marine environment, including the NEPA, the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), the National Marine Sanctuary Act (NMSA), the Magnuson-Stevens Fishery Conservation and Management Act/Sustainable Fisheries Act (MSFCMA/SFA), and Executive Order (EO) 13089 on Coral Reef Protection. The Navy implemented the MRA program to develop a comprehensive compilation of data and literature concerning the protected and managed marine resources found in its various OPAREAs. 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, ESA, and MSFCMA/SFA.

This MRA documents and describes the marine resources that occur in the Pacific Northwest OPAREA and Puget Sound Study Area. An overview of the marine environment off northern California, Oregon, and Washington State and the estuarine environment within the Puget Sound Study Area illustrates the important physical parameters that may affect the occurrence and distribution of protected and managed marine species. Detailed information is included on the characteristics and life history of federally protected marine mammals, sea turtles, birds, and fishes that may occur in the Pacific Northwest OPAREA and Puget Sound Study Area. 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 nearshore habitats such as seagrasses, kelp beds, and wetlands have been assessed. Oceanic habitats including artificial habitats, deep-sea corals, and chemosynthetic communities are also described and mapped. An overview of the fish assemblages associated with the waters of the Pacific Northwest OPAREA and Puget Sound Study Area as well as fishing activities (commercial, recreational, and tribal) are reviewed and their occurrences noted. Fish species for which essential

fish habitat (EFH) has been designated in the Pacific Northwest OPAREA and Puget Sound Study Area are described in detail, including their status, distribution, and EFH by life history stage. Information is provided on such additional considerations as U.S. maritime boundaries, ferry routes, navigable waterways, marine managed areas (MMAs), and self contained underwater breathing apparatus (SCUBA) diving sites in proximity to the Pacific Northwest OPAREA and Puget Sound Study Area.

Thorough and systematic literature and data searches were conducted, providing as much relevant information as possible for this assessment. Sighting, stranding, incidental fisheries bycatch, satellite-tracking, and haulout data for marine mammals and sea turtles were compiled and interpreted to predict the occurrence patterns in the Pacific Northwest OPAREA and Puget Sound Study Area for these protected and managed species. Predictions of the areas of occurrence for marine mammals and sea turtles are based on available occurrence data (e.g., sighting, stranding, and bycatch records) as well as scientific literature and expert opinion.

The geographical representation of marine resource occurrences in the Pacific Northwest OPAREA and Puget Sound Study Area is a major constituent of this MRA. A geographic information system (GIS) was used to store, manipulate, analyze, and display the spatial data and information accumulated for the MRA of the Pacific Northwest. Over 120 GIS-generated map figures are included in this assessment; data layers associated with these maps comprise bathymetry, sea surface temperature (SST), protected and managed species' occurrences, EFH, 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 Pacific Northwest OPAREA and Puget Sound Study Area is provided in both paper and electronic form.

REPORT ORGANIZATION

This report consists of nine chapters and five 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], and biological oceanography [plankton and primary productivity]) and habitats (e.g., estuarine, nearshore, and oceanic) of the Pacific Northwest OPAREA and Puget Sound Study Area;

Chapter 3 Species of Concern—covers federally protected marine mammals, sea turtles, birds, and fishes found in the Pacific Northwest OPAREA and Puget Sound Study Area, with detailed narratives of their morphology, status, habitat preferences, distribution, behavior, life history, acoustics, and hearing;

Chapter 4 Fish and Fisheries—investigates fish, fishing activities (commercial, recreational, and tribal), and EFH for managed species that occur within the Pacific Northwest OPAREA and Puget Sound Study Area;

Chapter 5 Additional Considerations—provides information on U.S. maritime boundaries, ferry routes, navigable waterways, MMAs, and SCUBA diving locations;

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 Pacific Northwest OPAREA and Puget Sound Study Area MRA report;

Chapter 8 Literature Cited—lists citations for all peer-reviewed literature referenced in the MRA report;

Chapter 9 Glossary—includes definitions of the terms used in the MRA report;

Appendix A—contains source information for marine mammal and sea turtle data, data confidence levels, map projection information, and map figures illustrating the sighting survey effort of aerial and shipboard surveys used in the Pacific Northwest OPAREA and Puget Sound Study Area MRA;

Appendix B—marine mammal occurrence and haulout maps;

Appendix C—sea turtle occurrence maps;

Appendix D—bird occurrence maps; and

Appendix E—EFH maps.

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percent
°C	Degrees Celsius
µm	Micron(s)
µP	MicroPascal
µsec	Microsecond
2D	Two-dimensional
3D	Three-dimensional
ABR	Auditory Brainstem Response
AEP	Auditory Evoked Potential
AFSC	Alaska Fisheries Science Center
AKR	Alaska Regional Office
AR	Aquatic Reserve
ASBS	Areas of Special Biological Significance
ASP	Amnesiac Shellfish Poisoning
ASW	Anti-Submarine Warfare
AUV	Autonomous Underwater Vehicle
AVHRR	Advanced Very High-resolution Radiometer
BA	Biological Assessment
BEMP	Bald Eagle Management Plan
BLM	Bureau of Land Management
C	Carbon
CA	Conservation Area
CCA	California Coastal Act
CCC	California Coastal Commission
CCL	Curved Carapace Length
CCS	California Current System
CDFG	California Department of Fish and Game
CEQ	Council on Environmental Quality
CERES	California Environmental Resources Evaluation System
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
chl *a*	Chlorophyll *a*
cm	Centimeter(s)
cm/d	Centimeter(s) Per Day
cm/sec	Centimeter(s) Per Second
cm/yr	Centimeter(s) Per Year
cm^2	Square Centimeter(s)
cm^2/hr	Square Centimeter(s) Per Hour
COMPACFLT	U.S. Navy Commander, Pacific Fleet
CPP	Count-Per-Pound
CPS	Coastal Pelagic Species
CRC	Cascadia Research Collective
CUD	Coastal Upwelling Domain
CVTS	Co-operative Vessel Traffic System
CWA	Clean Water Act
CZCS	Coastal Zone Color Scanner
CZMA	Coastal Zone Management Act
d	Day
DAP	Domoic Acid Poisoning
dB re 1µPa-m	Decibels at the Reference Level of One Micropascal at One Meter
dB	Decibel
DBRC	Dabob Bay Range Complex
DFO	Department of Fisheries and Oceans, Canada
DoAF	Department of the Air Force

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

DoD	Department of Defense
DoE	Department of Energy
DoI	Department of the Interior
DoN	Department of the Navy
DoS	Department of State
DoT	Department of Transportation
DSL	Deep Scattering Layer
EA	Environmental Assessment
ECC	Environmental Cooperation Council
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EFL	"Eye-to-Fork" Length
EIS	Environmental Impact Statement
ENSO	El Niño/Southern Oscillation
EO	Executive Order
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
EPO	Eastern Pacific Ocean
ERA	Estuary Restoration Act
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
ESU	Evolutionary Significant Unit
ETP	Eastern Tropical Pacific
FACSFAC	Fleet Area Control and Surveillance Facility
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization
FCMA	Fishery Conservation and Management Act
FHS	For-Hire Surveys
FL	Fork Length
Fleet	U.S. Pacific Fleet
FM	Frequency-modulated
FMC	Fishery Management Council
FMP	Fishery Management Plan
FR	Federal Register
FSJ	Friends of San Juan
FWPCA	Federal Water Pollution Control Act
g	Gram(s)
$gC/m^2/yr$	Gram(s) of Carbon Per Square Meter Per Year
GIS	Geographic Information System
GMI	Geo-Marine, Inc.
GPS	Global Positioning System(s)
ha	Hectare(s)
HAB	Harmful Algal Bloom
HABHRCA	Harmful Algal Bloom and Hypoxia Research and Control Act
HAPC	Habitat Area(s) of Particular Concern
HMS	Highly Migratory Species
HPA	Hydraulic Project Approval
hr	Hour(s)
HSP	Habitat Suitability Probability
HTML	Hyper Text Markup Language
Hz	Hertz
IATTC	Inter-American Tropical Tuna Commission
IMO	International Maritime Organization

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

in	Inch(es)
INRMP	Integrated Natural Resource Management Plan
IPHC	International Pacific Halibut Commission
ITOS	International Tug Opportunity System
IUCN	International Union for Conservation of Nature and Natural Resources
IWC	International Whaling Commission
JFL	“Tip of Lower Jaw to Fork” Length
kg	Kilogram(s)
kHz	Kilohertz
km	Kilometer(s)
km/d	Kilometer(s) Per Day
km^2	Square Kilometer(s)
km^3	Cubic Kilometer(s)
KMZ	Klamath Management Zone
kph	Kilometers Per Hour
l	Liter(s)
lbs	Pounds
lbs/yr	Pounds Per Year
LC	Location Class
m	Meter(s)
m/sec	Meters Per Second
m^2	Square Meter(s)
m^3	Cubic Meter(s)
m^3/sec	Cubic Meters Per Second
MBTA	Migratory Bird Treaty Act
mg	Milligram(s)
mg/m^3	Milligram(s) Per Cubic Meter(s)
mgC/m^2/d	Milligram(s) of Carbon Per Square Meter(s) Per Day
MHHT	Mean Higher High Tide
MHHW	Mean Higher High Water
MHW	Mean High Water
mi	Mile(s)
min	Minute(s)
MLLW	Mean Lower Low Water
MLPA	Marine Life Protection Act
MLW	Mean Low Water
mm	Millimeter(s)
mm/d	Millimeter(s) Per Day
mm/yr	Millimeter(s) Per Year
MMA	Marine Managed Area
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MOA	Military Operating Area
MOU	Memorandum of Understanding
MP	Marine Preserves
MPA	Marine Protected Area
MPPRCA	Marine Plastic Pollution Research and Control Act
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRA	Marine Resources Assessment
MRFSS	Marine Recreational Fisheries Statistics Survey
msec	Millisecond(s)
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

MSY	Maximum Sustainable Yield
mt	Metric Ton(s)
NAP	Nature Area Preserve
NARP	National Artificial Reef Plan
NAS	Naval Air Station
NASA	National Aeronautic and Space Administration
NASWI	Naval Air Station Whidbey Island
Navy	United States Navy
NBK	Naval Base Kitsap
NCCPA	Natural Community Conservation Planning Act
NEP	National Estuary Program
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NERRS	National Estuarine Research Reserve System
NFEA	National Fishery Enhancement Act
NM	Nautical Mile(s)
NM^2	Square Nautical Miles
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NMS	National Marine Sanctuaries
NMSA	National Marine Sanctuaries Act
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NP	National Parks
NPFMC	North Pacific Fishery Management Council
NPS	National Park Service
NPSG	North Pacific Subtropical Gyre
NPTZ	North Pacific Transition Zone
NRCA	Natural Resource Conservation Area
NRFCC	National Recreational Fisheries Coordination Council
NRKW	Northern Resident Killer Whales
NS	Naval Station
NSWC Det Brem	Naval Surface Warfare Center Detachment Bremerton
NUWC DIVKPT	Naval Undersea Warfare Center Division Keyport
NUWC	Naval Underwater Warfare Center
NWFSC	Northwest Fisheries Science Center
NWIFC	Northwest Indian Fisheries Commission
NWR	Northwest Region
NWRC	National Wildlife Refuge Complex
NWRS	National Wildlife Refuge System
OBIS	Ocean Biogeographic Information System
OCNMS	Olympic Coast National Marine Sanctuary
ODFW	Oregon Department of Fish and Wildlife
OMZ	Oxygen Minimum Zones
OPA	Oil Pollution Act
OPAC	Ocean Policy Advisory Council
OPAREA	Operating Area
ORBS	Ocean Recreational Boat Survey
OSP	Ocean Sampling Program
P.L.	Public Law
PacFIN	Pacific Coast Fisheries Information Network
PDF	Portable Document Format
PDO	Pacific Decadal Oscillation

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

PFMC	Pacific Fishery Management Council
PI	Principal Investigator
ppb	Parts Per Billion
ppm	Parts Per Million
ppt	Parts Per Thousand
PSC	Pacific Salmon Commission
PSMFC	Pacific States Marine Fisheries Commission
PSP	Paralytic Shellfish Poisoning
PSR	Puget Sound Region
PST	Pacific Salmon Treaty
psu	Practical Salinity Unit(s)
PTS	Permanent Threshold Shift
QUTR	Quinault Underwater Tracking Range
RAC	Regional Airspace Coordinator
RCA	Rockfish Conservation Area
RCW	Revised Code of Washington
RecFIN	Recreational Fisheries Information Network
RFRCP	Recreational Fishery Resources Conservation Plan
RMP	Recreational Marine Preserve
S.D.	Standard Deviation
SCB	Southern California Bight
SCUBA	Self Contained Underwater Breathing Apparatus
SEAL	U. S. Navy Sea, Air, and Land
SEAMAP	Spatial Ecological Analysis of Megavertebrate Populations
sec	Second(s)
SESEF	Shipboard Electronic Systems Evaluation Facility
SFA	Sustainable Fisheries Act
Si	Silicate
SJCMRC	San Juan County Marine Resources Committee
SL	Standard Length
SLP	Sea Level Pressure
SMA	Shoreline Management Act
SRKW	Southern Resident Killer Whales
SST	Sea Surface Temperature
SUBASE	Naval Submarine Base
SWFSC	Southwest Fisheries Science Center
SWR	Southwest Region
SWRCB	State Water Resources Control Board
TAC	Total Allowable Catch
TIN	Triangular Irregular Network
TL	Total Length
TTS	Temporary Threshold Shifts
TZCF	Transition Zone Chlorophyll Front
U&A	Usual and Accustomed
U.N.	United Nations
U.S.	United States
U.S.C.	United States Code
UNEP	United Nations Environment Programme
UP	Underwater Parks
USACE	U.S. Army Corps of Engineers
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

USMC	United States Marine Corps
USS	Underwater Surveillance System
USVI	United States Virgin Islands
USW	Undersea Warfare
WAC	Washington Administrative Code
WCMC	World Conservation Monitoring Centre
WCPFC	Western and Central Pacific Fisheries Commission
WDFW	Washington Department of Fish and Wildlife
WIDECAST	Wider Caribbean Sea Turtle Conservation Network
WNDR	Washington Department of Natural Resources
WSP&RC	Washington State Parks and Recreation Commission
XML	Extensible Markup Language
yr	Year(s)
ZTA	Zevenbergen and Thorn Algorithm

1.0 INTRODUCTION

The COMPACFLT contracted this MRA to compile existing data and information concerning the protected and commercial marine resources found in the Pacific Northwest OPAREA.

For the purposes of this MRA, the Pacific Northwest OPAREA refers to the Pacific Northwest Ocean Surface/Subsurface Operating Area which encompasses all waters offshore (greater than 3 NM) of Washington, Oregon and Northern California, as well as the nearshore areas (to the mean higher high tide line) of W237-A. The Puget Sound Study Area includes the waters of Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia.

1.1 PURPOSE AND NEED

The goal of this MRA is to provide a compilation of the most recent data and information on the occurrence of marine resources in the Pacific Northwest OPAREA and Puget Sound Study Area. This MRA includes a discussion of the physical environment, coastal and oceanic habitats, and federally protected species found in the OPAREA, Study Area, and near vicinity. Also addressed in this assessment are fish, EFH, fisheries, and other areas and activities of interest that occur in ocean waters off northern California, Oregon, and Washington State and inshore waters of the Puget Sound Study Area (which includes the Strait of Juan de Fuca, the Georgia Strait, Puget Sound, Hood Canal, the waters surrounding the San Juan Islands, and several other associated waterways in northwestern Washington State and southwestern British Columbia, Canada). The identification of data gaps and the prioritization of recommendations for future research in the OPAREA and Study Area are additional components of this report.

The DoN is responsible for organizing, training, and equipping naval forces for combat. The purpose of the Pacific Northwest OPAREA and Puget Sound Study Area is to support joint air/surface/subsurface operations such as air-to-surface bombing, air-to-air firing, combat tactics, intercepts, aerial refueling, instrument training, aerobatics, formation flight training, anti-submarine warfare (ASW), undersea warfare training, and transit (15 CFR 922; DoN 2000e). Section 4.1.1 of the 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 entrusted to DoD care 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 and estuarine environment. All species and habitats potentially affected by the Navy’s maritime exercises and protected by U.S. federal resource laws or EOs are considered in this assessment.

A search and review of relevant literature and data was conducted to provide information on important features of the marine and estuarine environment, the occurrence patterns of federally protected species, and the distribution of EFH and other Navy concerns in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. To describe the physical environment and habitats of the OPAREA, physiographic, bathymetric, geologic, hydrographic, and oceanographic data for the study region were compiled and the locations of seagrasses, macroalgae, wetlands, chemosynthetic communities, deep-sea corals, intertidal and colonized hardbottom, and artificial habitats were identified. Comprehensive sighting, stranding, incidental fisheries bycatch, haulout, and critical habitat data for marine mammals and sea turtles were collected and analyzed to qualitatively predict the areas of occurrence for these protected species in the OPAREA. Marine mammal and sea turtle areas of occurrence have been identified, mapped, and described along with the likely causative factors (behavioral, climatic, or oceanographic). Other protected species addressed in this assessment include federally listed birds and fishes.

Occurrence maps were also produced for these species and were developed from available sighting and habitat data as well as known distributional information (e.g., foraging/breeding ranges). Biological characteristics such as habitat preferences, behaviors, and life history patterns were researched for all federally protected species potentially occurring in the Pacific Northwest Region. Also reviewed were fish species and habitats (including EFH); commercial, recreational, and usual and accustomed (U&A) tribal fishing activities; U.S. maritime boundaries; commercial shipping lanes and ferry routes; federal and state MMAs; and SCUBA diving sites.

1.2 LOCATION OF THE PACIFIC NORTHWEST OPAREA

The Pacific Northwest OPAREA is located in the eastern North Pacific Ocean off the northwest coast of the continental U.S. and the southwest coast of Canada (**Figure 1-1**). The OPAREA lies in ocean waters off northern California, Oregon, and Washington State whereas the Puget Sound Study Area encompasses inshore waters of Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia between Washington State and British Columbia (**Figure 1-2**). Covering 445,344 square kilometers (km^2) of ocean and estuarine area, the Pacific Northwest OPAREA and Puget Sound Study Area and their associated ranges are regularly used for Navy and U.S. Marine Corps (USMC) exercises and training operations (**Table 1-1**). The vertical extent of the Pacific Northwest OPAREA and Puget Sound Study Area encompasses surface and subsurface areas that range from the mean higher high tide (MHHT) in the nearshore regions to a depth in excess of 4000 meters (m) in the offshore regions.

The northern boundary of the Pacific Northwest OPAREA and Puget Sound Study Area lies along 48.5°N in the eastern North Pacific Ocean and extends as far north as 49.5°N within the Georgia Strait. The southern boundary of the OPAREA is situated along the 40°N parallel while the western boundary lies more than 445 kilometers (km) from the Pacific coast of North America at 130°W. The shoreward boundary lies three nautical miles (NM) off the west coasts of northern California, Oregon, and Washington State except in waters of the Olympic A Military Operating Area (MOA), where it runs right along the shoreline (or MHHT). The Puget Sound Study Area also includes waters up to MHHT line (**Figures 1-1** and **1-2**).

The Pacific Northwest OPAREA and Puget Sound Study Area are a component of the Whidbey Island Complex, a complex of several land- and sea-based ranges and OPAREAs including the Darrington OPAREA, Olympic A and B MOAs, Boardman MOA/R-5706, Kodiak, AK (Navy Special Forces, Cold Weather Training Facility), Admiralty Bay Mining Range (R-6701), Lake Hancock, the Ediz Hook Shipboard Electronic Systems Evaluation Facility (SESEF), and 11 distinct warning areas located off the coasts of Oregon and Washington State (**Figures 1-1** and **1-2**).[1]

Another important area in the Pacific Northwest is the Northwest Range Complex. The Northwest Range Complex is comprised of the following marine ranging and instrumented areas:

- Dabob Bay Range Complex (DBRC) which includes the Dabob Bay MOA, two Hood Canal MOAs, and the connecting waters
- Keyport MOA
- Quinault Underwater Tracking Range (QUTR) MOA which is located within the Navy MOA W-237A
- Nanoose Range (joint U.S.-Canadian site)

This complex provides approximately 700 square nautical miles (NM^2) of above water tracking area, as well as over 100 NM^2 of underwater tracking area. The underwater tracking area is equipped with highly accurate underwater tracking arrays. This complex provides a variety of water conditions, bottom types, and depths for the intact recover of undersea vehicles and test data. In addition, there is a deployable tracking system that can provide sensors to broaden the extent of the tracking areas.[2,3]

Naval Air Station (NAS) Whidbey Island is assigned responsibility to manage offshore and inland OPAREAs dedicated for military use through coordination, scheduling, and, if applicable, control of

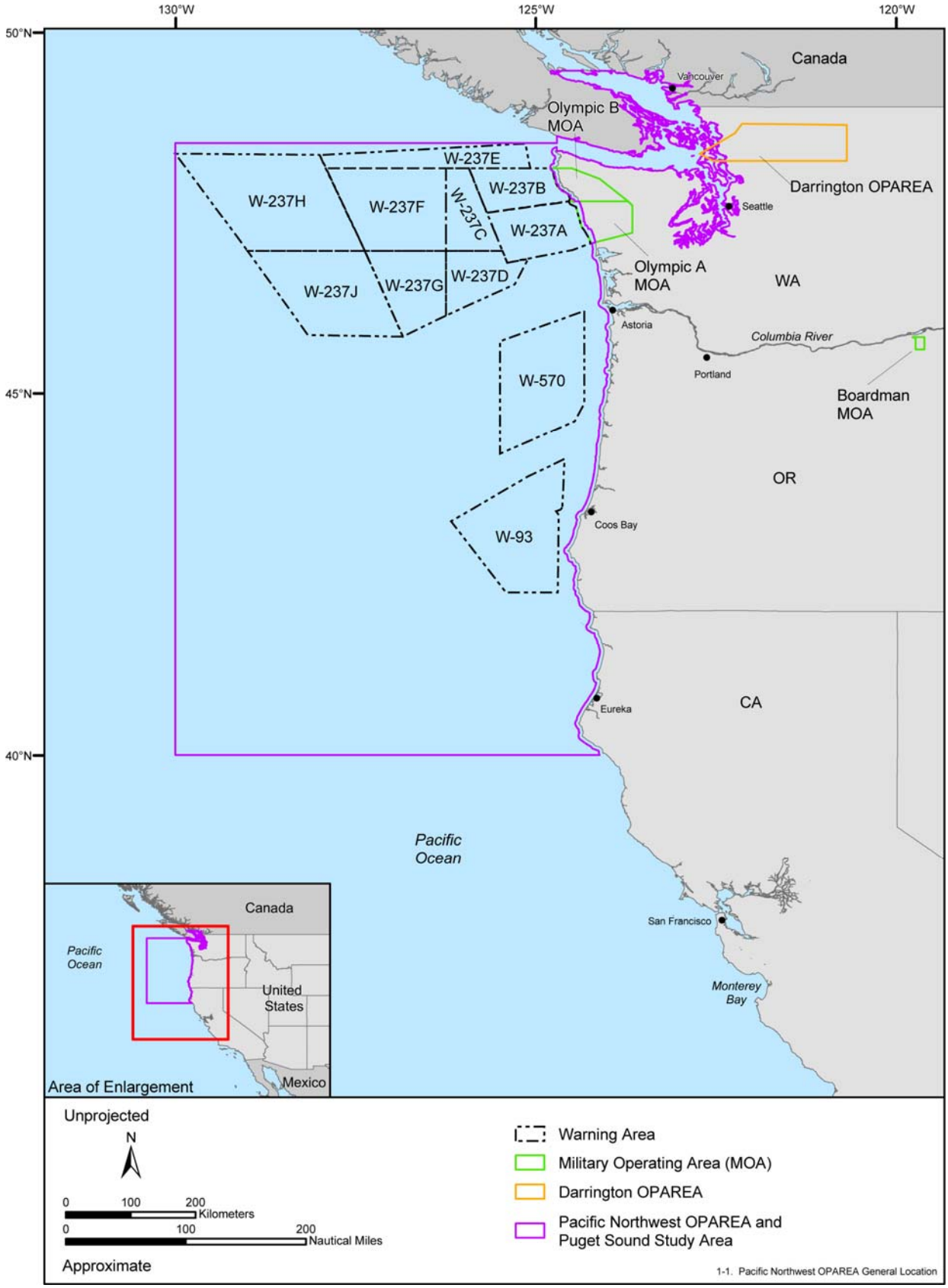

Figure 1-1. The Pacific Northwest OPAREA and Puget Sound Study Area is located in the eastern North Pacific Ocean off the coasts of northern California, Oregon, Washington State, and southern British Columbia. Source data: SRS Technologies, Inc. (2003).

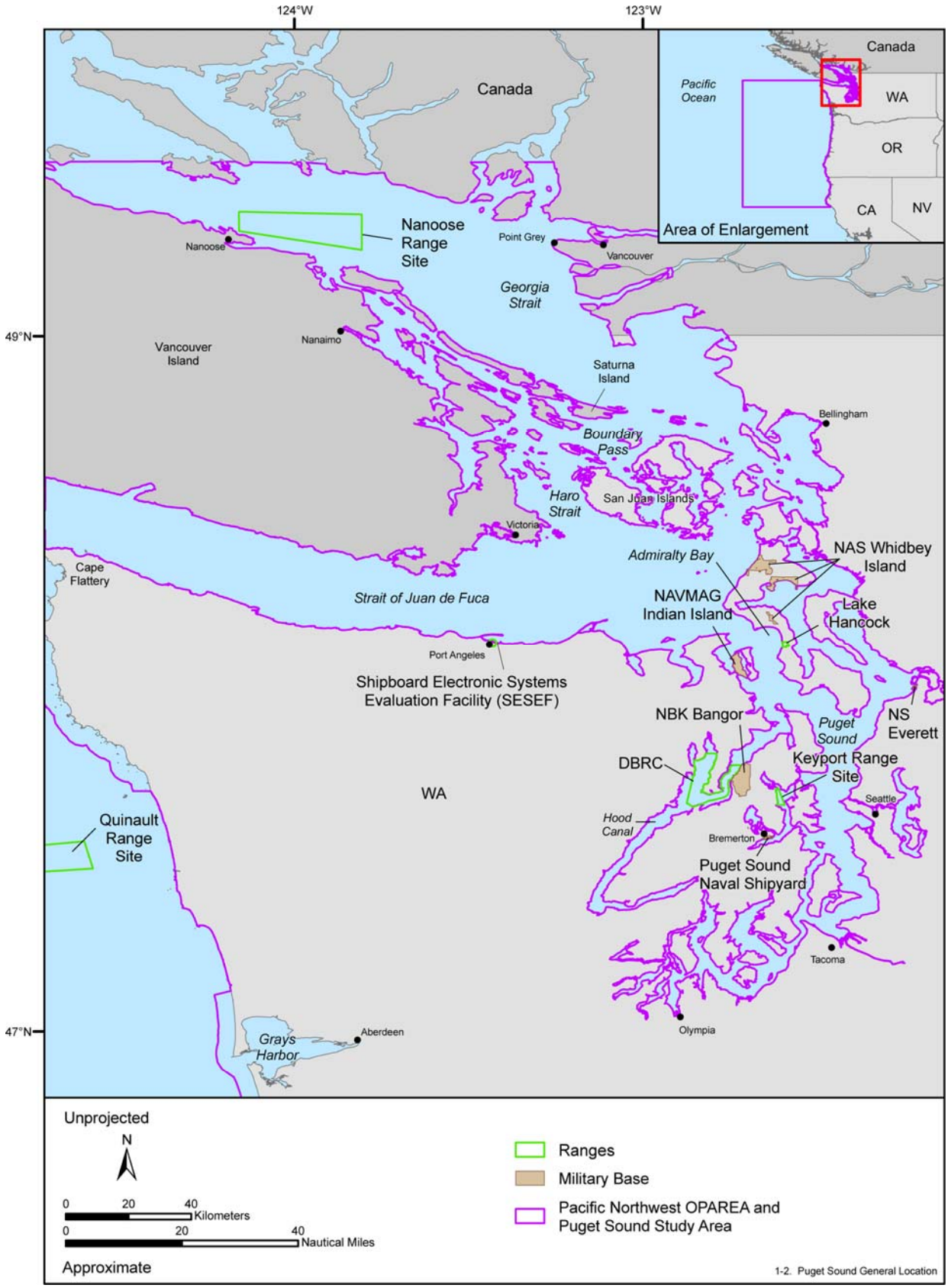

Figure 1-2. A zoom-in view of the Puget Sound Study Area and the inshore areas of the Pacific Northwest OPAREA. Important Navy installations and ranges within the region are also depicted. Source data: SRS Technologies, Inc. (2003, 2006) and DoN (2006).

Table 1-1. The major components of the Pacific Northwest OPAREA and Puget Sound Study Area, and their descriptions (Figures 1-1 and 1-2).

OPAREA/Study Area Components	Description
Washington Coastal Warning Area (W-237; A-J)	Warning Area W-237 consists of nine distinct subareas located off the coast of Washington. These areas are used for joint air/surface operations such as missile firings, air-to-surface bombing, air-to-air firing, combat tactics, intercepts, aerial refueling, instrument training, aerobatics, and formation flight training. W-237 is also a designated undersea warfare (USW) range for coordinated USW operations, sonobuoys, practice depth charges, and smoke markers.
Warning Area 570 (W-570)	Warning Area W-570 is located off the coast of northern Oregon. Air-to-air and air-to-surface firing, bombing, air combat maneuvering, dissimilar air combat tactics, intercepts, and joint military training exercises are conducted in this special use airspace.
Warning Area 93 (W-93)	Warning Area W-93 is located off the coast of southern Oregon. Operations conducted in this area include air-to-air and air-to-surface firing, air combat maneuvering, and joint military training exercises.
Darrington OPAREA	The Darrington OPAREA is located east of NAS Whidbey Island. It is bounded by the U.S.-Canada border to the north, 48°N to the south, 120°W to the east, and 122°W to the west. This area is used for Functional Flight checks.
Olympic MOAs	The Olympic MOAs are located on the Olympic Peninsula. They extend from the Strait of Juan de Fuca south to Hoquiam, and from the Olympic National Park west to the coastline. These areas are used for in-flight air refueling training, flight familiarization, and aircraft combat maneuvering.
Nanoose Range Site*	The Nanoose Range site is a joint U.S.-Canadian facility located on the eastern side of Vancouver Island, British Columbia in the Georgia Strait (about 148 km northwest of NAS Whidbey). This range is maintained and operated by the Naval Undersea Warfare Center Division Keyport (NUWCDIVKPT) and is utilized by all aviation warfare communities. It is also used as a torpedo testing range.
Dabob Bay Range Complex*	The DBRC is located in Puget Sound and contains the Dabob OPAREA, two Hood Canal OPAREAs, and the waters that connect them. The range has a fixed short baseline hydrophone array that is used to meet the Navy's need for test and evaluation of weapon systems, ships, research and development, and fleet training. The range covers 23.3 km^2 and ranges from 36 to 183 m in depth.

Table 1-1. Continued.

OPAREA/Study Area Components	Description
Quinault Range Site*	The Quinault Range site is an underwater tracking range located within Warning Area W-237A off the coast of Washington. This offshore range provides the capability to conduct USW operations, research and development activities, and independent ship qualifications. Services available include torpedo firing exercises, Surface Ship Radiated Noise Measurement trials, submarine Training Readiness Evaluations, and any operations for which precise, in-water spatial data are required.
Keyport Range Site*	The Keyport Range site is located along Washington's coast, adjacent to NUWCDIVKPT, and includes 5.2 km^2 of onshore and nearshore habitat. The purpose of the area is to support undersea training and tests. Training activities include USW, vehicle maintenance, and boat and driver instruction.
Admiralty Bay Mining Range (R-6701)	The Admiralty Mining Range is located off the southwest coast of Whidbey Island between Indian Island and Lake Hancock at Admiralty Bay. This range is frequently used by aviation communities for bombing and torpedo practice.
Lake Hancock Range	Lake Hancock is a 1 km^2 brackish lagoon on the west coast of Whidbey Island. The lagoon developed behind a gravel bar and low dunes, which faces west into Admiralty Inlet; it is surrounded by an extensive area of marsh. The outlets of Lake Hancock have been repeatedly diked. They have been reopened by storms prior to the 1940s when the area became a U.S. Navy bombing range.
Kodiak, AK	Navy Special Forces (Navy Seals) Cold Weather Training Facility.
Ediz Hook SESEF	The SESEF is a land based test facility that was established to facilitate the testing of electromagnetic transmitting and receiving equipment for U.S. Navy, USCG, and Military Sealift Command vessels.

* These areas are included within the Northwest Range Complex.
Source: DoN (2000e; 2003) and GlobalSecurity.org.[1,2,3,4]

surface and air platforms operating to and from these areas. Although Fleet Area Control and Surveillance Facility (FACSFAC) San Diego is designated as the DoN Regional Airspace Coordinator (RAC) in the Pacific Northwest Region, NAS Whidbey Island acts as a direct airspace liaison to the RAC and is responsible for the scheduling and management of all airspace matters that pertain to the Pacific Northwest OPAREA.[1] Several other Navy installations are also located in the Pacific Northwest Region, including Naval Station (NS) Everett, Naval Base Kitsap (NBK) Bangor, NBK Bremerton, Naval Magazine Indian Island, and NUWC Division Keyport (**Figure 1-2**).

One of the most highly studied areas of the Pacific Northwest is Puget Sound, located in northwestern Washington State. Puget Sound is a complex and intricate system of interconnecting channels, inlets, estuaries, and embayments that are the southernmost glacially carved waterways in western North America. The main basin of Puget Sound is a fjord-like estuary that is connected to the Pacific Ocean by the Strait of Juan de Fuca and Admiralty Inlet (Cannon 1983). There, Pacific Ocean waters reach over 100 km inland to provide all-weather ports for ocean-going ships at Seattle, Tacoma, and Olympia. Beginning at Admiralty Inlet, Puget Sound extends approximately 130 km to the south, terminating just north of 40°N. Outside Admiralty Inlet and to the northwest of Whidbey Island lie the San Juan Islands, which are located at the nexus of the Strait of Juan de Fuca and the Georgia Strait. The San Juan Islands and the Gulf Islands of British Columbia comprise more than 700 islands and reefs, of which about 176 are large enough to be named.

The inshore waters that lie between Washington State and British Columbia are a prominent feature of the Pacific Northwest Region. This entire body of water is often referred to as Puget Sound. This body of water is comprised of several separate and distinct water areas, including the Strait of Juan de Fuca, the Georgia Strait, the water area surrounding the San Juan Islands, Haro and Rosario Straits, Hood Canal, and Puget Sound. For the purposes of this MRA, the nearshore waters located between Washington State and British Columbia are collectively referred to as the “Puget Sound Study Area” or “Puget Sound and vicinity.”

An abundance of information on the Pacific Northwest Region and the Navy activities that occur there is contained in the following documents:

- Marine mammal facility: NBK Bangor, Washington (DoN 1988),
- Integrated Natural Resources Management Plan (INRMP): NAS Whidbey Island (DoN 1996a),
- NAS Whidbey Island: Bald eagle management plan (DoN 1996b),
- Final Environmental Impact Statement (EIS)/Management Plan: OCNMS (NOAA 1993),
- Environmental Assessment (EA) for NBK Bangor INRMP (DoN 2000a),
- Final EA: Pier replacement at Naval Undersea Warfare Center Division, Keyport (DoN 2000b),
- Final Biological Assessment (BA): Navy Explosive Ordnance Disposal (EOD) Operations, Puget Sound, Washington (DoN 2000c),
- NBK Bangor INRMP (DoN 2001a),
- Final Environmental Assessment for the ongoing and future operations at Navy Dabob Bay and Hood Canal Military OPAREAs (DoN 2002a),
- INRMP: Fleet and Industrial Supply Center, Puget Sound (DoN 2002b),
- Final Environmental Assessment for the Autonomous Underwater Vehicle (AUV) Fest, Keyport Range, Washington (DoN 2003), and
- EA: Installation and operation of Underwater Surveillance System (USS) at NBK Bangor, Silverdale, Washington (DoN 2005).

1.3 APPLICABLE LEGISLATION

The primary environmental laws that govern Navy activities in the marine environment include the National Environmental Policy Act, the Marine Mammal Protection Act, the Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act. In addition to these federal acts, there are several other federal mandates, EOs, and presidential proclamations that deal with resource conservation and management in ocean waters under U.S. jurisdiction and in foreign waters. The following is a list of the many laws and regulations that the Navy must consider when conducting maritime activities in the Pacific Northwest OPAREA. Environmental laws for California, Oregon, and Washington State are also discussed since the OPAREA and Study Area encompass a number of coastal and estuarine areas that are under state jurisdiction.

1.3.1 Federal Resource Laws

- Congress passed the **Rivers and Harbors Appropriation Act** of 1899 (33 U.S. Code [U.S.C.] §§ 401 et seq.) to restrict the building of structures over or in U.S. navigable waterways. Under Section 9, no bridge, dam, dike, or causeway may be constructed without Congress' approval. Structures contained within a state that have been approved by the state legislature may be built with the approval of the Secretary of Transportation or the Chief of Engineers and the Secretary of the Army. Section 10 prohibits the building of wharfs, piers, and jetties over or in navigable waterways without the approval of Congress. The Chief of Engineers and the Secretary of the Army must approve both structures and excavation in navigable waters.

- The **Migratory Bird Treaty Act** (MBTA) of 1918 (16 U.S.C. §§ 703 et seq.) prohibits the taking, transporting, and harming of migratory birds and their parts, eggs, nests, and young unless permitted by federal regulations. This act implements provisions from the 1916 convention between the U.S. and Great Britain that addressed the protection of migratory birds. Provisions from later conventions with Mexico, Japan, and the Soviet Union are also implemented as amendments to the MBTA. The U.S. Fish and Wildlife Service (USFWS) has the authority to enforce the act's provisions, which includes determining periodically when the taking of migratory birds may occur. State governments may pass laws that increase migratory bird protection as long as open seasons do not extend beyond those set at the national level.

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

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

  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). The purpose of the CEQ is to monitor the progress made towards achieving the goals set forth in Section 101 of NEPA. Other duties of the CEQ include advising the President on environmental issues and providing guidance to other federal agencies on compliance with NEPA.

  Section 102(2) of NEPA contains "action-forcing" provisions that ensure that federal agencies act according to the letter and spirit of the law. Federal agencies are required to give appropriate consideration to the environmental effects of their decision-making and must prepare detailed EAs or EISs to evaluate the potential impacts of proposed legislation or other major federal actions on 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 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). As a matter of policy, the DoN complies with the NEPA for proposed actions that could produce significant effects within 12 NM, or 22 km, of the U.S. coast.

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

- The **Coastal Zone Management Act** (CZMA) of 1972 (16 U.S.C. §§ 1451 et seq.) established a voluntary national program through which U.S. states and territories can develop and implement coastal zone management plans. The National Oceanic and Atmospheric Administration (NOAA), under the Secretary of Commerce, administers this act. States and territories use coastal zone management plans "to manage and balance competing uses of and impacts to any coastal use or

resource" (NOAA 2000). A coastal zone management plan must be given federal approval before the state or territory can implement the plan. The plan must include, among other things, defined boundaries of the coastal zone, identified uses of the area that the state/territory will regulate, a list of mechanisms that will be employed to control the regulated uses, and guidelines for prioritizing the regulated uses. Currently, there are 34 U.S. states and territories with federally approved coastal zone management plans. These states and territories manage over 153,500 km (99.9%) of U.S. shoreline along the Atlantic, Pacific, and Arctic Oceans as well as the Great Lakes. Washington State's coastal zone management program received federal approval from the NOAA in 1976, while those of Oregon and California were approved in 1977. The California Coastal Commission (CCC), the Oregon Department of Land Conservation and Development, and the Washington State Department of Ecology are the lead agencies that have regulatory authority over all federal activities, licenses, and funding approvals for projects that affect the coastal zone resources of these states.[5,6]

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

- The **Endangered Species Act** (ESA) of 1973 (16 U.S.C. §§ 1531 et seq.) established protection over and conservation of threatened and endangered species and the ecosystems upon which they depend. An "endangered" species is a species that is in danger of extinction throughout all or a significant portion of its range, while a "threatened" species is one that is likely to become endangered within the foreseeable future throughout all or in a significant portion of its range. All federal agencies are required to implement protection programs for threatened and endangered species and to use their authority to further the purposes of the ESA. The NMFS, also known as the NOAA Fisheries Service, and the 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 2004h). 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 2004h).

  In some cases, a specific population of a species, instead of the entire species itself, may be the listed entity (e.g., (Teaney 2004). For example, the Southern Resident Killer Whales (SRKW), which is a population segment of the killer whale, was recently listed as endangered under the ESA. The ESA defines "species" as "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Therefore, the SRKW is a listed "species" under the ESA.

  A species or population segment may be a candidate for listing as a threatened or endangered 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.

The **National Defense Authorization Act** is an amendment to the ESA. It has recently redefined critical habitat to exclude lands owned or controlled by the DoD or designated for its use, if they are subject to INRMPs that benefit listed species or are determined to have national security impacts that outweigh the benefit of critical habitat designations (U.S. Congress 2004). Military lands that are exempt from critical habitat designation based upon either INRMP status or national security impacts include:

- Naval Submarine Base, Bangor;
- Naval Undersea Warfare Center,Keyport;
- Naval Ordnance Center, Port Hadlock (Indian Island);
- Naval Radio Station, Jim Creek;
- Naval Fuel Depot, Manchester;
- Naval Air Station Whidbey Island;
- Naval Air Station, Everett;
- Bremerton Naval Hospital;
- Keyport facilities and Fort Lewis, Washington;
- Pier 23 (Army);
- Yakima Training Center (Army);
- Puget Sound Naval Shipyard;
- Naval Submarine Base Bangor security zone;
- Strait of Juan de Fuca naval air to-surface weapon range, restricted area;
- Hood Canal and Dabob Bay naval non-explosive torpedo testing area;
- Strait of Juan de Fuca and Whidbey Island naval restricted areas;
- Admiralty Inlet naval restricted area;
- Port Gardner Naval Base restricted area;
- Hood Canal naval restricted areas;
- Port Orchard Passage naval restricted area;
- Sinclair Inlet naval restricted areas;
- Carr Inlet naval restricted areas;
- Dabob Bay/Whitney Point naval restricted area;
- Port Townsend/Indian Island/Walan Point naval restricted area; and
- Naval Undersea Warfare Center Division, Newport, Washington (Dabob Bay and Crescent Harbor).

Section 4(a)(3)(B)(i) of the ESA (16 U.S.C. 1533(a)(3)(B)(i) states "The Secretary shall not designate as critical habitat any lands or other geographical areas owned or controlled by the DoD, or designate for its use, that are subject to an integrated natural resources management plan prepared under section 101 of the Sikes Act (16 U.S.C. 670a), if the Secretary determines in writing that such plan provides a benefit to the species for which critical habitat is proposed for designation" (NMFS 2005h).

There are 33 marine mammals (26 cetaceans, 6 pinnipeds, and one sea otter), four sea turtles, and a multitude of birds, fishes, and invertebrates with known or potential occurrence in the Pacific

Northwest OPAREA. Of these, 10 marine mammals, four sea turtles, five birds, and six fishes are listed as endangered, threatened, proposed threatened, or species of concern (**Table 1-2**). For the marine mammals, the NMFS has jurisdiction over cetaceans and pinnipeds while the USFWS has jurisdiction over sea otters. 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). The USFWS has sole jurisdiction over the birds. The NMFS and USFWS share jurisdiction over the fish species (see Chapter 4, **Table 4-1**), with the NMFS having jurisdiction over individuals in marine environments (oceans) and the USFWS having jurisdiction over individuals in freshwater environments (streams and rivers).

- The **Boldt Decision**, or *United States v. Washington*, was a controversial 1974 court case in which U.S. District Judge Boldt granted the right of half of the annual salmon harvest in Washington State to Native American tribes which had signed treaties with the U.S. government. The treaties with the Washington tribes were agreements made in the 1850s to move the tribes to reservations to make way for white settlers. Boldt determined that the treaties reasserted Native American rights to half of the harvestable surplus of fish passing their "usual and accustomed (U&A) grounds and stations" in perpetuity. The Supreme Court affirmed the substance of the Boldt decision following several years of resistance on the part of Washington State (U.S. versus Washington 1974).[22]

- The **Fishery Conservation and Management Act** (FCMA) of 1976 (16 U.S.C. §§ 1801 et seq.), later renamed the **Magnuson-Stevens Fishery Conservation and Management Act** (MSFCMA), established a 200 NM fishery conservation zone in U.S. waters and a network of regional Fishery Management Councils (FMC). The FMCs are comprised of federal and state officials, including the USFWS, which oversee fishing activities within the fishery management zone. The act also establishes national standards (e.g., optimum yield, scientific information, allocations, efficiency, and costs/benefits) for fishery conservation and management. In 1977, the multifaceted regional management system began allocating harvesting rights, with priority given to domestic enterprises. Since a substantial portion of fishery resources in offshore waters was allocated for foreign harvest, these foreign allocations were eventually reduced as domestic fish harvesting and processing industries expanded under the domestic preference authorized by the MSFCMA. At that time, exclusive federal management authority over U.S. domestic fisheries resources was vested in the NMFS.

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

- In 1977, Congress addressed the heightened concern over water pollution by amending the **Federal Water Pollution Control Act** (FWPCA) of 1948 (33 U.S.C. §§ 1251 et seq.). The 1977 amendments, known as the **Clean Water Act** (CWA), extensively amended the FWPCA. The CWA took the first step towards establishing a comprehensive solution to the country's serious water pollution problems. Through standards, technical tools, and financial assistance, the CWA works towards the accomplishment of two goals: (1) to make U.S. waters fishable and swimmable and (2) to eliminate contaminant discharge into such waters. Under the authority of the Environmental Protection Agency (EPA), the CWA sets water quality standards for all pollutants, requires a permit for the discharge of pollutants from a point source, and funds sewage treatment plant construction. Section 401 of the CWA requires that all applicants for a federal permit or license for activities that may result in a discharge to a water body obtain State Water Quality Certification stating that the proposed activity will comply with state water quality standards. Section 403 sets out permit guidelines specific to the discharge of contaminants into the territorial sea, the contiguous zone, and waters further offshore, while Section 404 establishes permit guidelines for the discharge of dredged or fill material into U.S.

Table 1-2. The ESA designated species with known or potential occurrence in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.

Taxon Group	Scientific Name	ESA Status[a]
Marine Mammals		
North Pacific right whale	*Eubalaena japonica*	E
Humpback whale	*Megaptera novaeangliae*	E
Sei whale	*Balaenoptera borealis*	E
Fin whale	*Balaenoptera physalus*	E
Blue whale	*Balaenoptera musculus*	E
Sperm whale	*Physeter macrocephalus*	E
Killer whale	*Orcinus orca*	E[b]
Guadalupe fur seal	*Arctocephalus townsendi*	T
Steller sea lion	*Eumetopias jubatus*	T[c]
Sea otter	*Enhydra lutris*	T
Sea Turtles		
Leatherback turtle	*Dermochelys coriacea*	E
Green turtle	*Chelonia mydas*	T[d]
Loggerhead turtle	*Caretta caretta*	T
Olive ridley turtle	*Lepidochelys olivacea*	T[d]
Birds		
Bald eagle	*Haliaeetus leucocephalus*	T[e]
California brown pelican	*Pelecanus occidentalis californicus*	E
Marbled murrelet	*Brachyramphus marmoratus marmoratus*	T
Short-tailed albatross	*Phoebastria albatrus*	E
Western snowy plover	*Charadrius alexandrinus nivosus*	T
Fishes		
Chinook salmon	*Oncorhynchus tshawytscha*	E/T/C[f]
Coho salmon	*Oncorhynchus kisutch*	E/T/PT/C[g]
Chum salmon	*Oncoryhnchus keta*	T[h]
Sockeye salmon	*Oncorhynchus nerka*	E/T[i]
Steelhead trout	*Oncorhynchus mykiss*	E/T/C[j]
Bull trout	*Salvelinus confluentus*	T

[a] E = Endangered, T = Threatened, PT = Proposed Threatened, C = Species of Concern.
[b] The Southern Resident Killer Whale population that occurs in the OPAREA and Study Area is listed as endangered while the other three populations of killer whales that are also found in the OPAREA and Study Area are not listed.
[c] The species as a whole is listed as threatened; the eastern population which is expected in the OPAREA and Study Area is listed as threatened while the western population which is not expected to occur here is listed as endangered.
[d] 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. 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 all green and olive ridley turtles found in the OPAREA and Study Area are endangered.
[e] In 1999, the USFWS proposed to remove the bald eagle from the Endangered Species List. At present, the delisting proposal is still pending.
[f] There are 17 chinook salmon ESUs found along the U.S. Pacific coast, each with its own status under the ESA. Of these, two are endangered, seven are threatened, and one is a species of concern.
[g] There are seven coho salmon ESUs found along the U.S. Pacific coast, each with its own status under the ESA. Of these, one is endangered, two are threatened, one is proposed threatened, and one is a species of concern.
[h] There are four chum salmon ESUs found along the U.S. Pacific coast, each with its own status under the ESA. Of these, two are threatened.
[i] There are seven sockeye salmon ESUs found along the U.S. Pacific coast, each with its own status under the ESA. Of these, one is endangered and one is threatened.
[j] There are 15 steelhead trout ESUs found along the U.S. Pacific coast, each with its own status under the ESA. Of these, two are endangered, eight are threatened, and one is a species of concern.

navigable waters at specified disposal sites. The U.S. Army Corps of Engineers (USACE), through issuance of CWA Section 401 and 404 permits, is the regulatory agency that approves all discharges of dredge or fill material into U.S. waters, especially water bodies with high resource value such as wetlands, riparian areas, and headwaters.[7,8]

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

- The **Northern Pacific Halibut Act** of 1982 (16 U.S.C. §§ 773-773k) calls for the U.S. and Canada to implement the 1979 Protocol for the Preservation of the Halibut Fishery of the Northern Pacific Ocean and the Bering Sea. The Act provides for the appointment of U.S. Commissioners to the International Pacific Halibut Commission (IPHC). In addition, the Act authorizes the Pacific Fishery Management Council to develop regulations to limit access regulations and govern the Pacific halibut catch in waters off Washington, Oregon, and California. All Council action must be approved and implemented by the U.S. Secretary of Commerce.

- In 1984, Congress passed the **National Fishery Enhancement Act** (NFEA; 33 U.S.C. §§ 2101 et seq.) in recognition of the social and economic value of artificial reefs in enhancing fishery resources. Under this act, the Secretary of Commerce and the USACE are charged with the responsibility for encouraging and regulating artificial reefs in the navigable waters of the U.S. (NOAA 2003). One of the primary directives of the NFEA was the preparation of a long-term National Artificial Reef Plan (NARP; 33 U.S.C. §§ 2103). Section 202 of the act recognizes the harmful effects of overfishing on fishery resources and proposes that properly designed, constructed, and located artificial reefs could enhance the habitat and diversity of these fishery resources. The NARP, which underwent revision in 2002, was implemented in November 1985 to provide guidance and/or criteria on various aspects of artificial reef use, including types of construction materials and planning, siting, designing, permitting, installing, maintaining, and managing artificial reefs (NMFS 2002c). One of the most significant recommendations in the NARP encouraged the development of state-specific artificial reef plans (Gordon 1993).

- The **Pacific Salmon Treaty** (PST) of 1985 (16 U.S.C. §§ 3631 et seq.) was established between Canada and the U.S. to establish a framework for managing salmon populations between the two countries. The Treaty principles were to (a) prevent overfishing and provide for optimum production; and (b) provide equivalent production benefits from salmon originating from the respective country's waters. The Treaty requires U.S. and Canada to meet international conservation and allocation objectives by taking into account ways of reducing interceptions and avoiding disruption of existing fisheries and stock abundances.

  This Treaty also called for the establishment of the Pacific Salmon Commission (PSC), to oversee the implementation of the Treaty. The PSC is comprised of representatives of both countries to provide regulatory and technical advice. Fisheries regulation is a shared responsibility of the U.S. and Canada.

  On June 30, 1999, the following PST provisions were implemented: (a) establish abundance-based fishing regimes for Pacific salmon fisheries under the jurisdiction of the PST; (b) create two bilaterally-based funds to promote cooperation, improve fishery management, and aid stock and habitat enhancement. Additionally, the PST includes provisions to enhance bilateral cooperation, improve the scientific basis for salmon management, and apply institutional changes to the PSC.

- Like the CWA, the **Marine Plastic Pollution Research and Control Act** (MPPRCA) of 1987 (33 U.S.C. §§ 1901 et seq.) also regulates the discharge of contaminants into the ocean. Under this federal statute, the discharge of any plastic materials (including synthetic ropes, fishing nets, plastic

bags, and biodegradable plastics) into the ocean is prohibited. The discharge of other materials, such as floating dunnage, food waste, paper, rags, glass, metal, and crockery, is also regulated by this act. Ships are permitted to discharge these types of refuse into the water, but they may only do so when beyond a set distance from shore, as prescribed by the MPPRCA. An additional component of this act requires that all ocean-going, U.S. flag vessels greater than 12.2 m in length, as well as all manned, fixed, or floating platforms subject to U.S. jurisdiction, keep records of garbage discharges and disposals.[9]

- Passage of the **Oil Pollution Act** (OPA) of 1990 (33 U.S.C. §§ 2701 et seq.) further increased the protection of our nation's oceans. In addition to amending the CWA, this act also details new policies relating to oil spill prevention and cleanup methods. Any party that is responsible for a vessel, offshore facility, or deepwater port that could potentially cause an oil spill must maintain proof of financial responsibility for potential damage and removal costs. The act details which parties are liable in a variety of oil spill circumstances and what damage and removal costs must be paid. The President has the authority to use the Oil Spill Liability Trust Fund to cover these costs when necessary. Any cost for which the fund is used must be in accordance with the National Contingency Plan, which is an oil and hazardous substance pollution prevention plan established by the CWA. Federal, state, Indian tribe, and foreign trustees must assess the natural resource damages that occur from oil spills in their trusteeships and develop plans to restore the damaged natural resources. This act also establishes the Interagency Coordinating Committee on Oil Pollution Research, whose purpose is to research and develop plans for natural resource restoration and oil spill prevention.[10]

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

- In 1996, the MSFCMA was reauthorized and amended by the **Sustainable Fisheries Act** (SFA). The SFA provides a new habitat conservation tool in the form of the EFH mandate. The EFH mandate requires that the regional FMCs, through federal Fishery Management Plans (FMP), describe and identify EFH for each federally managed species, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitats. Congress defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. §§ 1802[10]). The term "fish" is defined in the SFA as "finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds." The regulations for implementing EFH clarify that "waters" include all aquatic areas and their biological, chemical, and physical properties, while "substrate" includes the associated biological communities that make these areas suitable fish habitats (50 CFR 600.10). Habitats used at any time during a species' life cycle (i.e., during at least one of its lifestages) must be accounted for when describing and identifying EFH (NMFS 2002b).

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

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

- In response to the growing harmful algal bloom (HAB) and hypoxia problems, Congress passed the **Harmful Algal Bloom and Hypoxia Research and Control Act** (HABHRCA) of 1998 (Public Law [P.L.] 105-383). This statute formed an Inter-Agency Task Force on HABs and Hypoxia. The task force must compose a national assessment on the ecological and economic impacts of HABs, the same type of assessment for hypoxia, and a separate assessment for hypoxia in the Gulf of Mexico. All three assessments must also include plans on how to reverse these growing problems and detail the socioeconomic consequences of such solutions. The act appropriates a certain amount of funds to the Secretary of Commerce to use for the education, research, and monitoring needed to carry out the act's directives. In 2000, the National Science and Technology Council Committee on Environment and Natural Resources released its *National Assessment of Harmful Algal Blooms in U.S. Waters* (Luttenberg et al. 2000).

- The federal government furthered its estuary protection efforts by passing the **Estuary Restoration Act** (ERA) of 2000 (33 U.S.C. §§ 2901 et seq.). This act establishes the Estuary Habitat Restoration Council, a federal interagency council that must develop a national estuary habitat restoration strategy. Private entities propose projects to the council that must meet certain criteria and fulfill the council's strategy. The council chooses projects to recommend to the USACE. Projects recommended to the USACE are selected for implementation based on another set of criteria. The federal government pays up to 65% of the project costs, excluding operation and maintenance costs. The ultimate goal of the act is to restore 405,000 hectares (ha) of estuary habitat by 2010.

- In 2000, the **Shark Finning Prohibition Act** (16 U.S.C. § 1857(1)(P)) amended the MSFCMA to prohibit any person under U.S. jurisdiction from engaging in the finning of sharks, possessing shark fins aboard a fishing vessel without the corresponding carcass, and landing sharks without the corresponding carcass. This act also requires NMFS to issue regulations to implement the Act. The final rule published on February 11, 2002, prohibits any foreign fishing vessels from engaging in shark finning in U.S. EEZ, from landing shark fins without the corresponding carcass into a U.S. port, and from transshipping shark fins in U.S. EEZ.

1.3.2 Executive Orders and Presidential Proclamations

- **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 NEPA to the international stage. Under EO 12114, federal agencies that engage in major actions that significantly affect a non-U.S. environment must prepare an EA of the action's effects on that environment. This is similar to an EIS or EA developed under NEPA for actions conducted in areas under U.S. jurisdiction. Certain actions, such as intelligence activities, disaster and emergency relief actions, and actions that occur in the course of an armed conflict, are exempt from this order. Such exemptions do not apply to major federal actions that significantly affect an environment that is not within any nation's jurisdiction, unless permitted by law. The purpose of the order is to force federal agencies to consider the effects their actions have on international environments.

- **EO 12962 on Recreational Fisheries** (60 Federal Register [FR] 30769) was enacted in 1995 to ensure that federal agencies strive to improve the "quantity, function, sustainable productivity, and distribution of U.S. aquatic resources" so that recreational fishing opportunities nationwide can increase. The overarching goal of this order is to promote the conservation, restoration, and

enhancement of aquatic systems and fish populations by increasing fishing access, education and outreach, and multi-agency partnerships. The National Recreational Fisheries Coordination Council (NRFCC), co-chaired by the Secretaries of the Interior and Commerce, is charged with overseeing federal actions and programs that are mandated by this order. The specific duties of the NRFCC include: (1) ensuring that the social and economic values of healthy aquatic systems, which support recreational fisheries, are fully considered by federal agencies; (2) reducing duplicative and cost-inefficient efforts among federal agencies; and (3) disseminating the latest information and technologies to assist in the conservation and management of recreational fisheries. In June 1996, the NRFCC developed a comprehensive Recreational Fishery Resources Conservation Plan (RFRCP) specifying what member agencies would do to achieve the order's goals. In addition to defining federal agency actions, the plan also ensures agency accountability and provides a comprehensive mechanism to evaluate achievements. A major outcome of the RFRCP has been the increased utilization of artificial reefs to better manage recreational fishing stocks in U.S. waters.[11,12]

- **EO 13089 on Coral Reef Protection** (63 FR 32701) was issued in 1998 "to preserve and protect the biodiversity, health, heritage, and social and economic value of U.S. coral reef ecosystems and the marine environment." This EO directs all federal agencies to protect coral reef ecosystems to the extent feasible and instructs particular agencies to develop coordinated science-based plans to restore damaged reefs as well as mitigate current and future impacts on reefs, both in the U.S. and around the globe (Agardy 2000). This order also established the interagency U.S. Coral Reef Task Force, which is co-chaired by the Secretary of the Interior and the Secretary of Commerce through the Administrator of the NOAA.

- **EO 13158 on Marine Protected Areas** (MPAs; 65 FR 34909) was put into law in 2000 and is a furtherance of EO 13089. It created the framework for a national system of MPAs. The term MPA is defined in this EO as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Since its enactment, this EO has strengthened governmental interagency cooperation in protecting the marine environment. It also calls for improving the management of existing MPAs, the creation of new MPAs, and the prevention of harm to marine ecosystems by federally approved, conducted, or funded activities (Agardy 2000). Currently, the NOAA is redefining the criteria used to designate MPAs and has recently reclassified all existing MPAs as "marine managed areas." A more in-depth discussion on the NOAA's process of redefining MPAs is included in Chapter 5.

- **EO 13175 on Consultation and Coordination with Tribal Governments** (65 FR 67249-67252) was passed in 2000 to establish collaboration with Indian Tribal governments to develop federal regulatory practices; reduce the imposition on unfunded mandates on Indian Tribal governments; and streamline the application process and availability of waivers to Indian Tribal governments.

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

- **Presidential Proclamation No. 7264** (3 CFR 7264), issued by President William Clinton in January 2000, established the California Coastal National Monument for the purpose of protecting the islands, rocks, exposed reefs, and pinnacles above mean high tide found within 12 NM of the California shoreline. These habitats serve as havens for ecologically significant populations of marine mammals

and birds, including sea otters, Guadalupe fur seals, California sea lions, Steller sea lions, California brown pelicans, and California least terns. Encompassing the state's nearshore ocean zone, the California Coastal National Monument is rich in biodiversity and holds many species of scientific interest that can be particularly sensitive to disturbance. Under this proclamation, the Secretary of the Interior is charged with managing the monument through the Bureau of Land Management (BLM).

1.3.3 California State Laws

- The **Porter-Cologne Water Quality Control Act** of 1969, which was most recently amended in 2005, established the State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards as the principal agencies responsible for coordinating and controlling water quality in California. Each of these boards falls under the direction of the California EPA, which is the state-level agency ultimately in charge of enforcing water quality standards under the federal CWA. The mission of the SWRCB is to ensure the highest reasonable quality for waters of the state, while allocating those waters to achieve the optimum balance of beneficial uses. The joint authority of water allocation and water quality protection enables the SWRCB to provide comprehensive protection for all of California's waters, from inland rivers to coastal marine environments. Through the SWRCB and its nine regional boards, the state adopts basin plans, reviews and certifies federal permits and licenses for wastewater discharge, issues wastewater discharge requirements, and enforces water quality laws and regulations (SWRCB 2003).

- The **California Endangered Species Act** (CESA) of 1970, reamended in 1984, is part of the California Fish and Game Code and is administered by the California Department of Fish and Game (CDFG). The provisions included in the CESA generally parallel those in the federal ESA although, unlike its federal counterpart, the CESA also applies take prohibitions to species petitioned for listing (i.e., state candidates). **The Natural Community Conservation Planning Act** (NCCPA) was added to the CESA in 1991 (California Fish and Game Code §§ 2800-2840). This act calls for voluntary cooperation among the CDFG, landowners, and other interested parties to develop natural community conservation plans that provide for early coordination of efforts to protect listed or candidate species. The primary purpose of the NCCPA is to preserve species and their habitats while allowing reasonable and appropriate development to occur on affected lands.[18]

- The **California Coastal Act** (CCA) of 1976 provides long-term protection of California's 1,760 km coastline for the benefit of current and future generations. This act created a unique partnership between the state's coastal management agency, the CCC, and local governments (the state's 15 coastal counties and 58 coastal cities) to manage the conservation and development of coastal resources through a comprehensive planning and regulatory program. The policies of this act include (1) protection and expansion of public access to the shoreline and recreational opportunities, (2) protection, enhancement, and restoration of environmentally sensitive habitats, (3) protection of productive agricultural lands, commercial fisheries, and archaeological resources, (4) protection of coastal landscapes and seascapes, (5) establishment of housing and development standards to avoid urban sprawl, (6) provision for the expansion of environmentally-friendly industrial ports and power plants, and (7) protection against loss of life and property from coastal hazards. The CCC uses these policies when reviewing federal agency activities that affect California's coastal zone (CCC 1999).

- The **Marine Life Protection Act** (MLPA) of 1999 is also administered by the CDFG under the California Fish and Game Code. This act directs the state to design and manage an improved network of MPAs in order to protect marine life and habitats, marine ecosystems, and marine natural heritage, as well as improve recreational, educational, and study opportunities provided by marine ecosystems. The MLPA further requires that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines. The overarching purpose of the MLPA is to improve the existing array of MPAs in California waters through the adoption of a Marine Life Protection Program and a comprehensive master plan. In 2004, the CDFG, the California Resources Agency, and the Resources Legacy Fund Foundation entered into a MOU to create a program called the MLPA Initiative. This initiative is a

renewed commitment to implement the MLPA by incorporating previous work accomplished by the CDFG, the master plan team, and the regional working groups into a new process that builds upon prior efforts and provides necessary scientific and technical resources to ensure the successful completion of a statewide network of MPAs by 2011.[19]

1.3.4 Oregon State Laws

- The **Oregon Ocean Resources Management Act** of 1991 (ORS 196.405-196.515) designated the Oregon Department of Land Conservation and Development as the lead agency for ocean planning and created the Oregon Ocean Resources Management Program to ensure the conservation and development of Oregon's ocean resources. This Act also established the Ocean Policy Advisory Council (OPAC) which is responsible for giving coordinated policy advice to the Governor, state agencies, and others and preparing a Territorial Sea Plan for management of resources and uses of Oregon's territorial seas and ocean shores. The Act was amended in 2003 with the OPAC House Bill 3534 which restructured Oregon's Ocean Resources Management Program and revised statutes relating to the OPAC. The amendment also designated the State Department of Fish and Wildlife, instead of the Department of Land Conservation and Development, as liaison to NOAA and made the OPAC part of the State Department of Fish and Wildlife.[20,21]

1.3.5 Washington State Laws

- **Washington Administrative Code (WAC) 220-110-250** is a Hydraulic Code rule adopted by the Washington Department of Fish and Wildlife in 1994 to identify saltwater habitats of special concern. It provides protection for all fish life (e.g., surf smelt, Pacific sand lance, rock sole, Pacific herring, rockfish, lingcod, and juvenile salmonids) and habitats of special concern (e.g., juvenile salmonid migration corridors, eelgrass beds, macroalgae, intertidal wetlands, and juvenile rockfish and lingcod nursery areas) through the development of a statewide system of consistent and predictable rules. WAC 220-110-250 establishes regulations for the construction of hydraulic projects or performance of other work that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state, and sets forth procedures for obtaining a hydraulic project approval (HPA). Information concerning the location of habitats of special concern is available on request to the habitat management division of the department of fish and wildlife (Small and Carman 2005; WAC[23]).

- **Washington Administrative Code (WAC) 220-110-271** is a Hydraulic Code rule adopted by Washington Department of Fish and Wildlife in 1994 to restrict work times in saltwater areas. These restrictions apply to 17 tidal reference areas. It protects juvenile salmonid migration, feeding, and rearing areas; surf smelt, herring, sand lance, and rock sole spawning beds; and lingcod settlement and nursery areas. In addition, these timing restrictions may be applied for the protection of other important fish species or particular site.[24]

- **Washington Administrative Code (WAC) 232-12-297** is the primary law for the protection and management of endangered species in Washington State. It aims to identify and classify native wildlife species (excluding plants) that are in need of protection and/or management and to define the process by which listing, management, recovery, and delisting of those species can be achieved. This law was established to ensure that consistent procedures and criteria are followed when classifying wildlife as endangered, threatened, or sensitive. In many ways, this law mirrors the federal ESA. If a species is listed as endangered or threatened under the federal ESA, this law recommends that it be listed as endangered or threatened at the state level. However, unlike the federal ESA, listing of a species is based solely on its biological status, which is determined using scientific data only. Also, although recovery plans are required for all species listed as endangered or threatened, critical habitat designations and agency consultations are not.[13]

- **Revised Code of Washington (RCW) 77.110.030** is Washington State's policy for the management of natural resources. It declares that conservation, enhancement, and proper utilization of the state's natural resources, including but not limited to lands, waters, timber, fish, and game, are responsibilities of the State of Washington and shall remain within the express domain of the State of

Washington. Although the law fully respects private property rights, it deems that all resources in the state's domain are to be managed by the state alone such that conservation, enhancement, and proper utilization are the primary considerations. Under this law, no citizen shall be denied equal access to and use of any resource on the basis of race, sex, origin, cultural heritage, or by and through any treaty based upon the same.[14]

- The **Wild Salmonid Policy** was developed in response to the depressed status of wild salmonid populations in Washington. The purpose is to protect, restore, and enhance the productivity, production, and diversity of wild salmonids and their ecosystems to sustain ceremonial, subsistence, commercial, and recreational fisheries; nonconsumptive fish benefits; and other related cultural and ecological values.

- **Washington State's Shoreline Management Act (SMA) (RCW 90.58)** was adopted in 1972 with the goal of "prevent[ing] the inherent harm in an uncoordinated and piecemeal development of the state's shorelines." The provisions of this law are designed to manage shoreline development to preserve and enhance public access or recreational opportunities and at the same time protect water quality and the natural environment. The SMA states that "the interests of all the people shall be paramount in the management of shorelines of statewide significance." The protected shorelines in Washington State include the Pacific Coast, Hood Canal, and certain Puget Sound shorelines; all waters of the Puget Sound and Strait of Juan de Fuca; lakes/reservoirs; larger rivers; and all wetlands (Gates 1999).

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, symposium proceedings, project reports, threatened and endangered species recovery plans, stock assessment reports, EAs, EISs, FMPs, Navy INRMPs, 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 Pacific Northwest OPAREA and Puget Sound Study Area (all of which are mentioned below). Since the northern portion of the OPAREA and Study Area extends into Canada's Exclusive Economic Zone (EEZ), data were also obtained to characterize the marine resources in southwestern British Columbia, especially for nearshore areas that lie within the Study Area boundaries.

To investigate the physical environment and habitats of the OPAREA and Study Area; to summarize the occurrence patterns of federally protected species; to determine the locations of EFH; to describe the region's commercial, recreational, and tribal fisheries; and to ascertain the distribution of U.S. maritime boundaries, commercial shipping lanes, MMAs, and other concerns, data and information were either acquired or requested from the following sources:

- Academic and educational/research institutions (Blue Ocean Institute, Cascadia Research Collective [CRC], Center for Whale Research, LGL Limited Environmental Research Associates, Los Angeles County Museum of Natural History, Marine Conservation Biology Institute, Monterey Bay Aquarium, Moss Landing Marine Laboratory, Orca Network, Oregon State University [includes Oregon Cooperative Wildlife Research Unit], Pacific WildLife Foundation [formerly West Coast Whale Research Foundation], Puget Sound Action Team, Puget Sound Restoration Fund, San Diego State University, Scripps Institution of Oceanography, TerraLogic GIS, Tetra Tech EM Inc., Texas A&M University, Universidad Autónoma de Baja California, University of Alaska at Fairbanks, University of British Columbia, University of California at Santa Barbara, University of California at Santa Cruz, University of California at San Diego [includes California Sea Grant], University of Washington,

Vancouver Aquarium [includes the British Columbia Cetacean Sightings Network], Wider Caribbean Sea Turtle Conservation Network [WIDECAST], WiLDCOAST);

- The Internet, including various databases and related websites (Allen Press, Blackwell-Science, Elsevier, FR, FishBase, Food and Agriculture Organization [FAO], Google, MPA Global, National Sea Grant Library, NMFS, NOAA, North Pacific Fishery Management Council [NPFMC], Ocean Biogeographic Information System - Spatial Ecological Analysis of Megavertebrate Populations [OBIS-SEAMAP], OCNMS, Pacific Coast Fisheries Information Network [PacFIN], Pacific Fishery Management Council [PFMC], Recreational Fisheries Information Network [RecFIN], ReefBase, Science Direct, seaturtle.org, University of Florida Sea Turtle Bibliography, and USGS);

- U.S. federal agencies and commissions (DoD: DoN, Department of the Air Force [DoAF]; Department of Energy [DoE]: Oak Ridge National Laboratory, Pacific Northwest National Laboratory; Department of the Interior [DoI]: BLM - MMS, USFWS, USGS; Department of Transportation [DoT]; Marine Mammal Commission; National Aeronautic and Space Administration [NASA]; NOAA: National MPA Center, National Ocean Service [NOS], National Weather Service, Office of Restoration and Response; NMFS: NMFS-AFSC, Alaska Regional Office [NMFS-AKR], NMFS-NMML and Library, Northwest Fisheries Science Center [NMFS-NWFSC], NMFS-NWR, NPFMC, OCNMS, Office of Habitat Protection, Office of Protected Resources, PFMC, NMFS-SWFSC, NMFS-SWR);

- U.S. state, interstate, and regional agencies and commissions (CDFG, California Environmental Resources Evaluation System [CERES], California Geological Survey, Northwest Indian Fisheries Commission [NWIFC], Northwest Straits Commission, Oregon Department of Fish and Wildlife [ODFW], Pacific States Marine Fisheries Commission [PSMFC], Washington Department of Fish and Wildlife [WDFW]); and

- International agencies and commissions (Canada Department of Fisheries and Oceans [DFO], United Nations Environment Programme-World Conservation Monitoring Centre [UNEP-WCMC]).

1.4.2 Spatial Data Representation—Geographic Information System

The geographical representation of marine resource occurrences in the Pacific Northwest OPAREA, Puget Sound Study Area, 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. The spatial or geographical component that was common to all data sets allowed the widely dissimilar data to be visualized in a meaningful manner. Without this common data characteristic, graphical display of such disparate data would have been difficult, if not impossible, to achieve.

A GIS was used to store, manipulate, analyze, and display the spatial data and information accumulated for the Pacific Northwest OPAREA. For this project, Environmental Systems Research Institute, Inc.'s (ESRI) ArcView® version 8.3 GIS software was used to create the majority of the map figures and metadata. ArcView® was chosen for this project due to its widespread use, ease of operation, and its ability to create multiple views and layouts within the same project file.

The geographic locations of important marine resources in the Pacific Northwest OPAREA, Puget Sound Study Area, 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 geo-referenced, after which significant information was digitized into a shapefile format. Materials acquired as Adobe® portable document format (PDF) files were also treated as scanned source maps (i.e., they were geo-referenced

and pertinent information was digitized), since they were already in a digital form. A third type of source, "source information," encompasses information that was neither taken from a scanned map nor was available in coordinate form. For example, maps displaying non-coordinate data, information given via personal communication, or information extracted from a literature description are referenced as source information. In certain cases, source maps and/or information had to be interpreted to be usable in the GIS environment. Maps displaying geographic information that was interpreted or altered from the original source map/information are noted in the figure caption as being "adapted from" 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 chapter of the MRA. The two primary types of spatial information used in the Pacific Northwest OPAREA MRA were coordinate data and scanned maps. These two source types are associated with differing levels of data reliability or confidence (**Appendix A-1** contains a further explanation of data confidence). Numerical or authentic data are associated with the highest level of reliability while data obtained by scanning source maps are less reliable.

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

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 avoid conflict between theme coordinate systems and projections. In the GIS, the most flexible spatial data format is the unprojected geographic coordinate system, which uses decimal-degree latitude and longitude coordinates (**Appendix A-2** contains more information on map projections). The decimal-degree format is the only coordinate system format that allows unlimited, temporary, custom projection and re-projection in ArcView® and is therefore the least restrictive spatial data format. The printed maps and electronic GIS map data for this MRA report are unprojected and are 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 and an appropriate 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. Seasons throughout the report are defined as the upwelling season (April through September) or relaxed season (October through March). These divisions are based on general oceanographic conditions in the study region, which are summarized in Brueggeman (1992) and Airamé et al. (2003).

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.

1.4.2.1 Maps of the Physical Environment and Habitats

Bathymetry—The bathymetry data used in this MRA represent two levels of sampling resolution. Data from the NOAA's National Geophysical Data Center (NOAA 2002a, 2002b) were sampled at 3 arcsecond resolution and extracted at 15 arcsecond resolution to obtain a smaller and more usable file size. Bathymetric data from Scripps Institution of Oceanography[15] were sampled and extracted at 2 minute (min) resolution. Highly detailed vector bathymetry or depth contours (isobaths) were prepared with contour intervals of 10 m for depths shallower than 100 m while depths deeper than 100 m were contoured at 100 m intervals. Selected isobaths from the resulting two-dimensional (2D) contours are shown on the bathymetry figures and on various maps throughout the MRA report.

To illustrate the three-dimensional (3D) bathymetry of the Pacific Northwest OPAREA, triangular irregular networks (TIN), 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 Scripps Institution of Oceanography[15] were used to create the TIN, which depicts the 3D bathymetry of the Pacific Northwest OPAREA and Puget Sound Study Area (**Figures 2-1** and **2-3**). 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.

The true or natural continental shelf break for the Pacific Northwest OPAREA was derived using the detailed vector bathymetry contours that were adapted from the NOAA (2002a, 2002b) and Scripps Institution of Oceanography[15] raster datasets. The bathymetric contours were transformed into a 0.004-decimal degree grid of water depths. This grid was created using the Zevenbergen and Thorn (1987) algorithm (ZTA), which is a complex series of equations used to model elevation data. The ZTA analysis is based on a rectangular grid of evenly spaced depths that covers the OPAREA. An analytical unit composed of 3 grid cells by 3 grid cells was repetitively analyzed throughout the rectangular depth grid to derive a digital depth model. ArcView 3.3® was then employed to evaluate the gridded digital depth-model against the quartic formula (the ultimate of the ZTA equations). The resulting grid of depth gradient values was visualized as 50 continental shelf break classes (50 was an arbitrary value and represented neither too large nor too small a set of depth classes). The true continental shelf break was identified from within the 50 classes of grid cell values. The shelf-break class representing the grid cell value of 100 was determined to be the location of the true continental shelf break. The value of 100 best matched the gradient change associated with the continental shelf break as defined by Kennett (1982) where the depth changes from the gradient of 1:1000 on the continental shelf to 1:30 on the continental slope. The grid cells for the associated depth model were reclassified into two values: 1 (original depth values ≤100 m) and 0 (original depth values >100 m) to isolate the continental shelf break. The grid model was converted into polygons, which were then converted to line topology, removing all extraneous lines. The isolated shelf break line was then splined to smooth the 90° angles characteristic of grid cells. The model of the continental shelf break was then evaluated in conjunction with the detailed isobaths to determine positional accuracy. The resulting line feature represents the model of the "true" continental shelf break and is not representative of one depth but varies in depth.

Satellite Data—Seasonal averages of SST were compiled from weekly averaged Advanced Very High-resolution Radiometer (AVHRR) satellite data, which contain multi-channel SST pixel data.[16] Seasons were defined with the same monthly derivations used throughout the MRA report (upwelling period: April through September, relaxed period: October through March). Data for the OPAREA and Study Area were

collected from 1981 to 2001; these data were extracted from the global dataset and the pixel values were converted to SST using MATLAB® with the following function:

$$SST\ (°C) = 0.15 * DN - 2.1$$

where DN is the pixel value.

Day and night SST values were averaged and the data were parsed into seasons. The seasonal data were then converted to a grid with cell sizes of 0.12 km by 1.09 km and interpolated to produce a smoother image. In the GIS environment, the range of SST values for the OPAREA and Study Area (presented in degrees Celsius [°C]) are associated with a color spectrum grading from red (warmest) to blue (coldest).

Seasonal averages of chlorophyll *a* (chl *a*) concentrations were compiled from monthly averaged Coastal Zone Color Scanner (CZCS) satellite data to provide a proxy for primary productivity in the OPAREA and Study Area.[17] Pixel data for the OPAREA and Study Area extent from 1978 to 1986 were extracted and converted to chl *a* values using MATLAB® and the provided function:

$$chl\ a\ (mg/m^3) = 10^{(DN * 0.012) - 1.4}$$

where DN is the pixel value.

The chlorophyll data were parsed into seasons, converted to grid cell sizes of 0.12 km by 1.09 km, and interpolated. On the MRA map figures, the seasonal range of chl *a* concentrations (in milligrams per cubic meter [mg/m^3]) is presented as a color spectrum with chl *a* concentrations increasing from blue to red.

Habitat Data—Multiple sources of data and information were used in the creation of maps for the coastal and oceanic habitats of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. The maps displaying estuarine, seagrass, macroalgae, deep-sea coral, intertidal, colonized hardbottom, and artificial habitats are all examples of multiple data sources used in the creation of a single map. These maps were created using images, coordinate data, GIS shapefiles, and other information available from the scientific literature, technical reports, GIS databases, fish/dive charts, and federal, state, and non-profit agency websites.

1.4.2.2 Biological Resource Maps—Species of Concern

Marine mammal and sea turtle occurrence data were accumulated from every available source; however, it was impossible to obtain every data source in existence for the Pacific Northwest OPAREA. An overview of known marine mammal and sea turtle data sources for the Pacific Northwest Region is found in **Appendix A-3**. Marine mammal and sea turtle data that were provided for use in this MRA are listed in **Table A-1** and are displayed on the occurrence maps in **Appendices B** and **C**. The data described in **Table A-1** include occurrence data from aerial and shipboard (sighting) surveys, stranding records, incidental fisheries bycatch records, and other sources (e.g., opportunistic sighting programs and species occurrence databases). Sighting, stranding, and bycatch records available from the scientific literature or through personal communications with regional experts were also used in this MRA. The combined source data mentioned above were vital to the determination of areas of occurrence for marine mammals and sea turtles potentially occurring in the Pacific Northwest OPAREA and Study Area. Of greatest utility were sightings collected during NMFS and BLM-MMS aerial and shipboard surveys of the OPAREA, Study Area, and near vicinity.

Several assumptions were made regarding the marine mammal and sea turtle data collected for this MRA. First, it was assumed that the species identifications given in each dataset were correct. This assumption was necessary since the reliability of species identifications from one dataset to the next was not always known. Marine mammals and sea turtles are often difficult to distinguish to species when they are young (i.e., small size classes), during poor sighting conditions, and when those who observe them do not have a high level of identification experience. Correct species identification is highly dependent on

the skill level of the observer. Sighting data presented in this MRA range from those collected by experienced professionals during dedicated surveys (e.g., NMFS surveys) to those collected opportunistically and/or by less experienced observers. For the sake of consistency, reliability of species identification was not considered in the plotting of any marine mammal or sea turtle records.

Although it was assumed that the species identifications provided in each dataset were correct, it could not always be assumed that the locations of the occurrence records, when provided, were also correct. Problems were often encountered when original geographic coordinates were plotted and animals were shown to occur in unexpected locations or in areas far from the dedicated survey coverage. Occurrence records that were obviously erroneous were omitted if they could not be corrected through consultation with the data provider. It should be noted that some of the marine mammal and sea turtle datasets lacked geographic coordinates entirely. As a result, determination of the locations where the records occurred required educated predictions based upon physical descriptions of the locales.

In conjunction with the NMFS, regional experts, and hired subcontractors, marine mammal and sea turtle areas of occurrence were defined and then drawn for each species known to occur in the OPAREA. The areas of occurrence are based upon expert opinion (i.e., many years of survey experience in the area), known habitat preferences and distribution patterns of the animals, and the available sighting, stranding, bycatch, and haulout data. Four types of occurrence information may be displayed on each marine mammal or sea turtle species map: areas of **primary occurrence** (areas and habitats where a species is primarily found), areas of **secondary occurrence** (areas and habitats where a species may be found, especially during anomalous environmental conditions [e.g., El Niño events] or seasonal migrations), areas of **rare occurrence** (areas and habitats where a species is not expected to be found with any regularity), and areas of **no systematic survey effort** (areas and habitats that have not been adequately surveyed). An underlying premise used during the map creation process was that a conservative approach to delineating the areas of occurrence for marine mammals and sea turtles was necessary since all four sea turtle species and several of the marine mammal species are listed as either threatened or endangered under the ESA. The occurrence maps for marine mammals and sea turtles are displayed by season.

As a supplement to the seasonal occurrence maps and species-specific discussions, maps were also created to depict known movement patterns, critical habitats, conservation zones, and haulout areas for certain marine mammals and sea turtles that occur within the OPAREA. Section 3.1 of this MRA includes migration maps for the humpback and gray whales, which are summaries of the vast amount of data and information that have been collected on long distance movement patterns of these whale species in the North Pacific Ocean. Section 3.1 also includes maps of marine mammal critical habitats that have either been proposed or designated by the NMFS. In the eastern North Pacific Ocean, critical habitat has been proposed for the southern resident killer whale and has been designated for the North Pacific right whale and Steller sea lion. Section 3.1 also refers to maps of pinniped haulout sites in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity, which are included with the marine mammal occurrence maps in **Appendix B**. These maps were created using GIS shapefiles available from U.S. state and federal agencies as well as the Province of British Columbia.

Section 3.2 of this MRA includes a map of the NMFS-designated Pacific leatherback conservation zone, which is located off the coasts of California and Oregon and overlays a good portion of the OPAREA. This section also includes a map summarizing the developmental migration path of loggerhead turtles from nesting beaches in the western Pacific to juvenile developmental habitats in the eastern Pacific to adult foraging/breeding areas in the western Pacific. This map allows the reader to better visualize and understand the life history and migration patterns of this species in the North Pacific Ocean.

Sections 3.3 and 3.4 either contain or refer to maps that display important habitat and occurrence data on endangered, threatened, and species of concern birds and fishes. Several of these maps are syntheses of all available information on distribution patterns, survey sightings, and movements/migrations. Critical habitat maps were prepared using GIS shapefiles produced by the NMFS and USFWS. Foraging habitats were mapped for bird species that had sufficient information available; these maps are presented in

Appendix D. In addition, a distribution map for all salmon species was constructed using information from the scientific literature and a salmon research program website.

1.4.2.3 Biological Resource Maps—Fish and Fisheries

Maps displaying the EFH for all lifestages of salmon, coastal pelagic, groundfish, and highly migratory species found within the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity were created from official FMP habitat descriptions, maps produced by the PFMC and CDFG, and GIS shapefiles created by TerraLogic GIS (2004). Most of the EFH data were not available in a usable electronic format. As a result, the locations of EFH were determined by developing polygons based on jurisdictional limits (salmon) or encompassing known temperature ranges (coastal pelagic), physical habitats (groundfish), or bathymetric ranges (highly migratory) occupied by each species or lifestage.

EFH designations can include the entire water column or a subsection of the water column (e.g., benthic, surface, or from 50 m to 250 m). The subsection of the water column where EFH is designated has been included in parentheses after the lifestage category. If there are no parentheses after the lifestage, then EFH is designated for the entire water column. All EFH maps for this MRA are located in **Appendix E**.

1.4.2.4 Maps of Additional Considerations

Information on the locations of U.S. maritime boundaries, navigable waterways, MMAs, and SCUBA diving sites in the Pacific Northwest OPAREA and Puget Sound Study Area was gathered from a wide array of sources. Maps displaying the major commercial shipping lanes, ferry routes, and MMAs of the Pacific Northwest Region were created from geographic data available on U.S. and Canadian government agency websites. GIS shapefiles for U.S. federal and state level MMAs were downloaded from the NOAA's MMA Inventory website, while geographic coordinates for Canadian MPAs and Rockfish Conservation Areas were amassed from the MPA Global and Canada DFO websites. SCUBA diving sites in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity were depicted using geographic data, maps, and information available from SCUBA diving books and websites as well as the Business Solutions Branch of the Province of British Columbia.

1.4.2.5 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 consist 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 hyper text 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.

1.4.3 Limitations of Marine Survey Sighting Data

When attempting to use sighting data from aerial and shipboard surveys as a major indicator of a species' occurrence, it is necessary to first recognize the inherent biases associated with each survey type. One of the main drawbacks of surveys in the marine environment is that shipboard and aerial surveys count only the number of animals at the water's surface, where species such as marine mammals and sea turtles spend relatively little time. Sea turtles often spend over 90% of their time underwater (e.g., Byles 1988; Renaud and Carpenter 1994; Mansfield and Musick 2003). As a result, it has been postulated that marine

surveys undersample (underestimate) the total number of sea turtles in a given area by as much as an order of magnitude (Shoop and Kenney 1992). While scientists have devised mathematical formulas to account for animals not seen at the surface, the diving behavior of one animal may be different from that of other members of the same species. Even though marine mammals and sea turtles are obligated to come to the surface to breathe, many individuals will not surface within an observer's field of view. This is of particular concern when attempting to sight species that dive for extended periods of time; do not possess a dorsal fin; and are known to exhibit cryptic behavior, such as beaked whales, *Kogia* spp., and sperm whales (e.g., Würsig et al. 1998; Barlow 1999). Beaked whales are often solitary individuals, which makes their sightability much different from a species that regularly occurs in large groups, such as dolphins in the genus *Stenella* (e.g., Scott and Gilbert 1982).

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

Problems also arise when attempting to select an optimal and efficient survey method for sampling marine mammals and sea turtles. Since most sighting surveys target multiple species, the sampling designs, although likely cost- and labor-efficient, cannot be considered optimal for each species (Scott and Gilbert 1982). The altitude at which marine mammal aerial surveys are flown is much higher than is desirable to sight sea turtles (which are typically much smaller than cetaceans). Shipboard surveys designed for sighting marine mammals are adequate for detecting large sea turtles but usually not the smaller-sized turtles. Their size, diving behavior, and startle responses to vessels make smaller sea turtles difficult to sight or visually observe from a ship. The youngest age-classes of sea turtles, which often inhabit waters far from land, are extremely difficult to spot. There have been no shipboard surveys in the Atlantic or Pacific Oceans designed to specifically address information needs relative to sea turtles. Other difficulties with marine surveys include weather, time, and logistical constraints. For example, the operating cost for a research vessel is approximately $10,000 per day (Forney 2002).

In addition, data derived from marine surveys do not provide adequate information for scientists to accurately describe the seasonal occurrence of marine mammals and sea turtles in extremely large areas, such as the North Pacific Ocean. The occurrence of marine mammals and sea turtles in an area often changes on a seasonal basis in response to changes in water temperature, the movement and availability of prey, or an individual's life history requirements, such as reproduction. Therefore, the number of sightings on a specific date over a specific trackline may not be representative of the number of individuals occurring in the entire area over the course of an entire season. As a result, sighting frequency is often a direct result of the level of survey effort expended in a given area.

1.4.4 Limitations of Stranding Data

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

1.5 REPORT ORGANIZATION

This report consists of nine major chapters and five 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 OPAREA, 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 and estuarine wetlands (e.g., salt marshes, tidal flats, and lagoons), seagrasses, macroalgae, chemosynthetic communities, deep-sea corals, intertidal and colonized hardbottom areas, and artificial habitats (e.g., artificial reefs, shipwrecks, and buoys) in the OPAREA, Study Area, and vicinity. Chapter 3—Species of Concern covers all protected species found in the Pacific Northwest OPAREA: marine mammals, sea turtles, five species of birds, and six species of fish. For these species, detailed narratives of their morphology, status, habitat preferences, distribution (including migratory patterns), behavior, life history, and acoustics and hearing (if known) have been provided. Chapter 4—Fish and Fisheries investigates fish, EFH, and fishing activities (commercial, recreational, and tribal) that occur within the OPAREA. Chapter 5—Additional Considerations provides information on U.S. maritime boundaries, commercial shipping lanes and ferry routes, MMAs, and SCUBA diving sites. Chapter 6—Recommendations suggests future avenues of research that may fill the data gaps identified in this project and prioritizes research needs from a cost-benefit approach. Chapters 7, 8, and 9 are the List of Preparers, Literature Cited, and Glossary, respectively. Appendix A includes supplementary materials referred to in Chapter 1 (including the marine mammal and sea turtle data sources) while Appendices B, C, and D contain occurrence map figures that are described or referenced in the marine mammal, sea turtle, and bird sections (3.1, 3.2, and 3.3, respectively) of Chapter 3. Appendix E includes maps for all fish species that have designated EFH (for at least one lifestage) within the OPAREA.

This report is written in a format and reference style similar to that found in *The Chicago Manual of Style*, 14th Edition. Citations for all peer-reviewed literature referenced in this MRA are included in Chapter 8, while a list of websites accessed appears at the end of each chapter except in Chapter 3, Species of Concern, where they appear at the end of each section.

1.6 WEBSITES ACCESSED

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2.0 PHYSICAL ENVIRONMENT OF THE PACIFIC NORTHWEST OPAREA AND PUGET SOUND STUDY AREA

2.1 INTRODUCTION

The Pacific Northwest and Whidbey Island Complex is an offshore region located from roughly Point Delgado (40ºN) in the south to the Canadian border; the Puget Sound Region (PSR) spans into the Strait of Georgia and Canadian waters. Study areas include the regions off of northern California, Oregon, and Washington State and some inland marine waters of Washington, and Canada. The dynamic geological history of this region, where the Pacific, North America, and Juan de Fuca plates converge, has created a region containing submarine canyons and banks, fjords, and regions of active volcanism. Ocean processes in the region are generally large scale on the Pacific coast with the circulation driven by a major western boundary current, the California Current, and the outflow of the Columbia River; tides and winds drive circulation within the inshore regions. The upwelling of deep water supplies the region with the majority of nutrients necessary for production. The Pacific Northwest also contains a diversity of coastal and offshore habitats.

2.2 CLIMATE/WEATHER

The climate of the Pacific Northwest can be described as a marine west coast climate but it also includes some characteristics of Mediterranean climate in the south regions of the OPAREA (Greenland 1998; DoN 2000b; DoN 2000c; DoN 2002b). The Pacific coast marine climate typically occurs along on the west coast of midlatitude regions and is very humid (approximately 76%) through most of the year (Greenland 1998; DoN 2000c). The geographic location of the region places it in the path of westerly winds from the ocean that bring cloudy skies, precipitation, high humidity, and mild temperatures. The distribution of the climate is greatly influenced by the orientation of mountain systems in North America.[1]

Mediterranean climates are similar to the climates found in many regions of Europe, South Africa, and Australia (DoN 2002d). The climate regime is dominated by the strength and position of a semi-permanent high-pressure system located over the west coast of the U.S.; this high-pressure system creates a repetitive pattern of early morning cloudiness, hazy afternoon sunshine, and daytime onshore breezes (DoN 2000d; DoN 2002d); little seasonal or daily variability in the climate occurs throughout the year (DoN 2002d).

Approximately 80% of the precipitation in the Pacific Northwest region occurs during the cooler months of October through May (DoN 2000c). Rainfall amount varies dramatically throughout the region; annual rainfall averages 48 cm at Port Townsend which is in the rain shadow of the Olympic Mountains while Bremerton receives in excess of 129.5 cm (DoN 2000c). In the late fall and winter, days are typically cloudy with drizzle and the occasional fog. Average temperatures in the winter range from 1º to 5ºC with an occasional freeze. Snowfall during the winter months is generally light, rarely exceeding three to six inches accumulation per event (DoN 2000c). Summertime temperatures average 15.5º to 27ºC during the day and drop to 10º to 15ºC at night; occasionally, hot dry air descends over the area causing temperatures to exceed 32ºC (DoN 2000c; 2002b).

2.2.1 Seasons

The Pacific Northwest is exposed to distinct oceanographic seasons (Airamé et al. 2003). Seasonal variations in the oceanography of the region occur in response to solar heating and cooling, wind mixing, freshwater runoff, and coastal upwelling (Brueggeman 1992). These periods, described by intense coastal upwelling (April through September), relaxed winds (October through March), and strong winter storms (November to March), are associated with different degrees of upwelling or downwelling (Airamé et al. 2003).

The upwelling season generally occurs from April through September, although it can begin as early as mid-March. The strongest upwelling occurs during May and June off northern California and July and August off of Oregon and Washington (Brueggeman 1992; Airamé et al. 2003). During this season cold,

deep nutrient-rich water rises to the surface and replaces the surface water. In satellite images, upwelling areas can be observed as localized regions of cool SST. A period of frequent wind relaxation generally occurs throughout the remainder of the year. During this time, winds are light and variable and the seas can remain calm for extended periods (one to two weeks). These periods of wind relaxation typically last two to six days and may alternate with upwelling-favorable conditions during the spring. Periods of relaxation may persist longer during the late summer and early fall; the season of relaxed winds quickly disappears after the onset of upwelling winds or the return of winter storms. Winter storms generally occur between late November and mid-March disrupting the relaxed conditions. During this period, low pressure systems moving south of the Gulf of Alaska generate strong southerly winds and large waves (Airamé et al. 2003).

2.2.2 Winds

The driving force for surface winds off the Pacific Coast is the strength of the gradient between the North Pacific high and the continental thermal low over California (Gramling 2000). North of 40ºN, winds transition from a predominantly equator-ward flow to one that is pole-ward (Schwing et al. 1996). This gradient is strongest in the summer, creating northerly winds offshore. During the winter, the gradient weakens resulting in southerly winds off of Oregon and Washington (Hickey 1979). Transitions to upwelling-favorable winds usually occur in mid-April or May and continue through early September (Peterson 1997; Norman et al. 2004). These winds are not continuous; rather, the pattern is punctuated by periods of calm or reversed winds (Peterson 1997). In October or November, there is a shift in wind direction that predominantly results in winds that flow from the east/southeast (Norman et al. 2004). Thus, because of the seasonal wind patterns of the region, upwelling occurs along much of the coast in spring and summer and downwelling occurs during the fall and winter (Hickey 1998).

Winds within Puget Sound are an important driver of water circulation and transport. Winds follow the same general pattern as those along the Pacific Coast. The prevailing wind flow is from the south or southwest in the fall and winter and from the west or northwest during the spring and summer months (DoN 2000c). Wind velocities are generally light at less than 4.5 meters/second (m/sec). The strongest winds in the region typically blow from the south as intense Pacific storms move inland from the Pacific Ocean (DoN 1996a).

2.2.3 Storms

During the winter months, storms blow onshore from the southwest; the Aleutian Low pressure system helps to direct winter storms into the Pacific Northwest (Strub and Batchelder 2002). These winter storms create intense vertical mixing and alongshore northward advection which, for the most part, is not impeded by the straight coastline of the Pacific Northwest (Greenland 1998). These winter storm systems usually persist for only a few days and affect relatively small regions. These storms can deliver approximately 180 to 250 cm of rain per year. Coastal storm winds regularly top 18 m/sec; the annual peak speed of 25 m/sec can topple chimneys, utility lines, and trees. The highest storm winds recorded on Washington's coast, 67 m/sec, occurred at North Head in January 1941.[2]

2.2.4 Alterations in Climate

The Pacific Northwest ecosystems display a wide amount of variability; these ecosystems are located at the interface of the planet’s largest ocean and one of its largest continents (Greenland 1998). El Niño Southern Oscillation (ENSO) events and the Pacific Decadal Oscillation (PDO) produce extreme anomalies in both the atmosphere and the ocean on interannual to decadal time scales (Schwing et al. 1996). For further information on how these alterations in climate affect the biota of the area, please refer to Section 4.4 of this report.

2.2.4.1 El Niño/La Niña

El Niño (the little boy or Christ Child in Spanish) was originally defined by fisherman from the western coast of South America. The ENSO results from interannual changes in sea level pressures 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. 2002b; Schwing et al. 2002a); 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 sea level pressures 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, 1997 to 1998, and 2004 to early 2005 (Hayward 2000; Lyon and Barnston 2005).

La Niña is the opposite phase of El Niño in the Southern Oscillation cycle.[3] 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. Often with La Niña, the climatic effects are the opposite of those encountered during an El Niño warming event.[3]

Significant correlations exist between the climate of the Pacific Northwest and El Niño/La Niña events (e.g., Pulwarty and Redmond 1997; Cayan et al. 1999); the region has been impacted by numerous strong and moderate El Niños and La Niñas (Mantua 2002). El Niño events are characterized by increases in ocean temperature and sea level (10 to 30 cm), enhanced onshore and northward flow, and reduced coastal upwelling (Crawford et al. 1999; Smith et al. 1999; Freeland 2000; Airamé et al. 2003). The 1997 to 1998 El Niño was one of the largest ocean perturbations in the historical record; ocean temperatures in the upper 200 m were 2º to 3ºC warmer than historical averages (Castro et al. 2002; Airamé et al. 2003; Childers et al. 2005; Zamon and Welch 2005). This El Niño was immediately followed in 1999 by an equally strong, cold La Niña event.

2.2.4.2 Pacific Decadal Oscillation

The PDO is a long-term climatic pattern capable of altering the SST, surface winds, and sea level pressure (SLP) (Mantua 2002; Mantua and Hare 2002). Every 20 to 30 years, the surface waters of the central and northern Pacific Ocean shift several degrees from the mean. Such shifts in the mean surface temperatures, known as the PDO, have occurred 5 times in the last century and are linked to the 10 to 20 year variability of the Aleutian Low Pressure System; the PDO is often described as a long-lived El Niño-like pattern of Pacific climate variability with both warm (positive) and cool (negative) phases (Mantua 2002; Mantua and Hare 2002; Airamé et al. 2003; 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 (Hare and Mantua 2000). Third, the mechanisms controlling the PDO are unknown, while those forces creating ENSO variability have been well resolved (Mantua and Hare 2002).

During warm PDO regimes, the western and central North Pacific Ocean typically exhibits cold surface temperature anomalies while the eastern Pacific exhibits above average temperatures. The opposite condition exists during cool regimes. The PDO also appears to shift abruptly between warm and cool states, with observed shifts occurring in 1925, 1947 and 1977 (Hare 1996; Minobe 1997); the most recent shift, from a warm to a cool phase, occurred in 1998 (Airamé et al. 2003; Peterson and Schwing 2003; Childers et al. 2005; Gómez-Gutiérrez et al. 2005).

2.3 MARINE GEOLOGY

2.3.1 Geologic Setting

The Pacific Northwest has a dynamic geologic history. The region has been shaped by geologic forces (e.g., volcanism, glacial scouring, erosion, subsidence, and sea level rise) that have created mountains, canyons, fjords, and coastal lowlands. The region offshore of the Pacific Northwest generally consists of northern oriented ridges, banks, and submarine canyons cutting into the continental shelf (**Figures 2-1** and **2-2**). The ridge structures are located at the junctures between the Pacific, Juan de Fuca, and North American Plates. Intense seismic activity and volcanism is associated with the movement of the plates as the Pacific Plate slides past the Juan de Fuca plate and the Juan de Fuca plate subducts beneath the North American Plate (Melbourne and Webb 2003).

The Puget Sound Study Area includes the inland waters of the Strait of Juan de Fuca (Canada/U.S.), Strait of Georgia (Canada) and Puget Sound (U.S.) (**Figures 2-3** and **2-4**). The Strait of Juan de Fuca connects the inland waters of Puget Sound and the Strait of Georgia with the Pacific Ocean. Past ice ages have played a crucial role in the formation of the inland region; Puget Sound and the Strait of Georgia are the result of glacier scour that has occurred over the past 20,000 years (Morgan et al. 2005). During the last ice age the Puget lowland was repeatedly covered by a continental ice sheet that advanced from the north and repeatedly covered the area, scouring out the 2,600 km^2 of Puget Sound from the surrounding land mass (NOAA and WSDE 1999; DoN 2000b; 2000; 2002). The inshore regions comprise a complex system of interconnected channels and bays, with tidal seawater entering from the west, and freshwater entering from streams and rivers of the surrounding uplands (Morgan et al. 2005).

2.3.2 Physiography and Bathymetry

2.3.2.1 Pacific Coast

In general, the bathymetry of the offshore regions of the Pacific Northwest coast is smooth due to the long history of sediment accumulation. Northern California is characterized by the scarcity of submarine canyons and the absence of other conspicuous relief features (Shepard and Emery 1941). The continental shelf off of the Washington coast varies in width from 25 to 60 km and is broken by six canyons (Strickland and Chasan 1989); the canyons represent 5 to 20 km wide breaks in the otherwise smooth bathymetry along the coast (**Figures 2-1** and **2-2**).

2.3.2.2 Strait of Juan de Fuca

The Strait of Juan de Fuca is a 160 km long channel ranging from 22 to 60 km in width with an average depth of less than 200 m (Ott and Garrett 1998; Gramling 2000); the only exception is at the mouth where the depth extends to 250 m (Ott and Garrett 1998). The sides of the channel are relatively straight and except for a sill south of Victoria, British Columbia that extends across the majority of the straight, there are no distinctive bathymetric features (Ott and Garrett 1998).

2.3.2.3 Puget Sound

The main basin of Puget Sound is a partially-mixed, fjord-like estuary which connects through Admiralty Inlet to the Strait of Juan de Fuca and extends southward 100 km to Commencement Bay (Cannon 1983). The seafloor of Puget Sound is relatively flat with depths of approximately 200 m; the Sound is bounded by sills both seaward (Admiralty Inlet, 65 m depth) and landward (Narrows, 45 m depth; Strickland 1983; Matsuura and Cannon 1997). The sill at Admirality Inlet impedes the circulation between the Strait of Juan de Fuca and the main basin of Puget Sound (Burns 1985; Gramling 2000). Within the sound, four major basins (Main Basin, Whidbey Basin, Southern Basin, and Hood Canal Basin) are defined based upon their bathymetery and geographic location (Burns 1985; Gramling 2000).

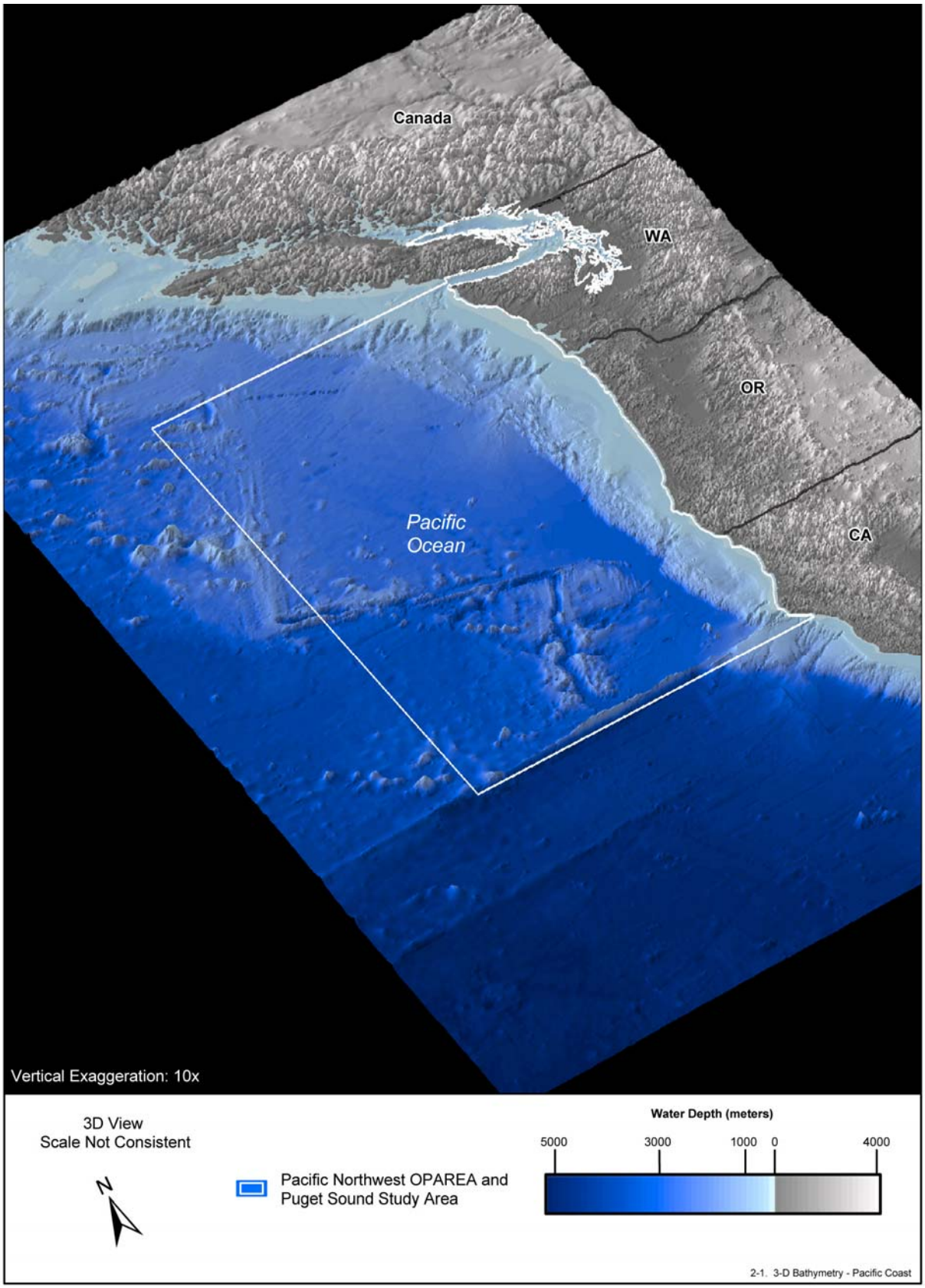

Figure 2-1. 3D bathymetry of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOAA (2002a, 2002b) and Scripps Institution of Oceanography.[4]

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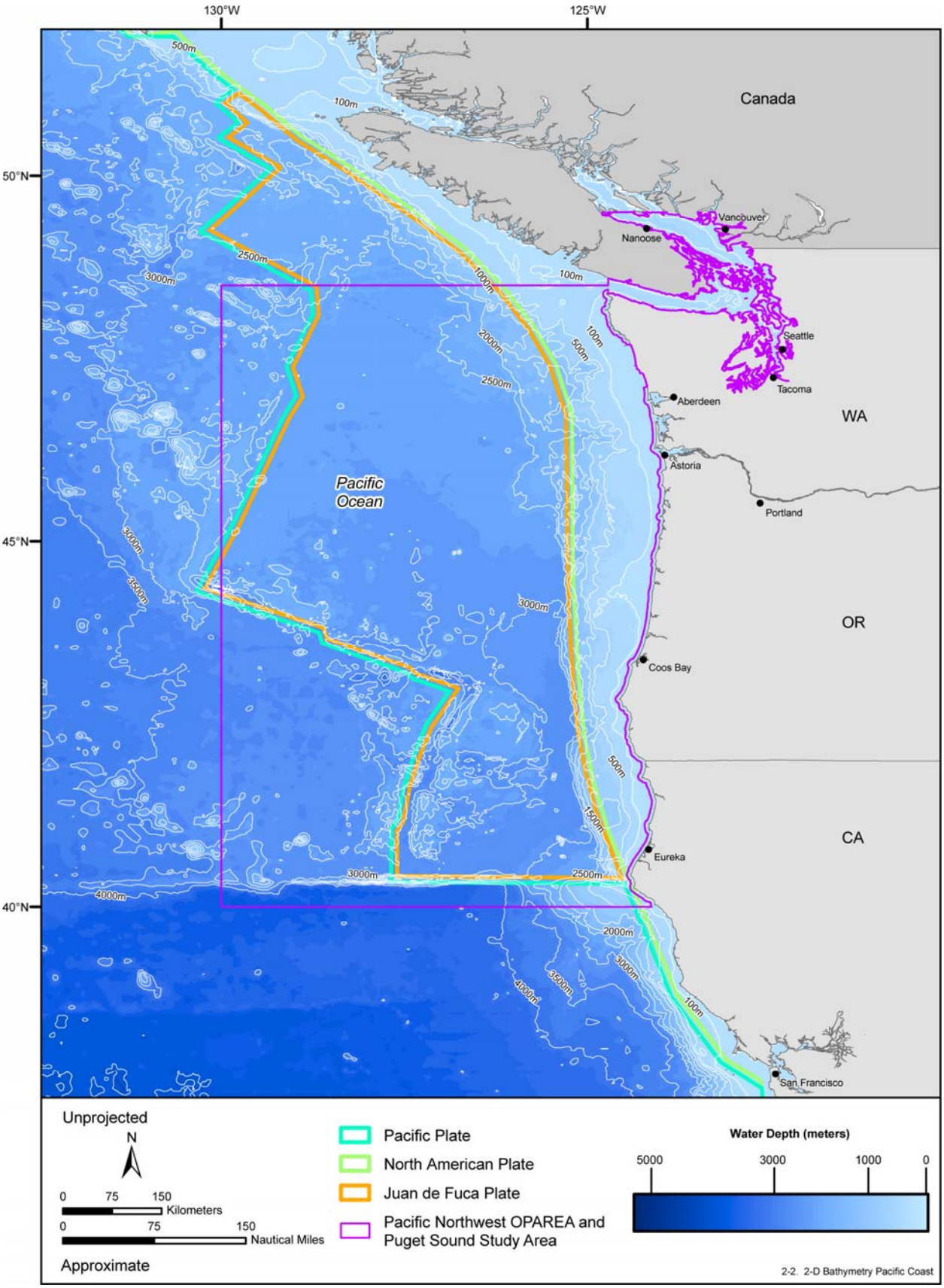

Figure 2-2. 2D bathymetry of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOAA (2002a, 2002b) and Scripps Institution of Oceanography.[4]

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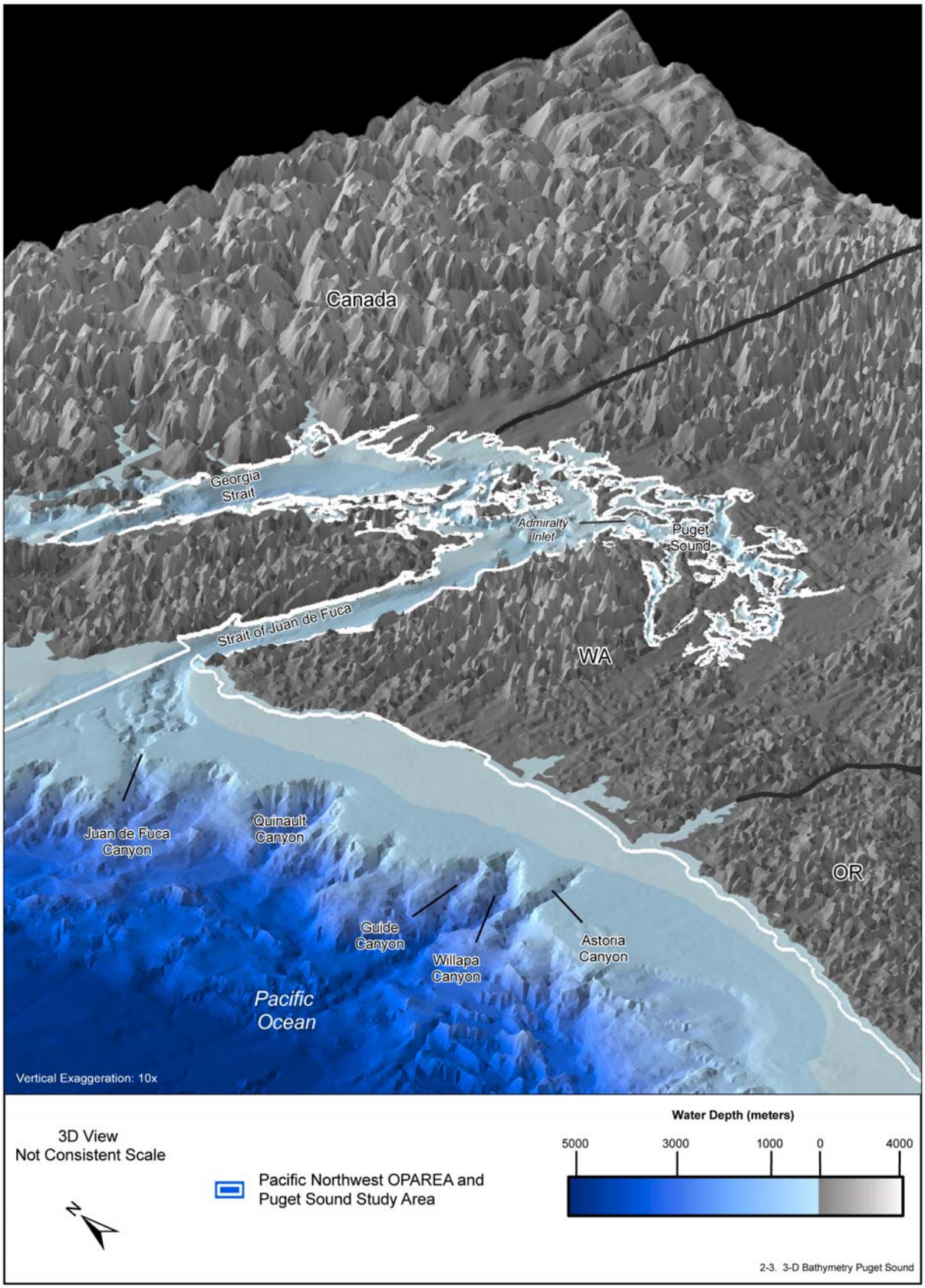

Figure 2-3. 3D bathymetry of the Puget Sound Study Area and vicinity. Source data: Scripps Institution of Oceanography[4] and NOAA.[5]

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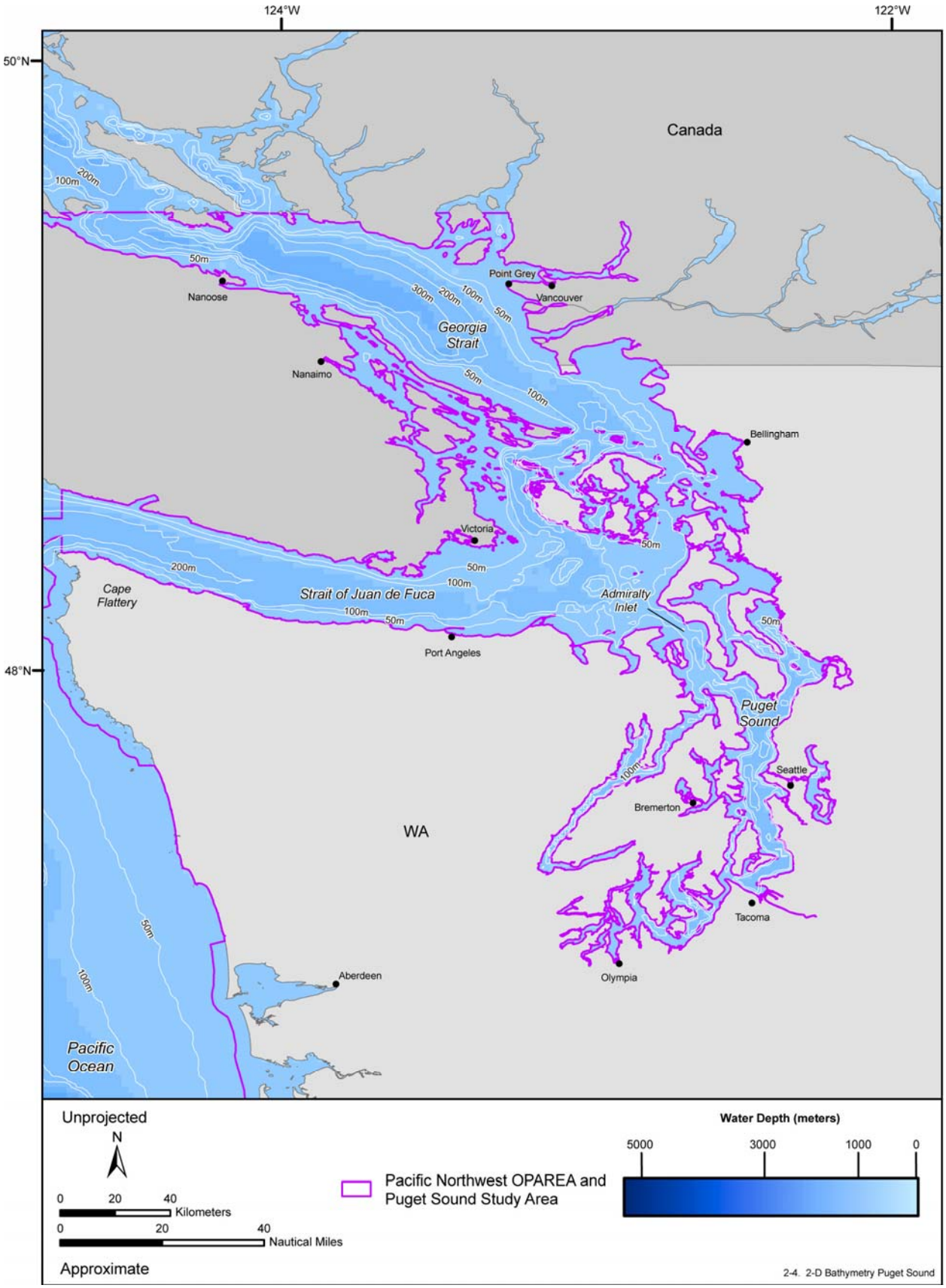

Figure 2-4. 2D bathymetry of the Puget Sound Study Area and vicinity. Source data: Scripps Institution of Oceanography[4] and NOAA.[5]

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2.3.2.4 Continental Margins

Active continental margins, including those located along the majority of the U.S. west coast, are often associated with trenches, volcanism, active mountains, and seismic activity (Kennett 1982). They mark the boundaries between two converging plates and are often referred to as a seismic margin; they are characterized by shallow, intermediate, and deep earthquakes resulting in the deformation or destruction of the earth's crust (Kennett 1982). Unlike more passive margins (as on the U.S. Atlantic coast), the continent and the adjacent ocean floor reside on two different plates. This results in a narrow continental shelf; the shelf along the Pacific Northwest OPAREA ranges in width from 25 to 80 km (Brueggeman 1992; Burger 2003; Norman et al. 2004; Barth et al. 2005; Swartzman et al. 2005). Water depth along the continental shelf is typically <200 m (Brueggeman 1992; Burger 2003; Norman et al. 2004). The continental shelf is widest along the Washington coast and is cut by several deep submarine canyons that run perpendicular to the shore (Burger 2003; Norman et al. 2004). Isobaths tend to parallel the coastline, except within submarine canyons, over the Heceta Bank complex off the coast of central Oregon, and at the mouth of the Strait of Juan de Fuca (Barth et al. 2005; **Figures 2-1** and **2-2**).

2.3.3 Bottom Substrate

2.3.3.1 Pacific Coast

A major source for sediment along the Pacific coastline is the Columbia River. The sediment from the Columbia river is initially deposited near the mouth of the river; however, as winter storms pass through the area, much of this sediment is transported northward along the coast resulting in a 10 m thick deposit of silt overlying the Washington continental shelf (Hickey and Banas 2003; **Figure 2-5**). These transported sediments also make their way into regional bays and harbors along the coastline. For example, the sediments of Grays Harbor, mainly sand and silt, contain marine sediments of Columbia River origin that have been transported via longshore and tidal currents (USACE 2000). Offshore sediments are primarily composed of pelagic mud with sandy areas occurring closer to the coastline. The floor of submarine canyons in the region are primarily comprised of mud; however, isolated sandy patches do occur along the canyon floors (Shepard and Dill 1966).

2.3.3.2 Puget Sound

The bottom sediments of Puget Sound are composed primarily of compact, glacially formed clay layers and relict glacial tills (Crandell et al. 1965; **Figure 2-6**). Major sources for sediments to Puget Sound are derived from shoreline erosion and river discharge (NOAA and WSDE 1999; 2000; 2002). Historically, the southern regions of the Strait of Georgia have been influenced by glaciation; currently, the region is influenced by the inflow of the Fraser River and delta. Sand and mud prevails in the eastern regions while the shores of Vancouver Island and the complex formation of the Gulf Islands have prominent slopes composed of bedrock and boulders (Palsson et al. 2003a).

2.3.4 Trenches

Offshore of Washington, Oregon, and northern California, the Cascadia subduction zone is the convergent boundary between the large North American plate and the smaller Juan de Fuca plate to the west. The Juan de Fuca plate is moving northeastward and subducts beneath the North American plate.[7] The subduction creates a trench in the seafloor to the west of the Pacific coast. However, this trench is not readily visible in the bathymetry because it has slowly been filled with sediments that have settled on the seafloor (Kulm et al. 1986).

2.3.5 Fjords

Fjords are long, narrow inlets that usually represent the seaward terminus of a glacial valley that has become partially submerged after the glacier has melted. Fjords are common along the coastlines of Norway, Canada, Alaska, and New Zealand (Thurman 1997); Puget Sound is also a fjord-like estuary that

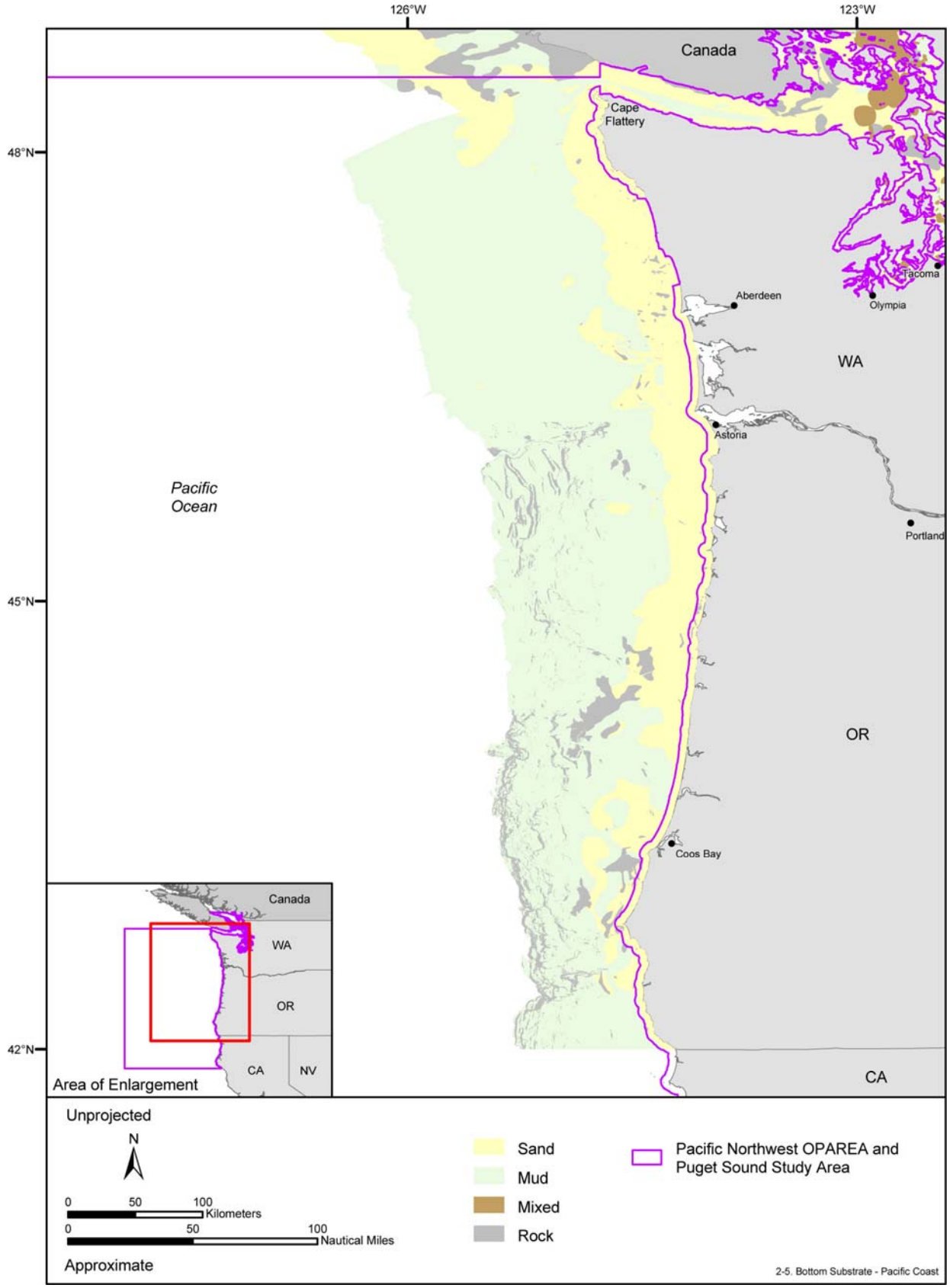

Figure 2-5. Distribution of bottom substrates in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOAA and WSDE (1999, 2000, 2002), TerraLogic GIS (2004), Reid et al. 2006, and Province of British Columbia.[6]

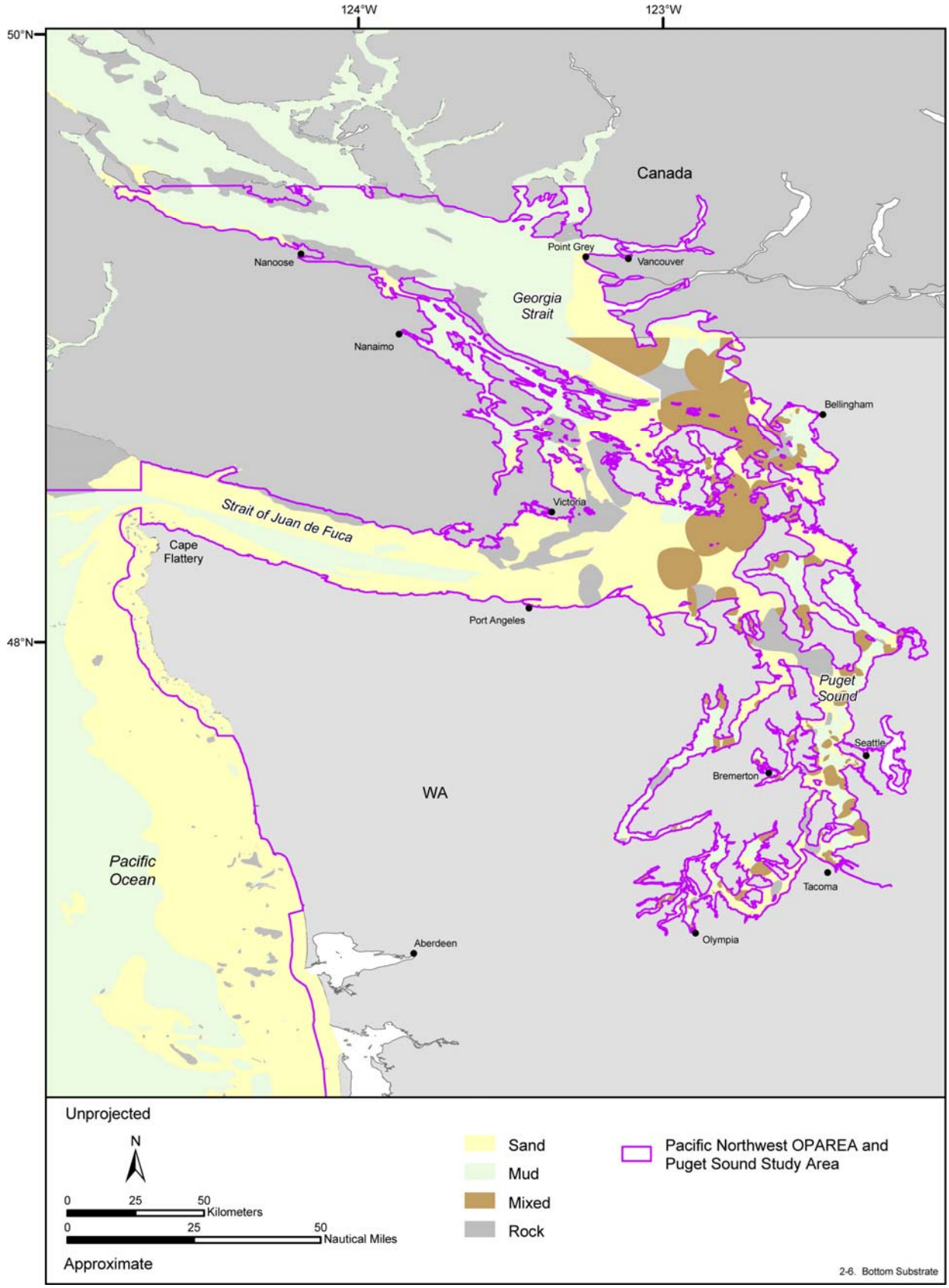

Figure 2-6. Distribution of bottom substrates in Puget Sound Study Area and vicinity. Source data: NOAA and WSDE (1999, 2000, 2002), TerraLogic GIS (2004), Reid et al. 2006, and Province of British Columbia.[6]

was formed during the last ice age when the region was repeatedly covered by a continental ice sheet advancing from the north and often extending beyond the southern reaches of the Puget Sound Basin (Cannon 1983; Matsuura and Cannon 1997; NOAA and WSDE 1999; DoN 2000b; Gramling 2000). Fjords are often enclosed areas with restricted water exchange resulting in strong levels of stratification in the water column (Boesch et al. 1997). Although stratification in Puget Sound is not as strong compared to other fjords around the world (Matsuura and Cannon 1997), regions such as Dabob Bay and Hood Canal can become highly stratified (Paulson et al. 1993; King 2004).

2.3.6 Seismic Activity

2.3.6.1 Earthquakes

Earthquakes in the Pacific Northwest region can be of three types: shallow, deep, and subduction. Shallow earthquakes occur in the North American Tectonic Plate as it adjusts to the strain along the plate where it borders another plate. Epicenters vary from 0 to 30 km beneath the surface. These quakes tend to be very intense near the epicenter, but their effects diminish rapidly with distance.[8] Deep earthquakes occur offshore on the Strait of Juan de Fuca Plate at depths between 35 and 70 km. These quakes do not tend to be as intense as shallow quakes, but occur over a wider area. Subduction earthquakes occur along the border of the North American plate off the Washington coast. These are the largest magnitude quakes and often measure at 8.0 to 9.0 in intensity.[8]

Puget Sound does not experience earthquakes as frequently as more seismically active areas, such as southern California; however, the earthquakes experienced can be just as severe. The Puget Sound region is the most seismically active region in Washington State. Of the 10 earthquakes with a magnitude of 4.9 or greater recorded in western Washington, eight occurred in the Puget Sound region.[8]

2.3.6.2 Tsunamis

A tsunami is a series of great waves most commonly caused by violent movements of the sea floor. It is characterized by high speed, long periods between successive crests, and low wave amplitude in the open ocean. Tsunami waves are imperceptible in the open ocean. In deep water, a large tsunami wave may measure less than 0.5 m high, but may span 200 km (Thurman 1997). The speed at which the tsunami travels will decrease as water depth decreases. Therefore, as depth shallows, the wavelength between crests is shortened, and the energy is crowded into less area, increasing the height of the wave (up to 30 m high; Thurman 1997).

Although tsunamis do occur in the Pacific Northwest, they are relatively rare; however, tsunamis in the region have the potential to be extremely dangerous.[8] A subduction zone earthquake (of Magnitude >7.0) off of Washington State could generate a regional tsunami. The last major tsunami to impact the region occurred on 17 March 1964, when waves of 3 to 6 m were reported (Greenland 1998). During the tsunami, flooding extended several miles up coastal rivers. Evidence has also been uncovered that suggests coastal marshes have been buried by tsunamis and additional tectonic events. The most recent extremely large tsunami in the Pacific Northwest occurred around 1700 (Jarman 1995).

2.3.7 Seamounts and Volcanism

The boundary between the Pacific Plate and Juan de Fuca Plates is marked by a broad submarine mountain chain about 500 km long, known as the Juan de Fuca Ridge (**Figure 2-7**).[7] The youngest of these ridges rise from 400 to 1000 m above the surrounding abyssal plain and were formed during the last 2 million years (Kulm and Fowler 1974; Kulm et al. 1986). The Juan de Fuca ridge is located a few hundred kilometers off the western coast of North America but does not form a continuous, uniformly high volcanic mountain range; rather, it varies in relief along its length (Porter et al. 2000; USGS[4]). Young volcanoes, lava flows, and hot springs were discovered along the crest of the ridge in the 1970's. At this location, the ocean floor is spreading and forms new ocean crust along a central valley or "rift" as hot magma from the Earth's interior is injected into the ridge and erupted at its summit

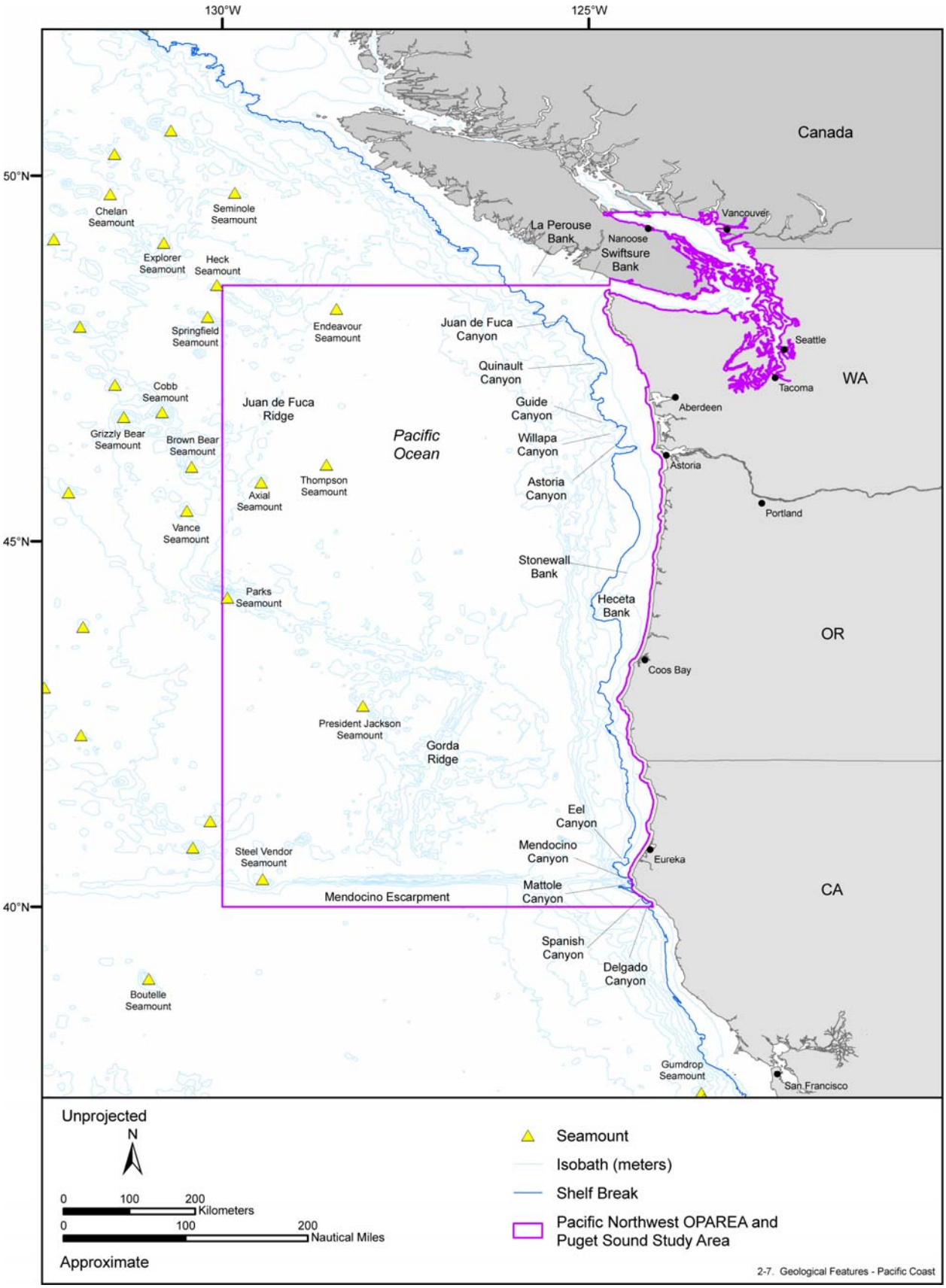

Figure 2-7. Major geological features of the Pacific Northwest OPAREA and vicinity. Source data: Shepard and Emery (1941), Hickey and Banas (2003), and MCBI (2003).

(Mather and Parkes 2000; Porter et al. 2000; Yatabe et al. 2000). These plumes of hot material from beneath the ocean floor have resulted in a number of hydrothermal vents becoming established in the region (see Section 2.7.2.8.2 below). Within the Juan de Fuca Ridge is Axial Seamount. This seamount rises 700 m above the mean level of the ridge crest and is the most seismically active site on the Juan de Fuca Ridge (**Figure 2-7**). The summit is marked by an unusual rectangular-shaped crater (3 km by 8 km) that lies between the two rift zones. Hydrothermal vents and their associated communities are located near the caldera.

South of the Juan de Fuca Ridge lies the Gorda Ridge. Much like the Juan de Fuca Ridge, the seafloor is undergoing active spreading along the axis of the Gorda Ridge. At present, the northern end of the ridge is spreading faster than the southern edge (Dziak et al. 2001; Chaytor et al. 2004). The Gorda Ridge is also a seismically active region off of the Pacific coast; from 1964 through 1966, over 600 low-magnitude earthquakes were recorded along the ridge (Walker and Hammond 1998). On 28 February 1996, a volcanic eruption occurred along Gorda Ridge (43.7ºN and 126.8ºW) in which hot-water plumes and fresh lava flowed from the sea floor (Chadwick et al. 1998; Fox and Dziak 1998). The Gorda Ridge is also home to a wide variety of hydrothermal vents and their associated communities (Fox and Dziak 1998).

2.3.8 Banks

Submerged banks are raised offshore plateaus that are similar to continental shelves except they lack a bordering land area (Emery 1960). Several rocky submarine banks are known to occur off the Washington and Oregon coasts (Norman et al. 2004; **Figure 2-7**). Recent work suggests that mesoscale features, such as submarine banks, may influence nutrient pathways, residence times, or mixing regimes sufficiently to make them important and even critical to the regional marine ecosystem (Hickey and Banas 2003). In the Pacific Northwest, seasonal eddies form off Heceta Bank and the banks offshore of the Strait of Juan de Fuca (Freeland and Denman 1982). Maps of ocean pigment in the Pacific Northwest also show a relationship to bank-like features; chlorophyll is greater and extends farther offshore in the bank region of the Juan de Fuca Strait as well as over Heceta Bank (Hickey and Banas 2003).

2.3.9 Submarine Canyons

Submarine canyons are among the most well studied features of the continental slope. They have steep walls, winding valleys, narrow “V-shaped” cross-sections, steps, and considerable irregularity along the sea floor; they often resemble the terrestrial canyons cut by rivers (Kennett 1982; Thurman 1997). Most submarine canyons commence on the continental shelf, are located at the mouths of rivers, and branch seaward perpendicular to the coastline. The turbidity currents associated with submarine canyons serve as major conduits for sediment transport to the deep sea; they erode canyon walls and transport loose sediments to the continental slope where they are ultimately deposited in a sediment cone or fan (Thurman 1997).

The northern half of the U.S. Pacific Northwest coast and Vancouver Island are indented by a number of submarine canyons. These canyons transect the shelf and slope along the California and Washington coasts but are absent on the Oregon coast (Norman et al. 2004). Major canyons located within the Whidbey Island Complex include Juan de Fuca Canyon, Quinault Canyon, Grays Canyon, Guide Canyon, Willapa Canyon, Astoria Canyon, and Columbia Canyon off of Washington State and Trinidad Valley, Eel Canyon, Mendocino Canyon, Mattole Canyon, Spanish Canyon, and Delgada Canyon off of northern California (Shepard and Emery 1941; Shepard and Dill 1966; Hickey and Banas 2003; **Figure 2-7**). These canyons are typically 5 to 20 km wide and at least 1,000 m deep. The largest of these is the Juan de Fuca Canyon, extending seaward from the Strait of Juan de Fuca (Burger 2003).

2.4 CHEMICAL OCEANOGRAPHY

2.4.1 Hydrography

Hydrography is the scientific study of the measurement and description of oceanic physical features. The following sections describe the temperature of water at the ocean surface and the distribution of the salinity in the Pacific Northwest OPAREA and Puget Sound Study Area in detail.

2.4.1.1 Sea Surface Temperature

The Pacific Northwest experiences relatively cool SSTs due to the southerly flow of the California Current through the region. Temperatures in the more offshore regions tend to be warmer than coastal waters due to the upwelling of cold waters from depth along the coast (Burger 2003; Yen et al. 2005; **Figure 2-8**). Winter SSTs range from 8ºC in the northern regions to 10ºC in the southern expanses (Greenland 1998); often warmer SSTs are located over the Juan de Fuca Canyon (Burger 2003). During the summers, water temperatures increase to 17ºC offshore while remaining cooler (11ºC) along the upwelling coasts (Greenland 1998). In addition, SSTs north of 40ºN exhibit little spatial difference in magnitude (Schwing et al. 1996). Water temperatures within Puget Sound vary considerably; average SST in Puget Sound is 10º to 12ºC, but can range from 3ºC during the winter to 23ºC during the summer in more enclosed areas (e.g., Holmes Harbor) (DoN 2000c).

The SST over the North Pacific has been observed to fluctuate considerably on decadal time scales over the past 50 years as long-term climatic phenomena (e.g., El Niño, PDO, and global warming) influence the SST of the region (Douglas et al. 1982; Trenberth 1990; Tanimoto et al. 1993; Airamé et al. 2003). El Niño increases local ocean temperature (approximately 2ºC) along the Pacific coast (Wheeler and Hill 1999; Airamé et al. 2003). In addition, the PDO-related climate shift in 1977 resulted in a cooling of the central Pacific Ocean and a warming of the Northeast Pacific Ocean. This shift resulted in higher than average (by 0.6º to 1ºC) SSTs in the Pacific Northwest (Hare and Mantua 2000). This shift in climate was slow off the Washington and Oregon coasts, taking several months to years to complete the shift to warmer SSTs (Schwing et al. 1996). Ocean waters off the Pacific coast have also been consistently warming over the last 40 years; it is not clear if this warming is due to interdecadal climate shifts or global warming (Roemmich and McGowan 1995a, 1995b; Airamé et al. 2003; Mendelssohn et al. 2003; MacCall et al. 2005).

2.4.1.2 Salinity

2.4.1.2.1 Pacific coast

Summer and winter distributions of salinity off the coast of the Pacific Northwest reflects the magnitude that the discharge of the Columbia River plays in the region (Greenland 1998). Salinity off the Pacific coastline typically ranges from 32 to 35 parts per thousand (ppt) (Open University 1995; McGowan et al. 1998; Huyer et al. 2002). In general, salinity increases southward along the Pacific coast (Hickey and Banas 2003). On a seasonal basis, the low-salinity plume from the Columbia flows northward in fall and winter over the Washington shelf and slope, and southward in spring and summer offshore of the Oregon shelf, lowering the salinity to as low as 8 ppt in some coastal regions (Hickey and Banas 2003; CORIE[10]). During the winter, the Columbia plume has a dramatic effect on the Washington coast, producing time-variable currents in the near surface layers (<20 m) as large as the local wind-driven currents (Hickey et al. 1998). In summer, freshwater from the Columbia gives rise to the low-salinity signal that separates from the shelf at Cape Blanco (Huyer 1983).

2.4.1.2.2 Juan de Fuca Strait and Puget Sound

Freshwater runoff into the Strait of Georgia is dominated by the Fraser River, and has a strong freshet associated with the spring snow melt (LeBlond et al. 1994). During the freshet period, Strait of Georgia waters are strongly stratified, with a 5 to 10 m warm brackish layer at the surface. En route to the ocean,

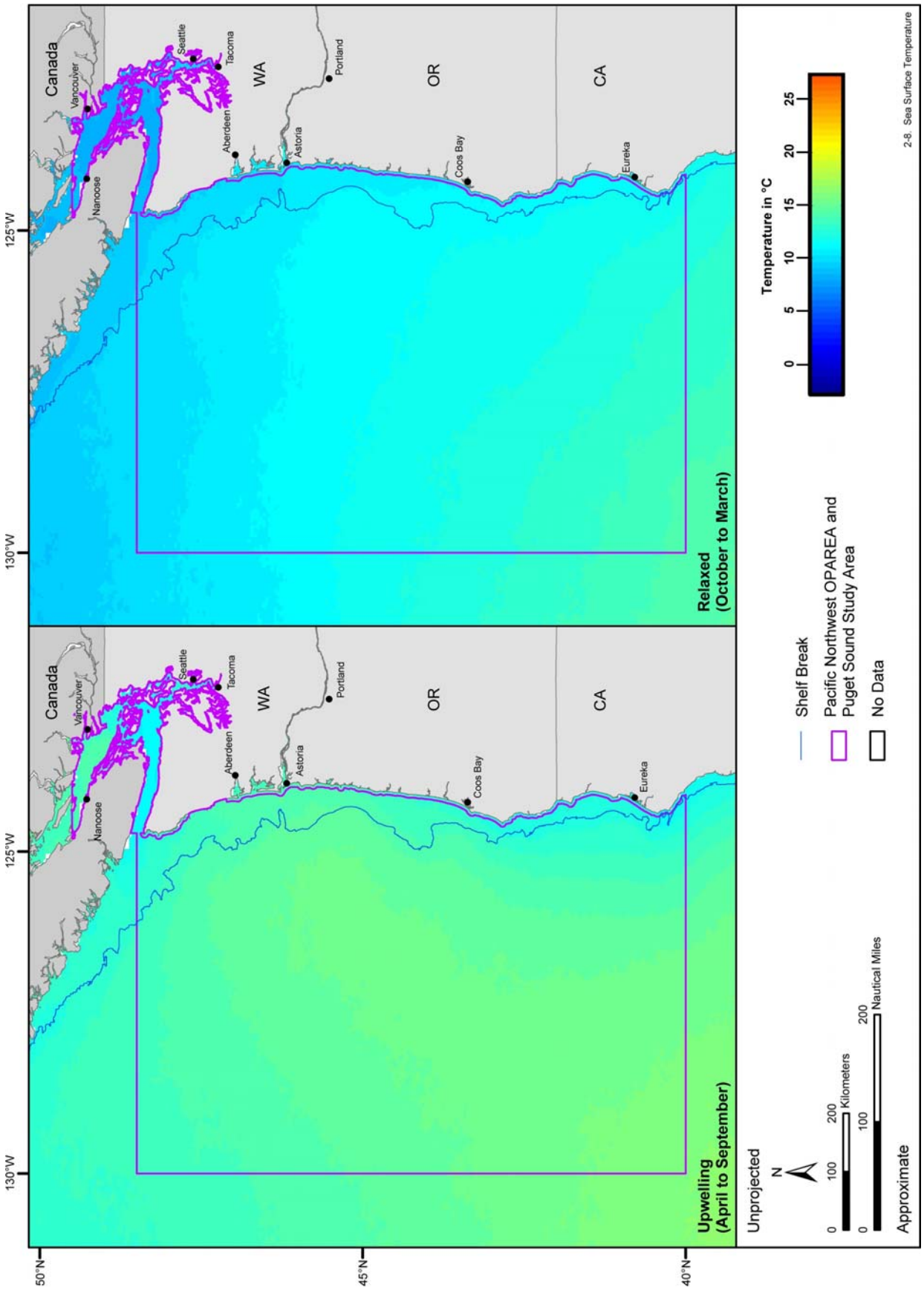

Figure 2-8. SST of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity during the upwelling season (April through September) and relaxed season (October through March). Source data: NASA.[9]

tidal currents are strong and cause vigorous mixing of the water column; these mixed waters then flow seawards over the saltier deeper waters of the Juan de Fuca Strait.

Salinity variations observed in the upper layer of the Juan de Fuca Strait suggest a strong correlation with the spring-neap cycle of tidal currents. Pulses of fresh water flow, associated with the tidal cycle, have been identified at the mouth of the Juan de Fuca Strait and in the waters of the continental shelf (Hickey et al. 1991). Waters flowing out of the Juan de Fuca Strait typically have a salinity of 31 ppt (F.A. Whitney et al. 2005); however, fresh water lenses observed during the summer on La Perouse Bank may be related to pulsations in freshwater outflow from the Juan de Fuca Strait; they may also be caused by variations in local runoff.

Within Puget Sound, rates of precipitation and runoff exceed those for evaporation. The abundance of freshwater inputs and lack of evaporation cause salinities in the sound to decrease to a minimum in late winter and early spring (Burns 1985). In the summer months, when precipitation decreases and is transported seaward with the surface waters, local salinities reach their maximum (DoN 2002a). Salinities in the Sound can range from 5 to 42 ppt (DoN 2000c). Average salinities range from 20.4 ppt for Saratoga Passage and 30 ppt for Port Townsend Bay (DoN 2000c). The waters in the Sound also tend to have a vertical stratification with less saline water overlying saltier bottom waters; marine waters enter the sound through the Strait of Juan de Fuca at depths of 100 to 200 m while the surface waters experience a net outflow seaward (Matsuura and Cannon 1997; NOAA and WSDE 1999; 2000; 2002). Depth of the pycnocline, which separates the two water masses, varies due to seasonal conditions (e.g., freshwater input, wind, and solar heating; DoN 2000c).

2.5 PHYSICAL OCEANOGRAPHY

Ocean variability along the Pacific Northwest generally occurs on a large scale (≥500 km) as a result of shifts in large-scale atmospheric systems (Halliwell and Allen 1987). The physical oceanography of the Pacific Northwest is largely controlled by Pacific-wide circulation (the California Current System), a major river plume (the Columbia River), the formation of large eddies (e.g., the Juan de Fuca Eddy), and seasonal wind stress (Barth and Smith 1997; Hickey and Banas 2003).

2.5.1 Pacific Coast

The coasts of Washington and Oregon are located in an eastern boundary current system where the North Pacific Current divides into the northward flowing Alaskan Current and the southward flowing California Current (Hickey 1998; Gramling 2000; **Figure 2-9**). Seasonal mean shelf currents in the upper water column along the Pacific coastline are southward from early spring to summer, and northward the remainder of the year. Geographic features underlying the surface (such as Cape Blanco and Heceta Bank) can play a large role in influencing local circulation patterns (Ressler et al. 2005).

2.5.1.1 California Current System

The Pacific Northwest coastal zone is embedded within the California Current System, a system of currents with strong variability that extends from British Columbia, Canada, to Baja California, Mexico (Hickey 1998; Hickey and Banas 2003; MacCall et al. 2005). The water properties of the California Current System are determined by three water masses: Pacific Subarctic, North Pacific Central, and Southern (sometimes termed Equatorial) waters (Hickey 1979). Pacific Subarctic water is characterized by low salinity and temperature and high oxygen and nutrients. This water mass is advected southward in the California Current System (Hickey 1979, 1998). North Pacific Central water, characterized by high salinity and temperature and low oxygen and nutrients, enters the California Current System from the west. Southern water has high salinity, temperature and nutrients, and low oxygen; it enters the California Current System from the south as a northward flowing undercurrent. The California Current System is composed of the California Current, California Undercurrent, the wintertime Davidson Current, and possibly a subsurface Washington Undercurrent.

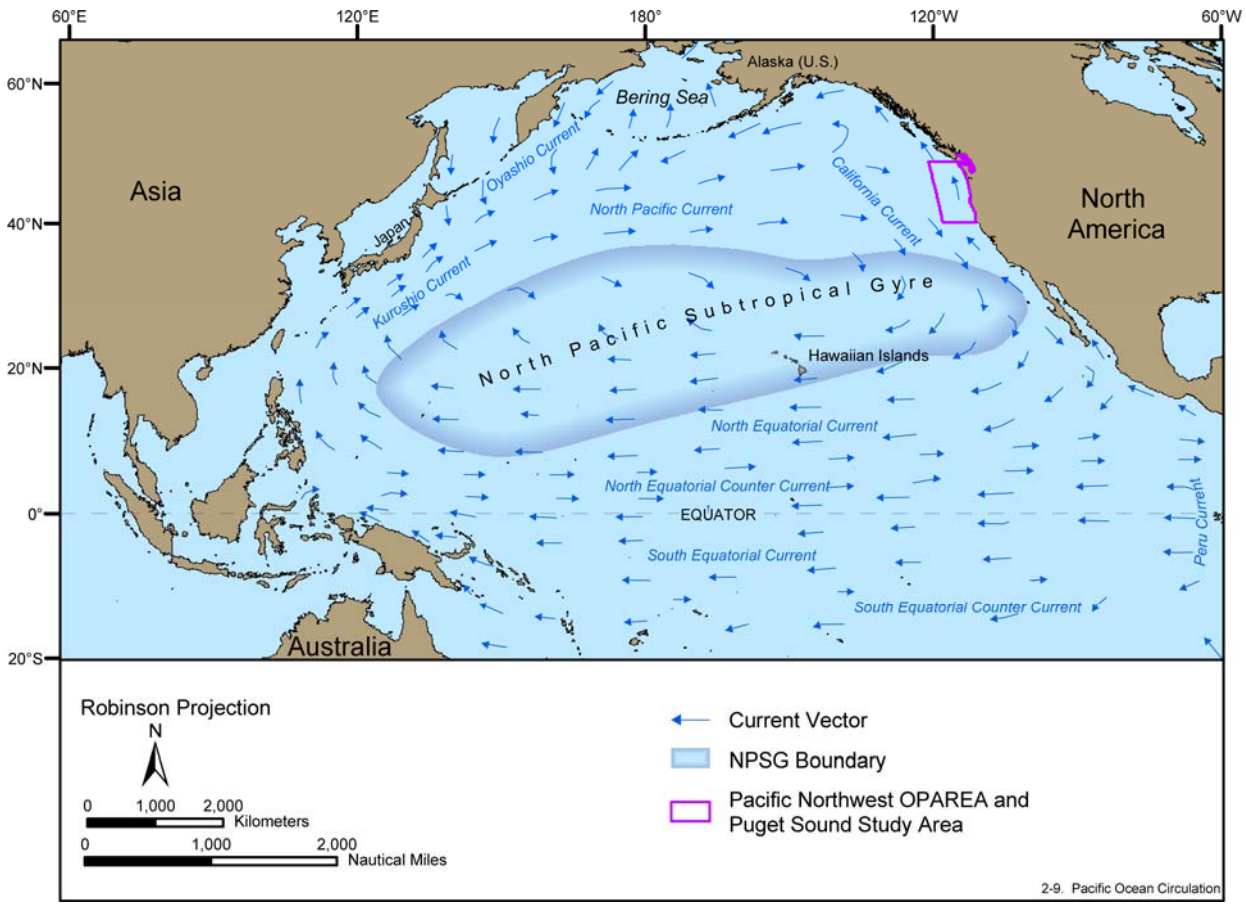

Figure 2-9. Surface circulation of the Pacific Ocean and outline of the NPSG. Source information: Karl (1999). Map adapted from: Pickard and Emery (1982).

A sudden and dramatic event in the California Current System occurs in the spring (Strub et al. 1987). Along much of the coast sea level drops, currents reverse from northward to southward within a period of several days, and density slopes toward the coast in response to coastal upwelling (R.L. Smith 1995). The transition is driven by changes in the large-scale wind field, which are caused by large-scale changes in the atmospheric pressure fields over the California Current System (Strub and James 1988). Cyclonic and anticyclonic eddies and offshore filaments are common during summer and fall in the California Current System (Huyer et al. 1998; Barth et al. 2000; Strub and James 2000; Ressler et al. 2005).

2.5.1.2 California Current

The California Current is a typical eastern boundary current that extends up to 1,000 km offshore and ranges from the colder, nutrient-rich, northern waters of Oregon to the southern waters of Baja California (Hickey 1979; Miller 1996; Hickey 1998; Burtenshaw et al. 2004). It forms the southward-flowing eastern segment of the North Pacific Subtropical Gyre (NPSG) and is a major force in shaping local ecosystems by affecting upwelling, downwelling, and production along the coast (Airamé et al. 2003; **Figure 2-9**). Despite being one of the most studied regions in the ocean, this meandering current is still obscurely understood and inadequately sampled (Miller 1996). The California Current is fed by the North Pacific Current (West Wind Drift), forms the eastern limb of the NPSG, and follows the edge of the continental shelf along the U.S. Pacific coast (Qiu 2002; **Figure 2-10**).

Flow of the California Current is strongest in the summer and early fall; weakest flow is in the winter (Hickey 1998; Gramling 2000; Hickey and Banas 2003). The width of the current is variable, ranging from

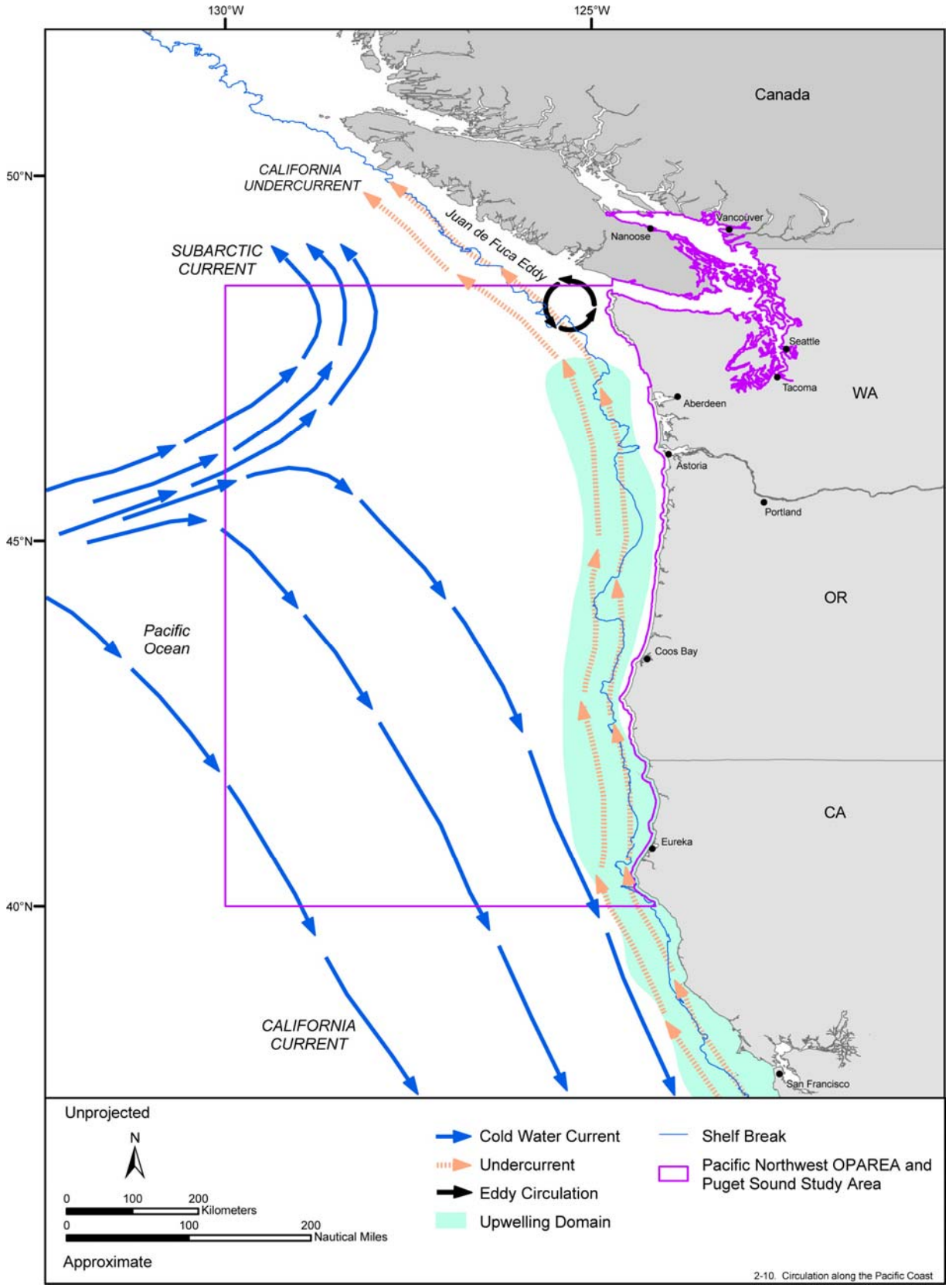

Figure 2-10. Regional surface circulation of the Pacific Northwest OPAREA and vicinity including major currents and eddies. Source maps (scanned): PFMC (2003). Source information: Reed and Halpern (1976), Freeland and Denman (1982), and Hickey and Banas (2003).

600 to 1,000 km and lacks a well defined western boundary (Purdy 1990). North of 38ºN, the California Current is characterized by the strong seasonality in wind forcing (Thomas et al. 2003). The California Current is located closer to the shoreline during the summer and further off the shelf in winter (Strickland and Chasan 1989). Flow is strongest at the surface; however, the current extends through the water column to a depth of approximately 500 m, and flows at a mean speed of 10 cm/sec (Gramling 2000; Hickey and Banas 2003). Two main branches of the California Current have been identified: a main branch and a nearshore branch. The main branch maximum is located 250 to 350 km from the Washington/Oregon coastline during the summer and fall. Maximum flow for the nearshore branch occurs in the spring and late summer (Hickey 1979). Shifts in regional climate can have dramatic effects on the flow of the California Current. During El Niño events, the flow of the California Current is unusually weak (Hickey 1979; Gramling 2000).

2.5.1.3 California Undercurrent

The California Undercurrent is a permanent feature located beneath the surface off of the U.S. Pacific coast (Ingraham 1967; Reed and Halpern 1976; **Figure 2-10**). The current is a relatively narrow (10 to 40 km) subsurface current that flows northward over the continental slope from Baja California to Vancouver Island (the current remains an identifiable feature to at least 50ºN; Reed and Halpern 1976; Hickey 1998; Neander 2001). It has its origin in the eastern equatorial Pacific, but along the U.S. coast is located 20 to 25 km off the shelf break. In some locations the current is confined quite close to the continental slope while it extends well offshore in others (Reed and Halpern 1976; Hickey 1979; Pierce et al. 2000). The current has a jet-like structure, with a core located just seaward and a little below the shelf break. Mean transport of the California Undercurrent is approximately 10 cm/sec (Pierce et al. 2000); the current is strongest at 100 to 300 m depths (30 to 50 cm/sec) and transports warm, saline, low oxygen, equatorial water to the northern Pacific (Neander 2001; Hickey and Banas 2003). The California Undercurrent is strongest in summer or early fall and minimum northward subsurface flow occurs in the spring (Hickey 1998). During El Niño years, when flow of the California Current is weakened, the California Undercurrent is unusually enhanced (Hickey 1979; Gramling 2000).

2.5.1.4 Davidson Current

During the winter, when the southward flowing California Current is weaker and further offshore, the northward flowing Davidson Current develops. The Davidson Current develops inshore of the California Current off the Washington/Oregon coast in September and has become well established by January (Gramling 2000). There is speculation that the Davidson Current is a surface expression of the California Undercurrent (Hickey 1979). The strongest flow of the current occurs during the winter months (Hickey and Banas 2003). Flow begins to decrease in the spring and disappears by May (Purdy 1990). The Davidson Current is 100 km in width and extends seaward of the slope and transports warm, saline, low oxygen, high phosphate, equatorial water to the north (Gramling 2000; Hickey and Banas 2003). Evidence suggests that the Davidson Current is split by the southward flow of the California Current because there is a second region of northward flow several hundred kilometers away from shore (Hickey 1979).

2.5.1.5 Washington Undercurrent

There is some indication that a southward undercurrent, the Washington Undercurrent, occurs over the continental slope of Washington and Oregon in the winter (Werner and Hickey 1983; Purdy 1990). This undercurrent is located at depths of 300 to 500 m, deeper than the northward flowing California Undercurrent (Hickey 1998; Hickey and Banas 2003).

2.5.2 Columbia River Plume

The Columbia River defines the coastal boundary between Oregon and Washington State. Its effluent contributes approximately 60% of the freshwater entering the Pacific Ocean between San Francisco, California and the Strait of Juan de Fuca during the winter and more than 90% throughout the remainder of the year, heavily influencing the oceanography of the Pacific Northwest (Barnes et al. 1972; Norman et

al. 2004; Barth et al. 2005). Discharge rate from the Columbia River varies between 2,500 m^3/sec in late summer to 17,000 m^3/sec in the spring of a typical year. During major freshets, discharge rates can reach 30,000 m^3/sec (Bottom et al. 2005).

The Columbia River plume is consistently changing direction, depth, and width in response to local wind strength and direction (Hickey et al. 1998; Berdeal et al. 2002; Hickey and Banas 2003). In addition, eddy-like features are generated within the plume under both steady (Berdeal et al. 2002) and unsteady (Yankovsky et al. 2001) discharge conditions. In the fall and winter months, the plume flows northward over the shelf and slope of Washington; in spring and summer, it moves southward, well offshore of the Oregon shelf (Hickey and Banas 2003). During the winter, the plume can have dramatic effects on the Washington coast, producing currents with magnitudes on the order of wind-driven currents in the near surface layer (Hickey et al. 1998). The structure and magnitude of the Columbia River plume has significant interannual variability (Hickey and Banas 2003). Years in which the snowmelt in the Pacific Northwest is high (such as 1999), freshwater generated from the plume can flood northern estuaries for prolonged periods of time.

Changes in climate also affect the discharge of the Columbia River. During positive (warm) PDO years, discharge of the Columbia River is decreased by approximately 14% when compared to discharge of the river during negative (cool) PDO years (Mantua et al. 1997).

2.5.3 Strait of Juan de Fuca

The Strait of Juan de Fuca exhibits a typical estuarine circulation pattern with fresher surface water flowing seaward above the colder, saltier seawater flowing landward (Holbrook et al. 1980; Ebbesmeyer et al. 1991; Thomson 1994; Ott and Garrett 1998). These layers are intermixed to a degree that varies with time and location within the strait (Washington Sea Grant Program 2000). Due to the rotation of the Earth and the width of the strait, the surface seaward outflow is stronger on the northern, Canadian side of the channel and surface inflow is stronger on the southern, U.S. side of the strait (Pease et al. 1979; Hickey et al. 1991; Thomson 1994).

The typical estuarine circulation pattern is highly seasonal in nature. Reversals in surface flow can result from southerly coastal winds and can last several days (Holbrook et al. 1980; Ebbesmeyer et al. 1991; Hickey et al. 1991; Thomson 1994). Although these reversals usually occur during the winter, they have been observed during the summer (Holbrook et al. 1980). In addition, tidal flow and the formation of eddies can also strongly influence surface circulation in the Strait (Ebbesmeyer et al. 1991; Ott and Garrett 1998; Gramling 2000).

2.5.4 Puget Sound

Circulation patterns in Puget Sound are largely driven by freshwater inputs, tides, and winds (NOAA and WSDE 1999; 2000; 2002). Freshwater enters Puget Sound via precipitation, surface runoff, groundwater inflow, and riverine discharge. Major rivers entering Puget Sound include the Skagit, Snohomish, Cedar, Duwamish, Puyallup, Stillaguamish, and Nisqually, with the Stillaguamish, Snohomish and Skagit rivers accounting for more than 75% of the freshwater input to the Sound (NOAA and WSDE 1999; 2000; 2002). In Puget Sound, the discharge of freshwater can result in strong levels of stratification between 10 and 30 m (Matsuura and Cannon 1997). When stratification is weak, high correlations between wind speed and currents can be found at depths to 100 m (Matsuura and Cannon 1997; Kawase 1998).

North of Seattle, the main basin exhibits a typical estuarine pattern of net seaward flow near the surface, due to riverine freshwater input, and a net landward flow at depth (Cannon 1983; Thomson 1994). The main basin of Puget Sound, a partially-mixed fjord-like estuary, connects to the Strait of Juan de Fuca (Gramling 2000; Washington Sea Grant Program 2000). Surface circulation in the main basin is driven by winds and tidal eddies. The more inland waters of Puget Sound are enclosed areas with restricted water exchange with the main basin (Boesch et al. 1997); currents tend to be tidally driven in these regions, although some wind-driven flow does occur (DoN 2000b).

Nine major rivers enter Hood Canal, along with many smaller creeks and streams, with the majority of water entering Hood Canal from Admirality Inlet. Although winds, bathymetry, freshwater inflow, and density gradients can all affect the currents, flow in Hood Canal is dominated by the tides. This results in a southward flow of water during the flood tide and a northward flow when the tide ebbs (DoN 2000c). Speeds up to 0.8 m/sec have been recorded (DoN 2000c; 2002a).

2.5.5 Thermocline

The thermocline is located between the surface and deepwater circulation zones; it is a transition region where water temperatures change rapidly from warmer surface waters to colder deep waters. Although temperature differences are important in determining the vertical structure of the water column, salinity tends to play a larger role in the Pacific Northwest (Matsuura and Cannon 1997). Depth of the thermocline in Puget Sound is relatively shallow, averaging 2 to 20 m (Callaway 1963; Dunne et al. 2002; Kringel et al. 2003). Depth of the thermocline off the Pacific coastline varies with distance from the shore. Inshore, where upwelling of colder waters occurs, the thermocline is located at a relatively shallow depth of only 40 to 60 m (Zhou and Huntley 2005). Farther offshore, the thermocline deepens to 180 m off of California and 400 m farther north (Francis and Hare 1997; Miller et al. 1997; Miller et al. 1998).

Interannual variations in the depth of the thermocline appear to be correlated with long-term climatic changes, including El Niño and the PDO (Miller 1996). The 1977 shift to a positive phase of the PDO led to a deepening of the thermocline off the Pacific coast (MacCall et al. 2005). During an El Niño event, the thermocline off the Pacific coastline shallows (Johnson and O'Brien 1990). Over the past 50 years, there has also been an increase in regional stratification that coincides with a deepening of the thermocline in the coastal California Current System (Palacios et al. 2004).

2.5.6 Upwelling off the Pacific Coast

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). Coastal upwelling zones are among the most productive regions of the global ocean (Mote and Mantua 2002). 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 nutrient-poor surface water transported offshore (Hickey and Banas 2003; Burtenshaw et al. 2004; MacCall et al. 2005; Sutor et al. 2005). Coastal upwelling is largely controlled by the along-shore component of the wind field and the Coriolis force. On the western shore of North America where the shoreline runs mainly north–south, winds from the south (southerlies) push surface waters towards the shore (downwelling), whereas winds from the north (northerlies) transport surface waters away from the coast (upwelling; F.A. Whitney et al. 2005).

Seasonal upwelling along the U.S. west coast brings colder, saltier, and nutrient-rich water to the surface adjacent to the coast (Huyer 1983; van Geen et al. 2000). The continental shelf is relatively narrow and the nutricline is positioned such that nutrient-rich, deeper water from the California Undercurrent can be rapidly brought to the surface by wind-driven upwelling (Hickey and Banas 2003; **Figure 2-10**). The upwelling of nutrients from deeper waters promotes coastal primary production. During an upwelling event, phytoplankton respond to the infusion of nutrients near the coast and the bloom is moved offshore, where they continue to grow while depleting the upwelled nutrient supply. With the exception of regions affected by the outflow of the Columbia plume, stratification along the Pacific coastline is largely controlled by seasonal changes in the upwelling of water masses (Huyer 1983; Hickey and Banas 2003).

Upwelling seasons are clearly defined along the Pacific coastline (Short 1992). Winds in the region become predominantly southward and "upwelling-favorable" following a spring transition that typically occurs in March or April (Barth and Smith 1997; Peterson 1997; Barth et al. 2005). The upwelling season tends to run from April through September, with maximum intensity in July and August (Short 1992; Norman et al. 2004; Gómez-Gutiérrez et al. 2005). In general, the strength and duration of upwelling (as seen at the sea surface) increases to the south off the coastline of northern California, Oregon, Washington, and British Columbia with upwelling-favorable wind stress reaching a maximum off of

northern California and the southern Oregon coast (Bakun and Nelson 1991; Short 1992; Thomas and Strub 2001; Hickey and Banas 2003). The Oregon coastline exhibits strong levels of wind-induced upwelling during the spring and summer while significantly weaker levels of upwelling occur along the Washington coastline (Smith 1968; Small and Menzies 1981; Huyer 1983; PISCO and GLOBEC 2001; Hickey and Banas 2003; Gómez-Gutiérrez et al. 2005; Suchman and Brodeur 2005).

During the fall and winter months, southeast winds force warmer nutrient-depleted surface waters towards the coast and inhibit local upwelling (Burger 2003; Hickey and Banas 2003; Ressler et al. 2005). The lack of upwelling in the region slows primary production and decreases the concentration of chlorophyll in the coastal ecosystem (Wheeler and Hill 1999).

Timing and intensity of regional upwelling varies from year to year (Huyer et al. 1979; Strub and James 1988) and with changes in long term climatic phenomena, including El Niño, PDO, and global warming (Huyer and Smith 1985; Barth and Smith 1997). Off the coast of California, El Niño events are characterized by increases in ocean temperature and sea level, enhanced onshore and northward flow, and reduced coastal upwelling of deep, cold, nutrient-rich water (Smith et al. 1999; Airamé et al. 2003). During this period, survivorship and reproductive success of planktivorous invertebrates and fishes decrease in response to decreased plankton abundance (Airamé et al. 2003).

Along with seasonal and climatic differences in upwelling intensity, local topography, bathymetry, and circulation patterns can also play crucial roles in the intensity of upwelling within a region. River plumes, eddies, submarine canyons, banks, and coastal promontories are capable of modulating local upwelling responses (Hickey and Banas 2003). Several studies have shown that along the Pacific coastline, the presence of submarine canyons can enhance the upwelling of water from depth (e.g., Burger 2003), and additional water upwelled over the canyons off of Washington may compensate for the overall weakness in upwelling-favorable winds in the region (Hickey and Banas 2003). Productivity in the Strait of Juan de Fuca is also controlled by canyon induced upwelling; nutrients are upwelled into Juan de Fuca and Tulley Canyons, pass through the canyons, and enter the Strait (Mackas et al. 1980; Hickey and Banas 2003; F.A. Whitney et al. 2005). In addition to the canyons, during the summer the cyclonic Juan de Fuca Eddy develops at the mouth of the strait and upwells nutrient-rich water that spills onto the continental shelf creating a large pool of colder surface water (Freeland and Denman 1982; Thomson et al. 1989; Freeland 1992).

2.5.7 Offshore Eddies

2.5.7.1 Juan de Fuca Eddy

During the spring, the large cyclonic Juan de Fuca Eddy (or Tully Eddy; Tully 1942) develops offshore of northern Washington at the mouth of the Strait of Juan de Fuca (Burger 2003; Hickey and Banas 2003). The eddy forms as a result of the interaction between effluent from the Strait, southward wind-driven currents along the continental slope, and the bathymetry of the region (Hickey and Banas 2003). At its maximum, the eddy has a diameter of approximately 50 km and it is the dominant circulation pattern off northern Washington until its decline in the fall (Freeland and Denman 1982; Hickey and Banas 2003). The eddy is visible via satellite imagery as a relative minimum in SST as cold nutrient-rich water is upwelled from depth (Freeland and Denman 1982; Thomson et al. 1989; Freeland 1992).

2.5.7.2 Ephemeral Eddies

Dependant upon local conditions, other eddies may form in the region. Sustainability of these eddies varies and they may persist for days, weeks, months, or even years. Cyclonic and anticyclonic eddies are common in the summer and fall in the California Current System (Huyer et al. 1998; Barth et al. 2000; Strub and James 2000; Ressler et al. 2005). An eddy generated off the west coast of the Queen Charlotte Islands in February 1998 persisted beyond December 1998 and was expected to be detectable for at least three years. Whereas most eddies in this region track westward to the Gulf of Alaska, this eddy traversed southward, potentially making it a major source of upwelled nutrients for waters overlying the

thermocline off the coast of the U.S. Pacific coast. Eddies of this nature tend to be larger and stronger during El Niño years (such as 1998; Crawford et al. 1999).

2.5.7.3 Subsurface Eddies

Cyclonic circulation patterns are generally observed within and overlying submarine canyons off the Pacific coast (Hickey and Banas 2003). Often, these circulation patterns do not extend to the sea surface. These subsurface eddies provide an effective mechanism for trapping suspended sediment and organic detritus over geological features of the region (Hickey 1995).

2.5.8 Fronts

Oceanic fronts, or zones of high water property gradients, often exist at the interface between upwelled water and ambient coastal water. These fronts tend to occur regularly at certain locations along the coast as evident by examination of historical satellite images (Short 1992). Thermal fronts associated with upwelling are common along the coast of the Pacific Northwest. These fronts are frequently observed in the vicinity of Cape Blanco in southern Oregon; these features may extend 100 km offshore (Short 1992). In the case of fronts off of Vancouver Island, they may extend southward off of the Washington coast (Freeland and Denman 1982).

2.5.9 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.

2.5.9.1 Pacific Coast

Tides on the Pacific coast are mixed-semidiurnal, with spring-neap amplitude variation on the order of 50% (Emmett et al. 2000). Mean tidal amplitude ranges from 1.7 to 2.1 m and tides are generally twice as large as those on the outer Atlantic coast (Hickey and Banas 2003). The general effect of these semi-diurnal and diurnal tides along the Pacific coast is two-fold. First, they cause large changes in the total volume of water located along the coastline twice a day. Second, flow of the tides promotes vertical mixing, breaking down the stratification water column (Pickard and Emery 1990; Greenland 1998). Tides along the shelf tend to follow a predictable pattern in that the flow is to the northeast on the flood tide and retreats to the southwest on the ebb tide (Strickland and Chasan 1989). Tidal current speed is variable; however, the maximum velocities rarely exceed 10 cm/sec (Gramling 2000). Closer to shore, tidal currents are much larger than wind-driven currents and are heavily influenced by estuarine flow.

2.5.9.2 Puget Sound, Straits, and Inland Waters

Tidal flows are naturally accelerated when constricted by topographic features such as estuaries. The same principle holds true within Puget Sound. Tidal velocities within the Sound range from 25 cm/sec to 80 cm/sec (DoN 2000b; 2002a). Tidal amplitude is also increased within the confines of the Sound. High and low tide can vary by as much as 3.1 m per day, but extreme high and extreme low can vary by as much as 5 m; average tidal amplitude is 2.2 to 2.3 m (DoN 2000b; 2002a; 2003). Currents within the intertidal zone can be generated within the Sound by the ebb and flow of the tides (DoN 2003).

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 inorganic carbon synthesized into organic matter in a fixed volume of water using the energy derived from solar radiation or chemical reactions over a given period of time (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 (Valiela 1995). Continental shelves and upwelling systems contribute almost half of the global ocean's primary production (Pauly and Christensen 1995; Yen et al. 2005). However, chemosynthesis is another significant form of primary production that occurs in the Pacific Northwest. Chemosynthetic communities that are common in the Pacific Northwest include hydrothermal vent, cold seep, and whale fall ecosystems (discussed in Section 2.7.2.8). Average annual primary production in the region has been estimated at 646 grams (g) of carbon (C) per square meter (m^2) per year ($gC/m^2/yr$) on the shelf, 294 $gC/m^2/yr$ on the slope, and 229 $gC/m^2/yr$ in oceanic waters off the Pacific coast (Ressler et al. 2005).

2.6.1.1 Phytoplankton

Phytoplankton are the most important community of primary producers in all of the ocean (Thurman 1997). They are freely floating photosynthetic organisms and are distributed by ocean currents. Photosynthesis is a chemical reaction that converts solar energy from the sun into chemical energy stored within organic molecules by combining water, carbon dioxide, and light energy to form sugar and oxygen. In the oceanic system, the majority of photosynthesis is carried out by phytoplankton utilizing a suite of light harvesting compounds to convert solar energy into chemical energy, the most common being chl *a* (Thurman 1997; **Figure 2-11**). Rates of photosynthetic production can vary from between less than 0.1 $gC/m^2/day$ in oligotrophic regions, such as the western equatorial Pacific, to more than 10 $gC/m^2/day$ in highly productive areas (Thurman 1997).

The coast of the Pacific Northwest supports high primary productivity (Sutor et al. 2005). Concentrations greater than 3.0 mg chl/m^3 are present throughout the spring, summer, and fall within 40 km of shore, and rarely expand beyond 100 km offshore (Thomas and Strub 2001). Lowest concentrations (<0.25 mg chl/m^3) are usually located over 200 km offshore and intrude towards the coast in mid-summer (June to July). Each year, two episodes of seasonal offshore expansion of elevated pigments occur, one in spring and another in summer. The timing of the first of these episodes varies, occurring from early April to May. The second offshore expansion typically occurs in August (Thomas and Strub 2001).

Seasonal time series of chl *a* demonstrate that chl *a* concentration is greater on the Washington shelf than the Oregon shelf (Hickey and Banas 2003). Off of Oregon, chlorophyll values approach those seen off the Washington coast only over Heceta Bank. Washington experiences two peaks in chl *a* concentrations; the first occurs from February to April and the second occurs in October. Oregon does not exhibit this bimodal pattern (Thomas and Strub 2001). The few available studies of primary production demonstrate higher growth rates off the Washington coast (Anderson 1972), suggesting that the difference between the Oregon and Washington coasts is not simply due to enhanced retention of chl *a* along the Washington shelf, but rather to higher growth rates. In addition, the continental shelf southwest of Vancouver Island also experiences high levels of primary production, with winter levels one tenth of those found in the summer months (Burger 2003). Further south, from Cape Blanco to Cape Mendicino, the seasonal cycle exhibits stronger interannual variability than what is experienced to the north.

Local topography can also play a role in the productivity of local regions along the shelf. Maps of photosynthetic pigments in the Pacific Northwest show a relationship to bank like features; chl *a* concentrations are enhanced and extend farther offshore in the bank region offshore of the Juan de Fuca Strait, Cape Blanco, and Heceta Bank (Strub et al. 1990; Batchelder et al. 2002). Chlorophyll patterns suggest that the physical or biochemical environment provided by banks must have properties that are significantly different from nearshore upwelling regions along straight coastlines (Hickey and Banas 2003).

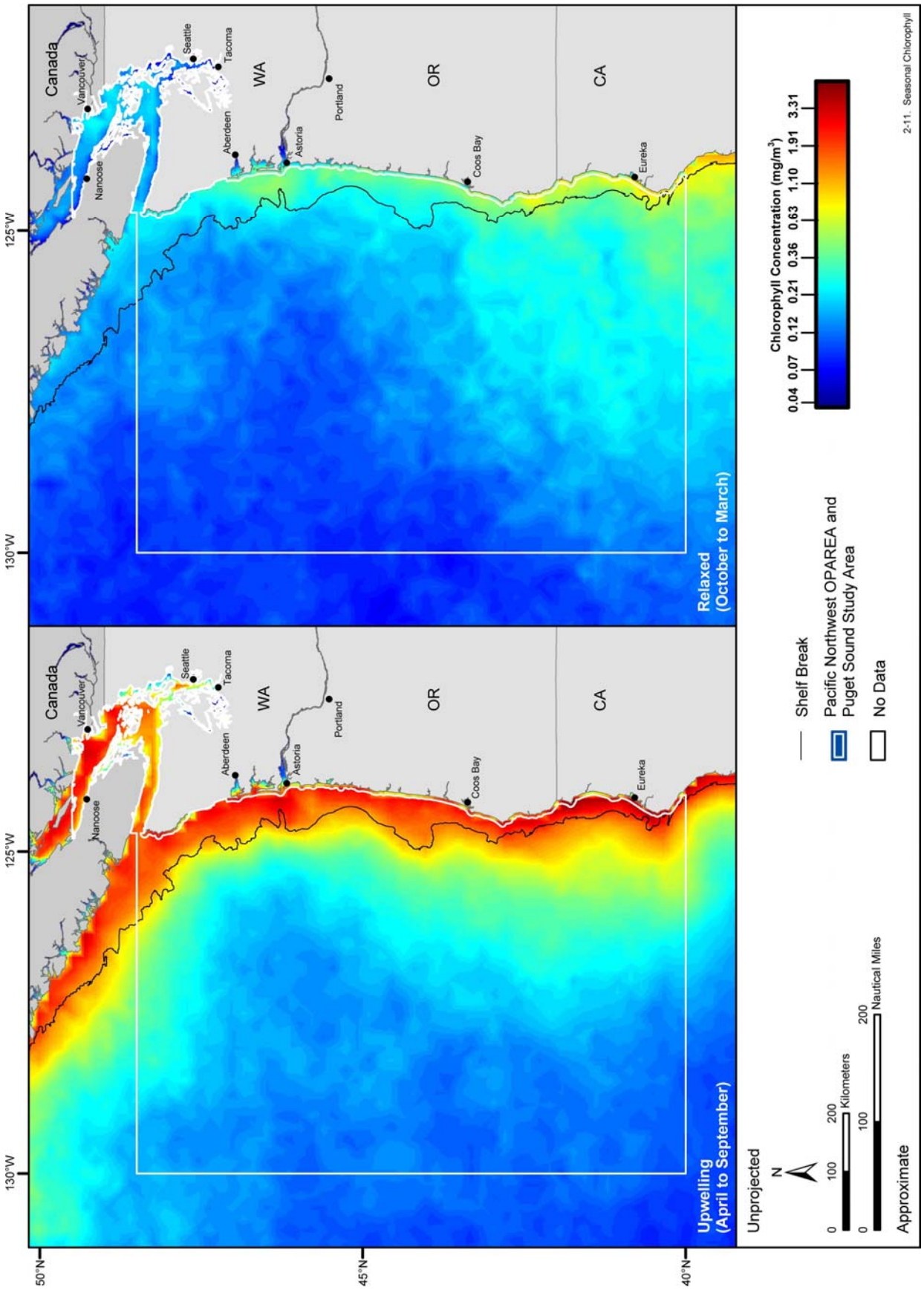

Figure 2-11. Seasonal distribution of chlorophyll throughout the Pacific Northwest OPAREA and Puget Sound study area during the upwelling season (April through September) and relaxed season (October through March). Source data: NASA.[11]

Phytoplankton blooms are common throughout shelf waters of the Pacific Northwest. During summer upwelling events on the Washington and Oregon coasts, chl *a* often exceeds 200 mg/m^2 (Landry et al. 1989). In 2002, the concentration of chl *a* was estimated to exceed 400 mg/m^3 in the surface waters off of the Oregon coast (Wheeler et al. 2003).

Offshore, and following upwelling events along the coast, there is a dramatic shift in the composition of the phytoplankton community within the California Current system; the composition changes from blooms of large-sized and chain-forming diatoms in newly upwelled water along the shelf to phytoplankton communities dominated by cells <5 microns (µm) in size (Sherr et al. 2005). The smallest of phytoplankton, the picoplankton (<1 to 3 µm), have low abundance in shelf regions but are considered to be the most important class of phytoplankton in open ocean gyres. Little is known about these smaller-size classes of phytoplankton (productive ocean systems are typically characterized by algal cells in the nanoplankton [2 to 20 µm] and microplankton [20 to 200 µm] size classes); however, these smaller cells are common in the pelagic ecosystems of the California Current System (Sherr et al. 2005). In California coastal waters these picoplankton are abundant and phylogenetically diverse (Putt and Prézelin 1985; Toledo and Palenik 1997; Worden et al. 2004). At two stations along an upwelling front off the Oregon coast, 2 to 5 µm eukaryotic cells (mostly picoplankton) dominate the total phytoplankton biomass (Hood et al. 1992).

During an El Niño event, less upwelling occurs, which in turn provides fewer nutrients for phytoplankton growth. As such, the waters of the Pacific Northwest experience decreased levels (by as much as 70%) of chlorophyll during El Niño years, when compared to an average year (Wheeler and Hill 1999; Thomas and Strub 2001). During this period, 80 to 90% of the chl *a* stocks along Pacific Northwest shelf waters are composed of phytoplankton smaller than 10 µm in size, as organisms this size are better adapted for survival during the low-nutrient period (Corwith and Wheeler 2002; Sherr et al. 2005). When average conditions return, enhanced upwelling provides the nutrients to support increased chlorophyll levels (Wheeler and Hill 1999). Warm phases of the PDO coincide with decreased productivity along the west coast of the U.S. (California, Oregon and Washington State; Hare et al. 1999; Childers et al. 2005). The opposite pattern emerges during cool phases.

2.6.1.2 Chemosynthesis

Another potentially significant source of biological productivity can occur in specific habitats that supply the nutrients necessary for chemosynthesis. In some locations, including the Pacific Northwest, hydrothermal vents, cold seeps, and whale falls can support vast benthic communities (e.g., Fisk et al. 2000; Hourdez et al. 2000; Durand et al. 2002; Rathgeber et al. 2002; Mehta et al. 2003; Thomson et al. 2003; Pruis and Johnson 2004). 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. Communities associated with hydrothermal vents, cold seeps, and whale falls are described in further detail in Section 2.7.2.8.

2.6.2 Secondary Production (Zooplankton)

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 and sea turtles, as well as species such as corals are found in later sections of this chapter or later chapters of this MRA. In this section, marine zooplankton are discussed.

The California Current System off of the U.S. Pacific Northwest is a dynamic and highly productive region with high levels of spatial and temporal variability. The zooplankton inhabiting this region have been investigated for several decades (Peterson and Miller 1975, 1977; Richardson and Pearcy 1977; Morgan

et al. 2003; Reese et al. 2005). Juvenile crabs (*megalopae*), copepods, amphipods, euphausiids, and chaetognaths tend to dominate the near-surface zooplankton community (Peterson 1997; Reese et al. 2005; Swartzman et al. 2005). The distribution of zooplankton along the coastline can be described as "patchy" with localized regions of high zooplankton concentrations spanning a distance from the coastline out to 150 km offshore (Swartzman and Hickey 2003; Ressler et al. 2005; Swartzman et al. 2005); highest zooplankton abundances are found within the upper 20 m of the water column over the inner- and mid-shelf (Peterson and Miller 1975, 1977). In general, the distribution of zooplankton is highly correlated to the concentration of chl, with the highest abundance of zooplankton occurring in regions of high primary production (Reese et al. 2005; Ressler et al. 2005) and SST (Reese et al. 2005). Consequently, zooplankton densities along the Pacific Northwest are highly seasonal, with summer densities ten times greater than those observed during the winter months (Burger 2003; Reese et al. 2005).

Copepods form the largest fraction of the zooplankton biomass in the main basin of Puget Sound. Small copepods are numerically dominant, with the genus *Acartia* being the most abundant. The larger copepods make up the majority of the zooplankton biomass, specifically the genus *Calanus* (Strickland 1983). These copepods tend to feed on the diatoms that dominate the spring bloom in the region. Euphausiids, amphipods, and mysids are also important components of the zooplankton in Puget Sound (Strickland 1983).

Along with the small zooplankton, gelatinous zooplankton can play a critical role in structuring coastal and estuarine ecosystems. These taxa can exert significant predation pressure within the coastal region (e.g., Kideys 2002). Although gelatinous medusae are widespread throughout the Pacific Northwest, their distribution tends to be patchy with high densities confined to smaller areas; their occurrence appears to be dependant on latitude, distance from shore, and water depth (Suchman and Brodeur 2005).

Climate changes also play a large role in the abundance and distribution of zooplankton in the region. The 1997/1998 El Niño resulted in a reduction in biomass and production of local zooplankton species due to a shortened upwelling season in 1997 and a delayed start of upwelling in 1998. Also, species that typically inhabit the waters offshore of Northern California and Oregon were observed inshore due to shoreward advection (Peterson 1999). In addition, following the shift to a warm phase of the PDO in 1977, salp biomass declined, euphausiid biomass remained unchanged, and copepod biomass increased, resulting in a change in zooplankton community structure within the region (MacCall et al. 2005).

2.6.3 Harmful Algal Blooms

In the U.S, the two major toxic syndromes caused by HABs that are found along the entire west coast are paralytic shellfish poisoning (PSP) and domoic acid poisoning (DAP), also known as amnesic shellfish poisoning (ASP). Certain species of phytoplankton from the genus *Pseudo-nitzschia*, and the genus *Alexandrium* are consumed by filter-feeding shellfish and finfish; when these organisms are subsequently consumed by humans, marine mammals, or birds, poisoning such as ASP and PSP can occur. Each state along the west coast has different monitoring programs for HABs (Trainer 2002).

2.6.3.1 Paralytic Shellfish Poisoning

On the west coast and inland waters of Washington, PSP is an annual problem along the coasts of northern California, Oregon, Washington, and Alaska (Boesch et al. 1997). Overall, PSP affects more coastline than any other HAB. Blooms can be either localized (e.g., restricted to the inland waters of Puget Sound) or wide spread along the Pacific Ocean coast.

Along the Washington coast, the highest levels of PSP toxins have been measured in August through October in blue mussels and other shellfish. Repeated outbreaks of human illness due to PSP have been reported along the Washington coast and in Puget Sound (Strickland 1983). In late August 2000, an outbreak of PSP in mussels from South Puget Sound resulted in the illness of nine people; levels exceeded 13,500 µg toxin/100 g. Five were hospitalized and three of the five were placed on artificial

respiration (Trainer 2002). The primary species responsible for PSP in Washington State is the dinoflagellate *Alexandrium catenella*.

The geography of the Oregon coast differs from its more northerly neighbors because there are no inland waterways or fjords that must be monitored for HAB toxins. A geographical difference in HAB occurrences in the northern and southern Oregon beaches has been observed over the past few years. For example, in 2001, PSP affected the southern beaches during the entire summer; whereas, the northern beaches were not affected (Trainer 2002). The causative species of PSP in Oregon is *A. catenella*.

The two largest PSP outbreaks in California, in 1927 and 1980, began during July. The majority of PSP cases in other years have also occurred during the summer months (June through September), with July being the peak month. It is hypothesized that the onset of PSP toxicity is linked to the onshore movement of warm, stratified waters following the relaxation of coastal upwelling. The relaxation events or downwelling, brought about by a change in wind speed or direction, carry established *Alexandrium* populations toward shore, resulting in rapid increases in toxicity in nearshore shellfish (Boesch et al. 1997; Langlois 2001). However, toxic dinoflagellate blooms are not limited to the warmer months of the year. Toxic blooms have caused numerous extensions of the quarantine period into November, and early-season quarantines as early as April have been common in recent years (Trainer 2002).

2.6.3.2 Domoic Acid Poisoning

Domoic acid frequently results in closures of razor clam beaches and Dungeness crab fisheries along the Washington coast and has been responsible for a number of mortalities in seabirds and marine mammals in California (Boesch et al. 1997; Trainer et al. 2000). A single event of ASP that occurred in Washington in Oregon created a loss of $15 to 20 million as a result of the closures in razor clam and Dungeness crab fisheries (Boesch et al. 1997). The diatom *Pseudo-nitzschia* is always present in significant numbers when the acid is present and these diatoms are known toxin producers (Hickey and Banas 2003).

The seasonality of coastal domoic acid events is similar across the coast of the Pacific Northwest. Typically, domoic acid poisoning has occurred in October and November, but events are occasionally documented in the spring (Trainer 2002). Within Washington, it is believed that *P. pseudodelicatissima* accounts for the largest toxigenic coastal blooms with *P. australis* contributing only occasionally to low level razor clam toxicity on the beaches on the southern coasts. Detailed studies of *Pseudo-nitzschia* species present at the time of high domoic acid on the Oregon coast have not been done (Trainer 2002).

2.6.3.3 *Heterosigma* Blooms

In addition to PSP and ASP blooms, additional blooms of toxic algae occasionally affect the Pacific Northwest. *Heterosigma* blooms cause problems at high cell densities, usually exceeding 10^7 cells/L. These blooms often start in shallow back bays of enclosed waters such as Puget Sound and are transported to the main waterways by tides and currents. A massive bloom of the alga *H. carterae*, a bi-flagellated, unicellular golden-brown microalga about 10 to 20 µm in diameter, was recorded in the main basin of Puget Sound during mid-July 1997 (Connell and Jacobs 1998). Although blooms of *H. carterae* in Puget Sound are infrequent, small blooms have been reported near Port Orchard in 1993, near Case Inlet (south Puget Sound), which caused fish losses in September 1994 (Hershberger et al. 1997). Also, several small sustained blooms have been reported along the west side of Bainbridge Island, near Brownsville, Washington, and in Liberty Bay (Connell and Jacobs 1998). It should be noted that *Heterosigma* blooms in Puget Sound tend to occur when freshwater influx increases (Boesch et al. 1997).

2.7 HABITAT

The majority of the habitats discussed for the Pacific Northwest are located 3 NM offshore; however, two major nearshore areas (1) the Puget Sound Region, which includes the nearshore U.S. waters of Puget Sound and the nearshore Canadian waters of Georgia Strait and (2) the nearshore waters of the W-237A region of the Whidbey Island Complex. Marine ecosystems in the waters of the Northeast Pacific Ocean are diverse and extensive. Habitat can be defined as (1) the area or type of environment within a

biological zone in which an organism, population, or community normally lives or occurs, (2) the sum total of environmental conditions of a specific place that is occupied by an organism, population or community, or (3) the particular preferred environment of an organism (Proctor et al. 1980b).

Habitats of the northeastern Pacific Ocean are demarcated based upon their inhabitant components, including plants, invertebrates, fishes, birds, and mammals. These inhabitants generally have geographical distributions that coincide with major oceanographic shifts, such as the bifurcation of currents or the intersection of two bodies of water. With reference to major biogeographic boundaries, the majority of species in the Pacific Northwest OPAREA occur in suitable habitats along the coast from the Gulf of Alaska to Point Conception, California (Airamé et al. 2003).

Habitat and species composition is strongly influenced by the dominant forms of vegetation, tidal influence, depth, and type of substrate (Proctor et al. 1980b). The habitats described herein have been identified and described based upon the habitat classification scheme developed by Greene et al. (1999) which was modified after Cowardin et al. (1979). Descriptions of habitats have been organized as mega-, meso-, macro-, and micro-habitats. Megahabitats have dimensions ranging from kilometers to tens of kilometers and lie within major physiographic provinces (e.g., continental shelf, slope and abyssal plain). Mesohabitats are of meters to a kilometer in scope and include small seamounts, canyons, banks, rocky reefs, caves, and bedrock outcrops. Macrohabitats range from 1 to 10 m and include seafloor materials, features, and biogenic structures, e.g., boulders, kelp beds, algal mats and crevices. Microhabitats include individual biogenic structures such as solitary gorgonian corals, sponges and sea anemones that are centimeters in size and smaller (Greene et al. 1999).

In the following habitat descriptions for the Pacific Northwest, several habitat types (i.e., macroalgae, seagrass, sargassum, etc.) and habitat areas (i.e., rocky intertidal, beaches, seamounts, etc.) are mapped. Significant data gaps make it impossible to represent a comprehensive depiction of habitat types or habitat areas. In addition, maps based upon habitat type may vary in location and extent over time and for this reason offer only a first approximation. Further, many of the habitat types overlap habitat areas. For example, kelp assemblages are also generally found along rocky intertidal shorelines. The content of each map is organized to best provide information for each habitat type and habitat area while minimizing the amount of overlap.

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 Pacific Northwest OPAREA and Puget Sound Study Area (**Figure 2-12**).

Marine and estuarine wetlands are dynamic environments; they are governed by many factors such as climate, oceanography, and terrestrial input. Wetlands form the transition zone between terrestrial and marine systems; because of this, they help to prevent shoreline erosion, reduce flood damage, and improve water quality (Carlisle et al. 2002). 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).

Marine and estuarine wetlands are among the most productive natural systems on earth, capable of producing more food per acre than the richest farmland (RAE/ERF1999). Per unit surface area, wetlands are more diverse and more productive than any other marine habitat (Bertness 1999; Airamé et al. 2003). 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. For example, wetlands provide important habitat for five species of Pacific salmon (*Onchorhynchus* spp.) and both migrant and wintering populations of migratory birds along the Pacific Flyway (Quinn 2005).

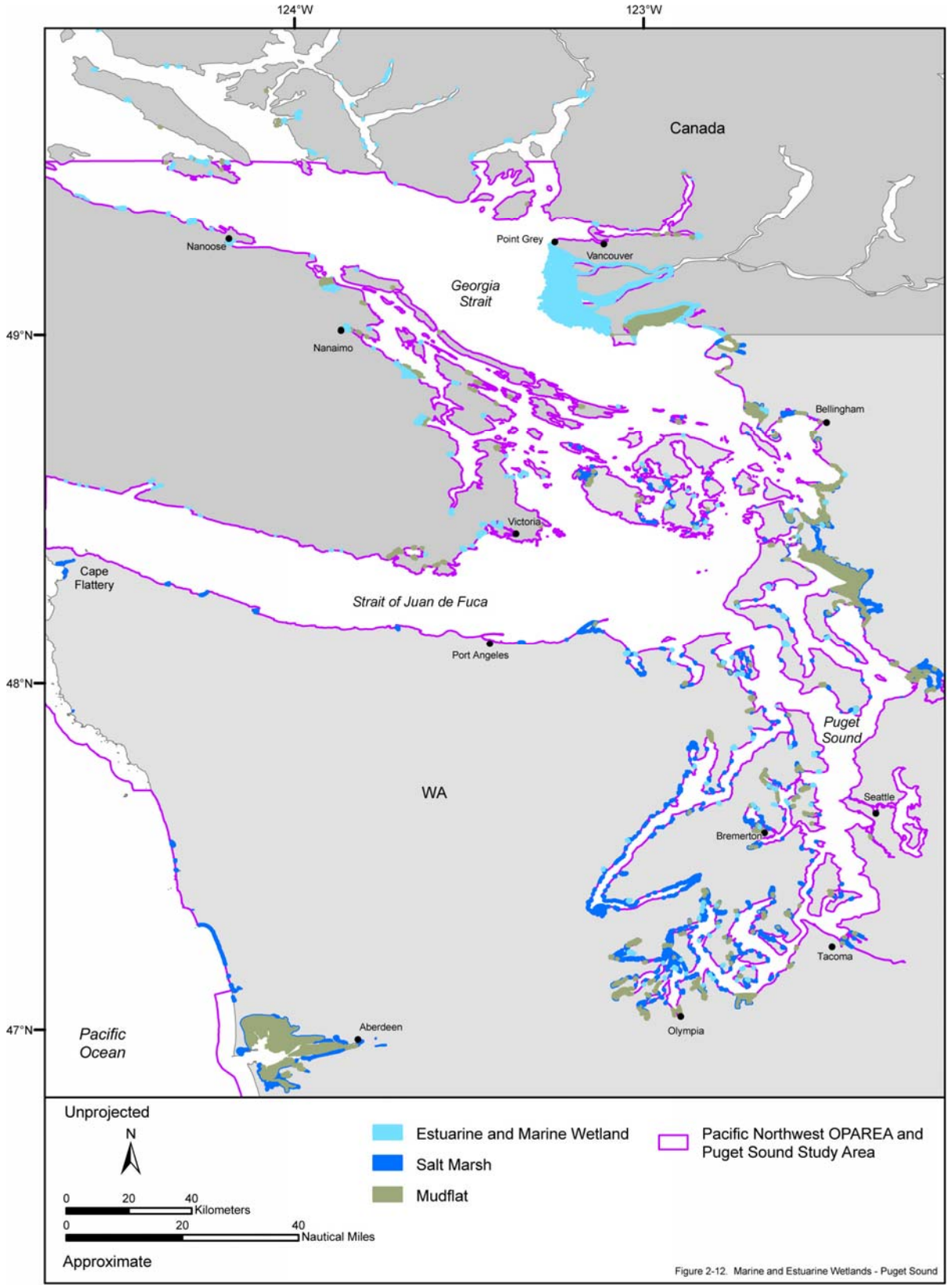

Figure 2-12. Distribution of marine and estuarine wetlands, salt marshes, mudflats, and tidal channels within the nearshore regions of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: WADNR[22,23,24], PECP (2004), TerraLogic GIS Inc. (2005), USFWS[12], and Province of British Columbia[13].

There are four types of major estuaries in the Pacific Northwest: bar-built, blind, drowned-river, and fjord (Seliskar and Gallagher 1983). Bar-built estuaries are formed by the accumulation of sand along bars; when connected to the shore, these sand bars restrict water flow to coastal embayments. Netarts Bay, Sand Lake, Grays Harbor, and Willapa Bay are examples of bar-built estuaries along the Pacific coast. The blind estuary develops from a bar-built estuary when freshwater or tidal flow is low; this restricted flow causes beach sediments to close the mouth of a river. Elk River, Pistol River, Sixes River, and the Winchuck River in Oregon are examples of blind estuaries that occur in the region. Drowned-river valley estuaries were formed at the end of the last ice age when rising sea level flooded river valleys. Examples of drowned-river estuaries include Coos Bay, Yaquina Bay, Nehalem Bay, and Siletz Bay. Some estuaries are formed via multiple mechanisms. For example, the Columbia River Estuary was formed from a stream-cut channel rather than a drowned-river valley, and Tillamook Bay shows both bar-built and drowned-river characteristics. Puget Sound also exemplifies a collection of estuaries of several types; it is the most complex nearshore ecosystem of the Pacific Northwest. Many elements of the Puget Sound region are of the fjord type, that is, they were carved out by glaciers (Seliskar and Gallagher 1983).

Along the Washington coast, marine and estuarine wetlands cover about 817 km^2, approximately 22% of the total wetland acreage in Washington. Major expanses of estuarine wetlands exist around Grays Harbor and Willapa Bay along the coast, at the mouth of the Columbia River, and around Skagit and Padilla Bays in Puget Sound. The wetlands in Washington provide primary feeding or breeding habitat for more than 315 species of wildlife and critical habitat for at least one-third of the state's threatened or endangered species (Lane and Taylor 1997).

Historically, the Pacific Northwest has experienced the exploitation of the wetlands via both natural processes and human activities (e.g., agricultural and coastal development) (Seliskar and Gallagher 1983). Several causes of wetland loss or degradation in the Pacific Northwest include flood-control projects, pollution, intentional fills, land clearing, grazing, invasion of exotics (e.g., *Spartina*), harvesting and oyster culturing, and recreational activities such as fishing, hunting, and boating (Kjelstrom and Williams 2000; Hacker et al. 2001; Reeder et al. 2001; Airamé et al. 2003). Continuing reductions in the quantity and quality of wetlands has serious effects on nutrient cycling, wastewater filtration, pollutant removal, and the endangerment of flora (plants) and fauna (animals) (Schafale and Weakley 1990). Some urbanized areas of Puget Sound have experienced wetland losses from 70 to 100%. For Washington State, wetland loss has been estimated to range from 3 to 8 km^2 per year and most of the state's remaining wetlands have been significantly degraded (Lane and Taylor 1997).

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). Coastal salt marshes experience various levels of tidal inundation; this leads to very distinctive zonation and vegetation succession based upon low, mid, and upper marsh elevations. In general, low marsh regions are flooded at every high tide and exposed at every low tide, middle marsh regions are flooded only during higher than average tides, and upper marsh regions are only flooded during extremely large tides and during storm surges or wind-driven tidal inundations (Tiner 1984).

In the Pacific Northwest, coastal salt marshes form discontinuous marshes that may extend miles inland and can develop along the intertidal flood plains of estuaries (**Figure 2-12**). They may also develop along the unexposed boundaries of sand spits, which have enclosed embayments along the rocky coast. Transitions between coastal salt marshes and upland in the Pacific Northwest are generally abrupt. Adjacent ecosystems at lower elevations such as mud flats, sand flats, eelgrass beds, and tidal creeks and channels interact with coastal salt marshes via tidal flow to carry nutrients and detrital material (Seliskar and Gallagher 1983). The interaction between coastal salt marshes and adjacent ecosystems is considered one of the most important functions of coastal salt marshes.

The tides of the Pacific Northwest create a complex pattern of flooding to produce a high diversity of environmental gradients in moisture, salinity, and nutrients that affects both plant and animal distribution (Seliskar and Gallagher 1983). Overall, taxonomic diversity is greatest in the high marsh, less in the low marsh, and least at the debris line (Seliskar and Gallagher 1983). Coastal salt marshes are generally characterized as having a low to mid marsh dominated by salt grass (*Distichlis spicata*) and pickleweed (*Salicornia virginica*) succeeded by a low marsh that is usually an open mudflat with very little vegetation. The six dominant coastal salt marsh species in the Pacific Northwest includes the Lyngby sedge (*Carex lyngbyei*), tufted hairgrass (*Deschampsia caespitosa*), salt grass, Reed canary grass (*Phalaris arundinacea*), pickleweed, and seaside arrowgrass (*Triglochin maritima*) (Thom et al. 2002). Algal populations are prominent on the coastal salt marsh surface and faunal components are dominated by insects on the marsh plants (Seliskar and Gallagher 1983). About one-half of commercially harvested fish and shellfish species in the Northeastern Pacific waters depend on coastal salt marsh habitat for food, spawning, or nursery habitat during some stage of life (Lane and Taylor 1997; Kjelstrom and Williams 2000).

Coastal salt marshes in the Pacific Northwest are continuously impacted by logging operations and diking. Log storage by logging operations has resulted in marsh plant smothering and hydrology changes. In addition, many of the lower marshes have been “reclaimed” by the construction of dikes. Diking has prevented the natural functioning of more coastal salt marsh than any other type of intrusion (Seliskar and Gallagher 1983). For various purposes, in the last 100 years, 90% of the Coos Bay coastal salt marsh has been destroyed (Seliskar and Gallagher 1983).

2.7.1.2 Tidal Creeks

Tidal creeks allow estuarine waters to circulate in and out of wetlands (Seliskar and Gallagher 1983). Tidal creeks are a major source of fresh water and are among the lowest salinity habitats that are associated with estuaries and bays. However, tidal inundation may extend brackish water into the creeks during high tides (Airamé et al. 2003).

The structure and density of the tidal creek system is governed by the elevation, wetland type, and drainage patterns of each particular habitat. These extensive channel systems provide access for animals to use coastal salt marsh, tidal flats, and other tidally inundated wetlands as a nursery grounds and/or feeding sites (Seliskar and Gallagher 1983). In the Nehalem Bay marsh, tidal creeks extend no more than 2.8 m above mean lower low water (Airamé et al. 2003).

2.7.1.3 Channels

Channels are a deep subtidal habitat that can be a naturally occurring or artificially dredged portion of the estuary (**Figure 2-12**); in comparison to tidal creeks, which are a much shallower tidally influenced habitat, channels are significantly deeper than adjacent habitats and are characterized by different sedimentary and faunal assemblages (Proctor et al. 1980a). Many channels have been dredged, which significantly modifies the benthos. In these deeper channels, respiration and decomposition coupled with slow water circulation cause low concentrations of dissolved oxygen which in turn causes reduced population sizes and modified species compositions (Proctor et al. 1980a). It should be noted that **Figure 2-12** shows only those channels that have been documented for the region.

2.7.1.4 Fjords

Many of the estuaries within the Puget Sound region are of the fjord type and some exceed 700 m in depth making the Sound region the most complex nearshore ecosystem of the Pacific Northwest (Seliskar and Gallagher 1983). The Canadian coastline of the Puget Sound and Pacific coast is indented with several hundred fjords. In a study by Leys et al. (2004), the coastal waters of British Columbia were examined to document the hexactinellid (glass sponge) communities that inhabit the fjords. They found 9 species of hexactinellid sponges that were observed on vertical or near-vertical walls and on bare rock or on rock with only a light sediment cover. These sponges occurred in most of the fjords in the Pacific Northwest and were exceptionally abundant in some locations (Leys et al. 2004).

2.7.1.5 Tidal Flats

Tidal flats are relatively broad, flat intertidal habitat submerged during high tide and located along protected coastal intertidal areas (DoN 2000d). In the Pacific Northwest region, tidal flats are typically inundated with meandering tidal creeks and channels. 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.

Abundant fauna utilize the nutrient-rich detritus found in tidal flats (DoN 2000d). The flora and fauna supported by tidal flats are typical of that found in the bays and estuaries of the Pacific Northwest region and serve as the food base for regional fishes and birds. Seasonally, many tidal flats serve as essential stopovers for migrating birds to rest, feed and breed.[20]

Sand flats are comprised of sand particles with low organic matter content (1% to 2%).[20] They form in areas of higher current and wave energy than mud flats and are usually no more than 1 km in width. The characteristic fauna of a sand flat is similar to that of the mud flat with cockle (*Clinocardium nuttalli*), white-sand clam (*Macoma secta*), and bent-nosed clam (*M. nasuta*) being the dominant benthos; however, the benthic populations in sand flats are less abundant than in mudflats (Proctor et al. 1980a).

Mudflats (**Figure 2-12**) form in protected areas that experience lower current and wave energy and are usually at least 5 km in width. They are comprised of smaller silt/clay sediments; this small sediment size makes for a tightly compacted sediment bed.[20] Well-developed mudflat sediments are anaerobic, stable, and harbor substantial amounts of organic matter and microorganisms. Algae dominate the flora because current velocities, light penetration, or other factors prevent the growth of eelgrass or emergent vegetation. Detrital and filter feeding food webs are characteristic, with fish (at high tide), clams (e.g.,soft-shell clam [*Mya arenaria*]), and polychaete worms dominating the benthos (Proctor et al. 1980a). Migratory water birds utilize the extensive algal cover and resident fauna present in mudflats (DoN 2000d).

2.7.1.6 Beach

A beach environment can be defined as the intertidal zone of unconsolidated material that extends landward from the low water line. Wind and waves continually influence the deposition and erosion of sediments; therefore, beach environments are constantly changing (Airamé et al. 2003). The upper intertidal beach is submerged for a short time and exposed to the widest range of temperatures; the animals inhabiting this zone rely on unpredictable and patchy food sources. This zone is used as a breeding habitat by a variety of birds and pinnipeds. The mid-littoral beach is alternately submerged and exposed for moderate periods of time; the characteristic fauna is dominated by species with high mobility (e.g., isopods, sand crabs, and polychaetes). The swash zone is submerged for approximately 12 hours per day. The low intertidal zone is exposed for brief periods of time during the lowest tides; the characteristic fauna is dominated by species that burrow into the sediments for protection. The surf zone is constantly submerged and subjected to the motion of breaking waves. The animals in the surf zone are subjected to nearly constant and intense physical agitation (Proctor et al. 1980a; Airamé et al. 2003).

Extensive beach habitat can be found throughout the nearshore regions of the Pacific Northwest (**Figure 2-13**). In the Pacific Northwest there are two main types of beaches (1) those that are protected and exist in low energy environments and (2) unprotected beaches that are exposed to constant high-energy wave action. Beach sand tends to be coarser in unprotected, wave-exposed regions and finer within protected estuaries and bays (Proctor et al. 1980a).

- Protected beach—Topographically, protected beaches tend to be wide with a low relief during the summer when sand is deposited on the shore. These beaches are typically associated with headlands and exist behind protective barriers (e.g., offshore reefs). They generally contain a higher concentration of organic material in the sediments than the concentration found in the sediments of

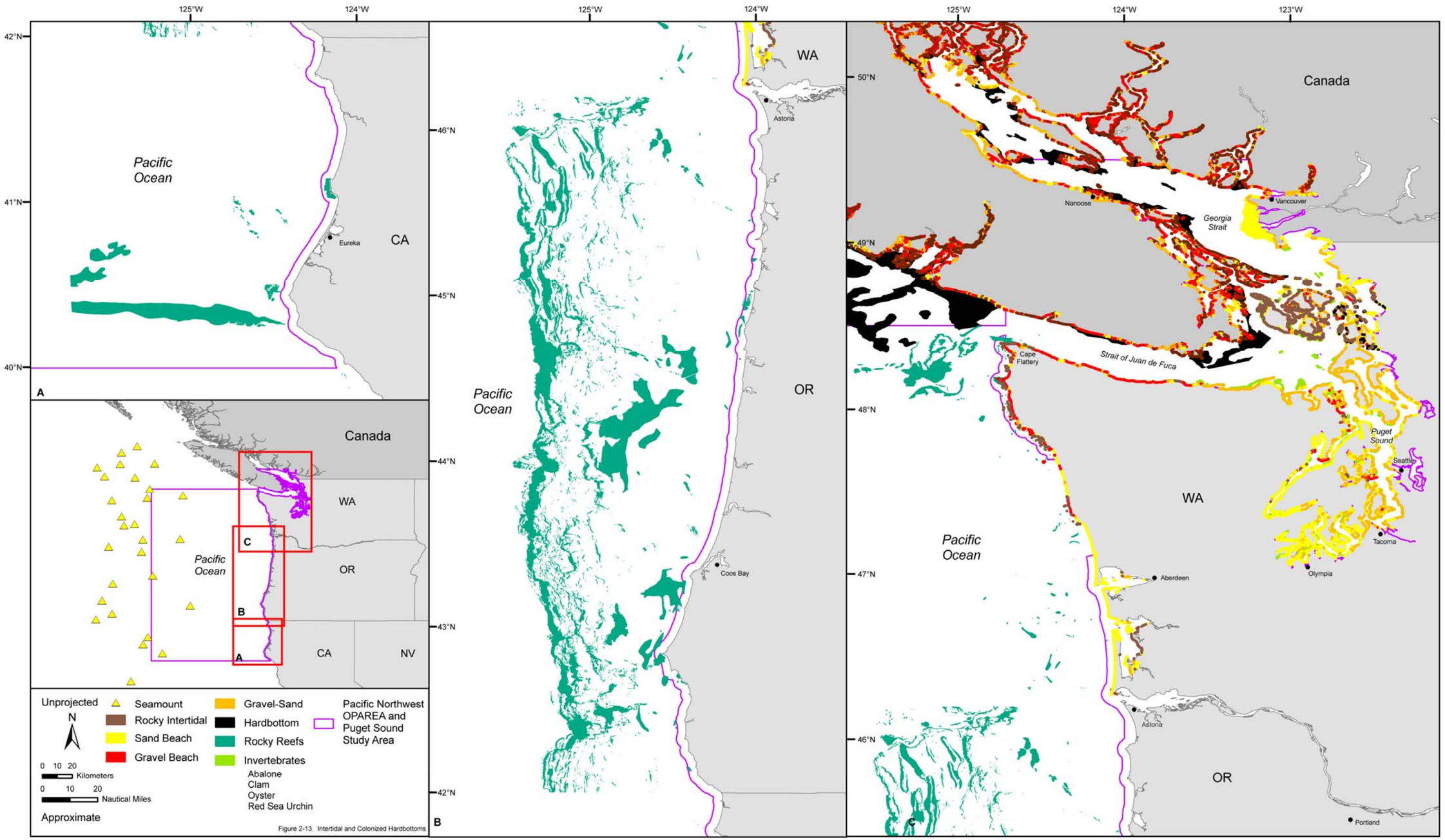

Figure 2-13. Intertidal and colonized hardbottom habitat located within the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity, including rocky intertidal, sand beach, gravel beach, gravel-sand beach, potential colonized hardbottom, and areas of invertebrate colonization (e.g., red sea urchin, oyster, clam, and abalone), rocky reef, and seamount habitats. Source data: WADNR[22,23,24], USFWS[12], Province of British Columbia[13], MCBI (2003), Scripps Institution of Oceanography[4], and TerraLogic GIS Inc. (2005).

unprotected beaches. Protected beaches are not as subjected to the erosional forces of the pounding surf as unprotected beaches are; therefore, they provide a more stable habitat for diverse fauna (Proctor et al. 1980a). The substratum in sheltered situations can be considered muddy. For instance, in most bays, a muddy sand substratum will change gradually to mud (Kozloff 1993).

- Unprotected beach—Unprotected beaches are exposed to significant wave action or large waves generated by winter storms. Along the outer coast, much of the sandy beaches along the shoreline are pounded by the surf (Kozloff 1993). As a result, the sand is continually in motion parallel to the coast and may be eroded and deposited offshore or onshore depending on the season (Airamé et al. 2003). Summer movement is toward the south and onshore causing a gentle gradient; winter movement is to the north and offshore causing a steep gradient. Because unprotected beaches are rigorous environments, these habitats experience low faunal abundance and diversity (Proctor et al. 1980a). In some places, gravel and pebbles make up more than half the volume of the sediment. The coarseness of the sand strongly influences the nature of the substratum and the associated organisms (Kozloff 1993).

In the Pacific Northwest OPAREA and the Puget Sound Study Area, a two-part beach profile is typical; the steep foreshore is typically composed of course sand or gravel and the subtidal area is generally of a lower-gradient with sand or mud terrace.[12] Furthermore, the beaches are representative of the glacial terrain of the Puget Lowlands with its complex morphology and sedimentary character. Additionally, these beaches provide nesting sites for birds and resting areas for some marine mammals; see Chapter 3 for specific haulout, rookery, and nesting sites. See Kozloff (1993) for an expansive description of the flora and fauna that occur in beach habitats within the Puget Sound and along the outer coast of the Pacific Northwest OPAREA.

2.7.1.7 Rocky Intertidal

Rocky intertidal habitat forms along the shoreline between high and low tide and is present on all shorelines of the Pacific Northwest where sand is absent due to constant wave action, currents, steep submarine slopes, and a lack of offshore sand reservoirs (Airamé et al. 2003; **Figure 2-13**). Biological assemblages common to rocky intertidal habitats are defined by extreme physical factors including exposure to air and potential desiccation, tidal inundation, 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). In general, diversity of the benthos (e.g., algae and invertebrates) increases with depth in rocky intertidal habitats (Airamé et al. 2003). Four zones of biological assemblages are traditionally associated with different tidal heights, similar to the ecological zonation characteristics of sandy beaches (Airamé et al. 2003). These four zones are the splash zone, the upper intertidal, the mid-intertidal, and the lower intertidal (Juvik and Juvik 1998).

Some areas of the coast are protected against wave action by offshore rocks, reefs, or islands while other unprotected areas of the coast, particularly rocky headlands and the exposed outer coast, are subjected to high wave action (Airamé et al. 2003). In the Pacific Northwest, rocky intertidal shores can be categorized as protected or unprotected habitats.

- Protected rocky intertidal—These areas are sheltered from heavy wave energy; however, wave action is high enough so that almost no fine sediments and very little sand occur. These areas also form pools known as tide pools; tide pools are flooded during rising tides and are continuous with the open ocean at the surface. Extremes in temperature and salinity that are characteristic of this environment cause a strong vertical zonation of biological assemblages. Two other benthic habitats coincide with the protected rocky intertidal habitat; they are the surfgrass (*Phyllospadix* spp., and the associated macroalgae) and the nearshore kelp (*Nereocystis* sp., and other brown algae). In addition, various sea anemones, sea stars, and brittle stars are very prominent (Proctor et al. 1980a).

- Unprotected rocky intertidal—These areas are exposed to high wave energy. The biological assemblages inhabiting this zone are adapted to high disturbances, extreme temperatures, and salinity variability. The surfgrass and nearshore kelp communities found in the protected rocky intertidal environment also play a major role in this region; however, the macroalgae associated with these habitats are the most visible flora. In addition, mussels (*Mytilis* spp.) and barnacles form a biotic substrate that provides the necessary habitat for many other species. The predacious sea star (*Pisaster ochraceous*) is also characteristic to this region (Proctor et al. 1980a).

Even in calm weather, much of the Pacific coast of North America is subject to strong wave action. Offshore islands, submarine ridges, and projecting headlands, provide protection from wave action. In some places, large offshore kelp beds act as wave retardants. Within Puget Sound, wave action is usually negligible. However, there are unprotected areas of the Puget Sound that experience stronger wave action. For instance, the Strait of Juan de Fuca, the Strait of Georgia, the waters surrounding the San Juan Archipelago, and shorelines along the southwest coast of Vancouver Island sustain considerable wave action. Elsewhere, however, the water is relatively quiet. Along the Strait of Juan de Fuca toward the inland Puget Sound regions there is a gradual change from outer coast conditions to those characteristic of the inland waters (Kozloff 1993).

Much of the flora and fauna common on Vancouver Island and northern Washington are primarily northern species near the limits of their southern range and drop out before they reach Oregon. Similarly, the flora and fauna in central California are near the northern limits of their ranges in northern California and Oregon. In general, the flora and fauna of the Puget Sound are similar to that of the outer coasts (Kozloff 1993). See Kozloff (1993) for an expansive description of the flora and fauna of the rocky intertidal zone in the Puget Sound and along the outer coast of the Pacific Northwest OPAREA.

2.7.2 Benthos

The bottom environment of the Pacific Northwest is complex due to the variety of bottom substrates and the complicated system of water circulation and bathymetry (Chikuni 1985). The distribution of the benthos is determined by a vertical zonation pattern that is mainly a function of depth (i.e., light penetration, temperature, and wave action) and substrate (i.e., availability and type of substrate and movement and accumulation of sediments; Maragos 2000).

Marine benthic assemblages are extremely diverse and include representatives of nearly all phyla. With increasing depth, light intensity declines and eventually algae and plants are unable to survive; therefore, benthic algae and reef-building corals decrease in abundance and size. Below 100 m only a few, small, stony corals are found (Chave and Malahoff 1998). At greater depths, animals, including non-reef-building corals, obtain their food through suspension feeding.

2.7.2.1 Flora

Benthic flora is 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 approaching 270 m (Littler et al. 1985). Macroflora (large plants) forms significant habitat 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 and diverse populations of macroflora 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.

In the Pacific Northwest, the distribution of marine algae is governed by biogeographic boundaries that are defined by oceanographic and topographic patterns. Vancouver Island is a transition zone for 77 species that occur to the north and 63 species that are found south of the island (Airamé et al. 2003). The most common macroflora found on sandy substrates at all depths are the turf algae; the most common turf algae include red algae (Rhodophyta) and green algae (Chlorophyta). In Dabob Bay and in northern Hood Canal, the most conspicuous macroflora in the littoral zone include the green algae, the sea lettuce

(*Ulva* spp.), the brown algae (Phaeophyta), the wrack (*Fucus* spp.), and a diverse array of red algae in the subtidal zone. *Sargassum* is also common; however, it often disappears during the winter season (DoN 2002a).

The most conspicuous benthic macroflora in the Pacific Northwest are the brown algae commonly known as kelp. Kelp attach to rocky substrates at subtidal depths and form the distinctive "kelp forests" familiar to the Pacific Northwest region (**Figure 2-14**). They extend from seafloor to surface and form a vertically structured habitat that is the fundamental element to many important ecosystems in the Pacific Northwest (Rodriguez et al. 2001).

2.7.2.1.1 Kelp and associated biota

Kelp usually grow attached to rocky substrate and can grow up to 50 m in length in nearshore areas of 2 to 60 m depth (Rodriguez et al. 2001). It persists on rocky reefs that are occasionally subject to severe wave action and tidal currents. The stems and blades of kelp can form overlying canopies on the water's surface and provide unique habitat for underlying plant and animal communities (Rodriguez et al. 2001). The typical kelp habitat is multilayered; it is composed of canopy, understory, turf, and crustose layers (Proctor et al. 1980a). Kelp can grow up to 10 cm per day and is among the most productive of marine plants. Kelp forests exhibit extremely high rates of primary production, estimated at 350 to 2,800 $gC/m^2/yr$.

Temperature, light, sedimentation, substrate, relief, wave exposure, nutrients, salinity, 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 (Foster and Schiel 1985; Graham 1997). Wave exposure and interspecific competition affect both the temporal and spatial variability of kelp (Graham 1997). Kelp are sensitive to light irradiance; they are restricted from waters less than 2 m in depth even along protected shorelines (Rodríguez 2003).

In the Pacific Northwest, kelp forests provide refuge, forage, and nursery areas to support commercial and sport fish, invertebrates, marine mammals, and marine birds. For example, sea otters are important predators in kelp forests, consuming sea urchins and other invertebrates, indirectly increasing the abundance of macroalgae. With the increase in macroalgae, the habitat structure becomes more complex and supports a greater diversity of fishes. In addition to sea otters, several other marine mammals find food and shelter in kelp forests (Cummings and Thompson 1971; Nerini 1984); gray whales forage and escape predation by killer whales in kelp forests (Deysher et al. 2002).

In addition, to the primary habitat that kelp forests provide, kelp also provides secondary habitats via drift kelp (detached kelp). Kelp forests provide large quantities of drift 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 (Airamé et al. 2003). Tides, currents, and storm-generated waves may carry drift kelp to the shore, transport it as floating kelp masses, or cause it to sink through the water column to the deep benthos. The drift kelp that has been carried into nearshore areas provides important nutrients to beach and rocky intertidal communities. Floating kelp masses are important habitats for fishes because it provides a source of food and shelter. A small portion of the drift kelp sinks through the water column and provides nutrients to organisms on the continental shelf and slope and to the meso- and bathypelagic zones, contributing to production in the deep sea (Rodriguez et al. 2001).

The kelp beds in the Pacific Northwest are among the most extensive and elaborate submarine forests in the world (DoN 2002a; **Figure 2-14**). The majority of the canopy is composed of two species, bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis pyrifera*). Bull kelp grows in areas of high wave energy and giant kelp primarily grows in calm waters (Airamé et al. 2003). The understory is made up of several kelps, notably walking kelp (*Pterygophora californica*), drilly kelp (*Alaria marginata*), laminariales (*Laminaria saccharina* and *L. setchellii*), and feather boa kelp (*Egregia menziesii*), the turf layer is made

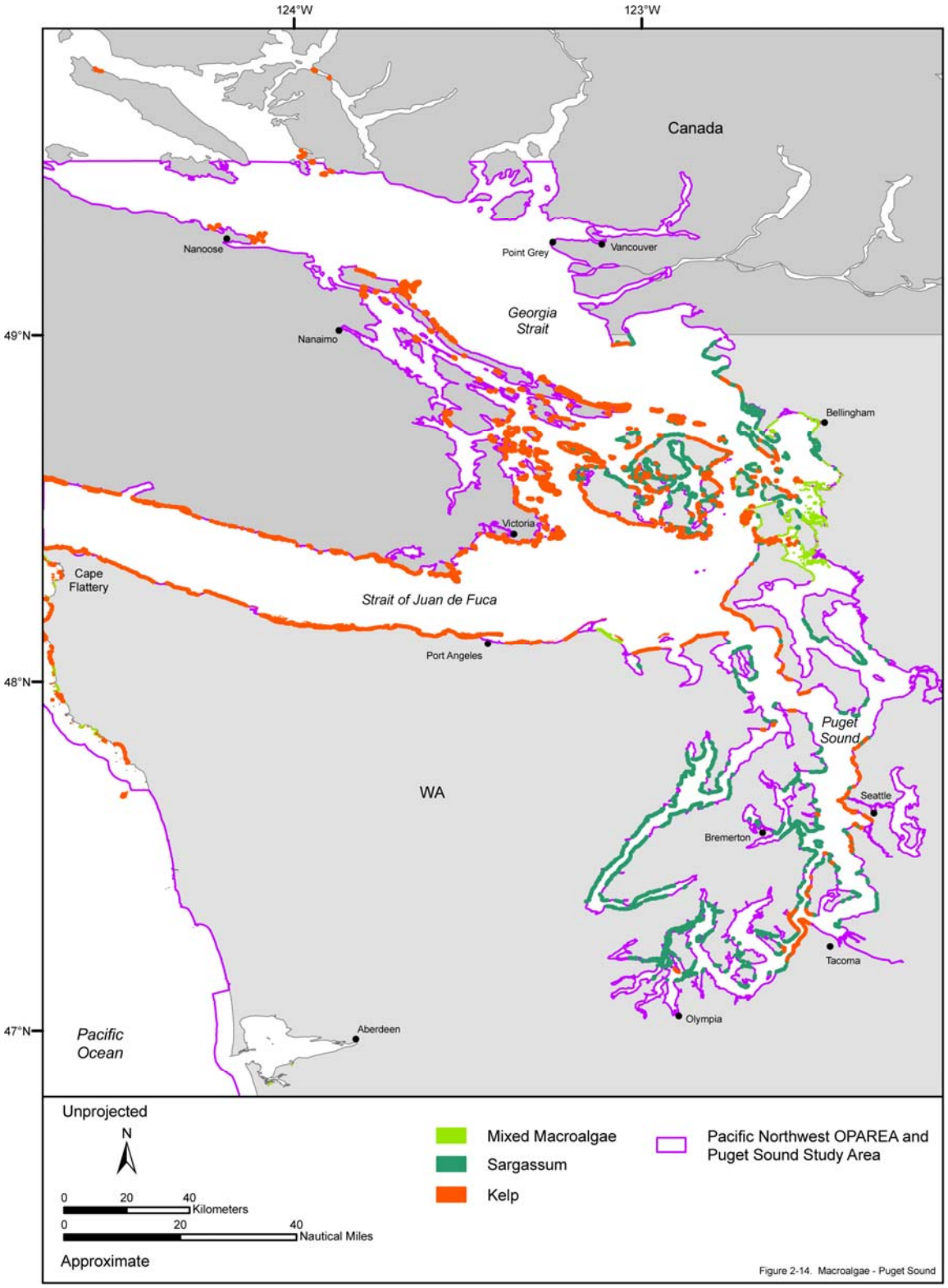

Figure 2-14. Distribution of macroalgae located within the nearshore regions of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Where available, the macroalgal data is designated by type including bull kelp (*Nereocystis* spp.), giant kelp (*Macrocystis* spp.), and Sargassum (*Sargassum* spp.). Where the data is not designated by type, it is labeled generally (e.g., kelp [unknown genera] and mixed macroalgae). Source data: WADNR[22,23,24,25], NOS (2001), TerraLogic GIS Inc. (2005), USFWS[12], and Province of British Columbia[13].

up of filamentous and thallose red algae, and the crustose layer is largely made up of encrusting (*Lithophyllum* spp.) and articulated corallines (e.g., *Calliarthron* spp. and *Bossiella* spp.) (Proctor et al. 1980a). Southern sea palm (*Eisenia arborea*) is a particularly important species found in low intertidal to subtidal (10 m) depths from Vancouver Island, British Columbia to Bahia Magdalena, Mexico (Abbott and Hollenberg 1976). It forms extensive subsurface canopies, 1 to 2 m above the bottom and can become the dominant alga in the absence of bull kelp or giant kelp (Edwards and Hernández-Carmona 2005). However, kelp are poorly represented in Dabob Bay and northern Hood Canal with only 0.3 to 0.5 % of the Hood Canal coastline having kelp present. The kelp beds that are present are those located near the Hood Canal Bridge; these beds are characterized by laminariales (e.g., *L. saccharina*), sieve kelp (*Agarum fimbriatum*), and ribbed kelp (*Costaria costata*), strangely there is an absence of bull kelp (Phillips and Meñez 1988).

2.7.2.1.2 Sargassum

Sargassum (*Sargassum muticum*) is a non-indigenous brown alga from Asia that has been established in the Pacific Northwest region for decades (**Figure 2-14**). Sargassum can be found colonizing cobble and rocky substrates in lower and shallow subtidal habitats. Little is known about its interaction with local species; however, it occurs along approximately 18% of the Washington State shoreline and its distribution is patchy. Sargassum is common along the shorelines of the Hood Canal, the San Juan Archipelago, and the Strait of Georgia; it is least common along the outer coast.[13]

2.7.2.1.3 Seagrass and associated biota

Seagrasses are submerged aquatic vegetation that form extensive underwater meadows (or beds). They are a group of approximately 60 species and are found in shallow-water depths and various temperatures and salinity ranges throughout many parts of the world (Thayer et al. 1984). Most seagrasses have flattened leaves that help them adjust to light restrictions and slow rates of gas diffusion in 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. The leaves are capable of transporting oxygen to the rhizomes, allowing seagrasses to grow in anoxic sediments (Phillips and Meñez 1988; Nybakken 1997).

Worldwide, seagrass beds are among the most productive habitats in the ocean and provide a substantial element in the sustainability of coastlines, fisheries, benthic invertebrates, marine mammals (e.g., manatees and dugongs), reptiles (e.g., 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 (Brouns and Heijs 1986). Seagrass beds slow currents and waves to prevent coastline erosion by stabilizing sediments and promoting sedimentation. In addition, seagrass beds improve water quality by filtering sediments and sediment borne pollutants, excess nutrients, and dissolved and particulate pollutants from terrestrial run-off (Phillips and Meñez 1988).

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; CalEPPC 1999). Seagrasses colonize carbonate or terrigenous sands and muds. In the Pacific Northwest, eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix* spp.) are the dominant native seagrasses (den Hartog 1970). Eelgrass grows in shallow, subtidal, or intertidal unconsolidated sediments and surfgrass grows on wave-beaten rocky shores.[19]

- Eelgrass—Eelgrass (*Z. marina*) is the dominant seagrass species in terms of biomass on the Pacific coast of North America. It grows in brackish to marine waters and can tolerate a wide range of temperatures and depths (up to 10 m below mean low tide; Proctor et al. 1980a; Airamé et al. 2003). Eelgrass is commonly found in bays and estuaries of soft sediment at intertidal and subtidal depths and in semi-sheltered areas with moderate currents (Airamé et al. 2003). The depth of growth is primarily controlled by the clarity of water and transmission of light to the seagrass bed. Eelgrass

does not generally grow in waters that carry substantial sediment loads due to the reduced light conditions (DoN 2002a).

Eelgrass beds are biologically rich habitats; amphipods feed on eelgrass and are an important food resource for juvenile chum salmon (*Oncorhynchus keta*), and Pacific herring (*Clupea pallasi*) utilize eelgrass beds as a nursery ground and spawning substratum (Proctor et al. 1980a). In addition, an extensive number of waterfowl utilize the flora and fauna associated with eelgrass habitats (Zimmerman 2003). Primary production by eelgrass beds can reach 84 to 480 $gC/m^2/yr$ making it one of the most productive habitats in the ocean (Green and Short 2003).

The lower intertidal and shallow subtidal of most of Puget Sound's shorelines are defined by a narrow, low-gradient bench (low-tide terrace), the primary habitat of eelgrass.[12] In the Puget Sound Basin approximately 200 km^2 (or 37% of the shoreline) is colonized by eelgrass beds (Airamé et al. 2003; **Figure 2-15**). Eelgrass habitat is found in the estuaries and bays throughout the Hood Canal and Dabob Bay region (FSJ 2004). San Juan County, an aggregate island group in northern Washington State, has 408 miles of shoreline, which provides valuable eelgrass habitat and is protected by Washington State largely because of the spawning habitat for Pacific herring, migrating corridors for juvenile salmon, and foraging grounds for Great Blue Herons. The Eelgrass Survey and Mapping Project completed comprehensive mapping of the deep-water edge of eelgrass growth in San Juan County. The entire shoreline of San Juan County was surveyed for eelgrass from 30 April 2003 to 25 September 2003 (Wyllie-Echeverria et al. 2003). The results indicate that more than 14 ha of eelgrass habitat have disappeared from two documented Pacific herring spawn sites in the northwest San Juan County, Washington. The causes of this loss are presently unknown; however, there is concern that similar conditions could be occurring throughout the Puget Sound Region (Proctor et al. 1980a).

- Surfgrass—Surfgrass (*Phyllospadix* spp.) is the dominant species in the rocky subtidal and intertidal zones of the Pacific Northwest where it has adapted to life in high wave exposure environments by clinging to rocky surfaces. It occurs along the protected outer coast areas from the intertidal zone to 7 m depth and from Alaska to Baja California; however, it is most common from southern Vancouver Island to Monterey (Ramírez-García et al. 2002). Infaunal polycheates are known to live in the rhizome mats of surfgrass stands (populations) and the primary production rate can reach 8000 $gC/m^2/yr$ making it the highest production rates reported for seagrasses (Proctor et al. 1980a). It is commonly associated with algal wrack (*Fucus*) (Green and Short 2003). Of three species of surfgrass, two (*P. scouleri* and *P. torreyi*) are found in the Pacific Northwest OPAREA and Puget Sound Study Area (**Figure 2-15**). *P. scouleri* inhabits the lower intertidal and shallow subtidal zones while *P. torreyi* grows at greater depths and is more abundant on the exposed parts of the coast (Ramírez-García et al. 2002).

2.7.2.2 Hard and Soft Substrates with Associated Fauna

The faunal (invertebrate) communities of the Pacific Northwest (**Figure 2-13**) have been well studied. The nature of these invertebrate communities depends on various local conditions including substrate type, water depth, the associated macrofloral communities, and geographical locations. In the Pacific Northwest, there are important biogeographical boundaries that define the northern range endpoint for over 100 species of marine benthic invertebrates; Vancouver Island is the northern range endpoint for 55 species and Sitka is the northern range endpoint for an additional 50 species (Miller et al. 1980).

During a seasonal survey of nearshore fishes in the Strait of Juan de Fuca from May 1976 to June 1979, a total of 191 species of invertebrates were identified. The most diverse taxa consisted of decapod crustaceans, amphipods, and gastropod mollusks; other less common taxa included isopods, mysids, polychaetes, and euphausids. Geographically, species richness increased from west to east; seasonally, species richness exhibited a minimum in fall and a maximum in spring with invertebrate abundances reaching a maximum in fall and winter (Fautin et al. 2002). In all studies concerning the invertebrate

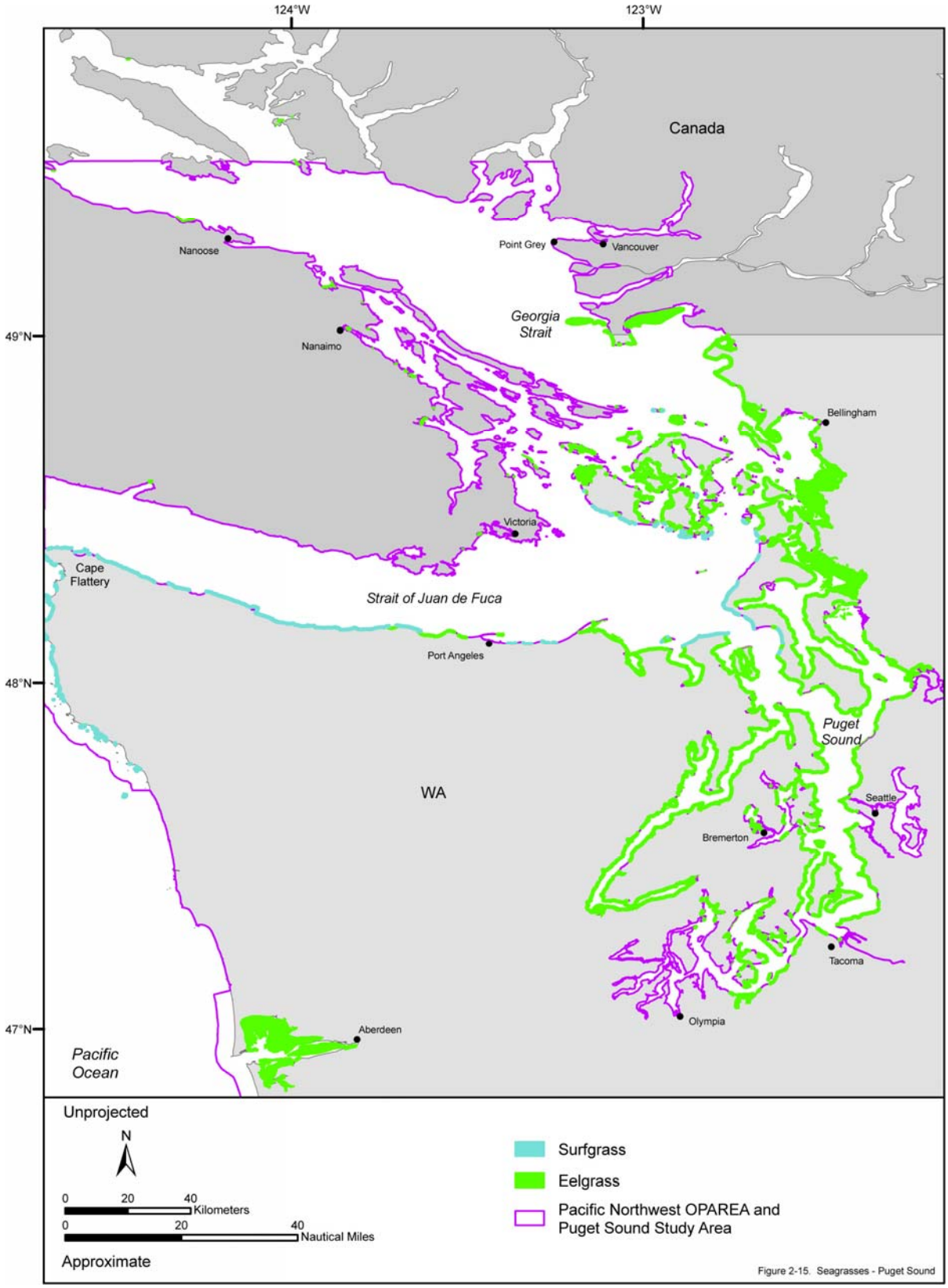

Figure 2-15. Location of seagrasses and seagrass beds located within the nearshore regions of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Seagrasses depicted include eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix* spp.). Source data: WADNR[22,23,24], NOS (2001), USFWS[12], and Province of British Columbia[13].

assemblages of the Pacific Northwest region, distribution is governed primarily by sediment type (for infaunal assemblages), substrate type, and water depth and secondarily by geographical location (Chess and Hobson 1997; Laetz 1998; Llansó 1998; Kanamori et al. 2004).

- Hard Substrates—Rocky substrate can provide support to extensive communities of marine plants and animals that require attachment for survival. For example, rocky substrates provide attachment sites for macroflora, which in turn provide habitat for a diverse ecosystem of fish and invertebrates. These areas can also be termed live bottoms or live hardbottom habitat (**Figures 2-13**). Live hardbottom habitat can be defined as areas that contain biological assemblages of sessile invertebrates living and attached to hard or rocky substrate with rough, broken, or smooth topography; these biological assemblages promote the congregation of a variety of marine life (Hobday et al. 2001). Rocky habitat may be composed of bedrock, boulders, or smaller rocks, such as cobble or gravel. Hard substrates and rocky reefs are among the most important habitats for groundfish. The Pacific Northwest OPAREA has a significant amount of rocky reef habitat located primarily along the outer coast of Oregon but also Washington and California (**Figure 2-13**; NMFS-NWR 2005).

  In the Puget Sound, hard substrate provides a substrate for the Olympia oyster (*Ostreola conchaphila*). The Olympia oyster is the only oyster native to the Pacific Northwest. Historically Olympia oyster beds existed throughout most of southern Puget Sound and specifically Willapa and Samish Bays. By 1960, overharvesting and pollution has nearly exterminated most of south Puget Sound's once-thriving Olympia oyster populations. In 1998, the WDFW developed the Olympia Oyster Stock Rebuilding Plan. Subsequently, Olympia oysters have survived in north and central Puget Sound, and populations in the south Sound and Hood Canal are gradually recovering (Peter-Contesse and Peabody 2005).

- Soft Substrate—Invertebrate communities that exist in the soft sediments of the Puget Sound are almost as rich as those that exist on the hard substrate. From 1989 to 1993, the invertebrate communities associated with soft substrate were documented at 76 monitoring stations located throughout Puget Sound, Hood Canal, and the Straits of Georgia and Juan de Fuca. Some species (e.g., the echinoderms, *Molpadia intermedia* and *Brisaster latifrons*) were restricted to deep water, and other species were characteristic of either north (e.g., the polychaetes, *Cossura* sp. and *Levinsenia gracilis*) or south (e.g., the polychaete, *Sigambra tentaculata*, and the bivalves, *Macoma nasuta* and *M. yoldiformis*; DoN 2002a).

  Many important commercial and recreational fisheries are dependent upon the soft substrate habitats of the Puget Sound. For example, adult Dungeness (*Cancer magister*) crabs can be found in waters as deep as 90 m and on substrates consisting of mud, rock, and gravel bottoms; however, they prefer soft substrates. Juvenile crabs are often found in the soft substrata of intertidal eelgrass beds. In addition, five species of shrimp are associated with softbottom benthic habitats, although some species move up into the water column at night to feed (DoN 2002a).

  Aquaculture is also dependent upon the soft substrate habitats of Puget Sound. Pacific oysters (*Crassostrea gigas*), geoducks (*Panope abrupta*), and other clams are cultivated in aquaculture operations in Puget Sound. Pacific oysters are widely cultivated in Dabob Bay; Dabob Bay is one of only 3 bays on the west coast where successful spawning of Pacific oysters occurs. Geoducks are the basis of an important commercial fishery in Puget Sound and are found in lower intertidal to subtidal soft bottom habitats in Puget Sound; they can be found in waters as deep as 110 m but are most abundant from 9 to 18 m below mean low water level (DoN 2002a).

2.7.2.3 Islets

Islet habitats support an abundant biota comparable to the benthic communities found on fringing and barrier reefs (Maragos 1998). Coastal islets occur almost continuously along the Pacific Northwest coastline except at the mouths of large bays and estuaries (e.g., Columbia River mouth). Headlands are also common along the open rocky coasts of the Pacific Northwest and are very similar in habitat to islets

(Proctor et al. 1980a). Islets and headlands along the Pacific coast are high-energy, unique habitats that support numerous rare, endemic species (Airamé et al. 2003). Seabirds have a positive impact on islet habitats; by depositing excreta, feathers, eggshells, and carcasses they provide organic material and nutrients. This nutrient input can increase plant productivity in the surrounding areas (Airamé et al. 2003) .

Human impact in these regions tends to be minor, allowing islets to provide sheltered habitat for coral communities, important nesting beaches, rookeries, and haulout sites (Maragos 1998; Etnoyer and Morgan 2003); see Chapter 3 for specific haulout, rookery, and nesting sites. Historically, islets have been strongly affected by hunting, resulting in the near extinction of northern elephant seals, northern fur seals, common murres, Cassin's auklets, and tufted puffins from the Pacific coast.

2.7.2.4 Coral Communities

Habitat-forming deep-sea corals occur in the Puget Sound, and on the continental shelf and the slope off Oregon and California (**Figure 2-16**). 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). While the mean depth range of deep-sea corals in the Northeast Pacific Ocean is 265 to 1,262 m, deep-sea corals of the Pacific Northwest OPAREA occur in water depths ranging from 9 to 3450 m (Etnoyer and Morgan 2003).

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.[15] Such communities of the Pacific Northwest OPAREA include sessile stony corals (Order Scleractinia), soft corals (Sub Class Octocorallia), black corals (Order Antipatharia), and lace corals (Freiwald et al. 2004; Hain and Corcoran 2004; Roberts and Hirshfield 2004). In complete darkness, deep-sea corals lack the symbiotic zooxanthellae found in their tropical counterparts and survive solely on suspension feeding. Yet, in the deep-sea, Scleractinia and hydrocorals can build very large three-dimensional structures, "cold-water coral reefs", comparable in size and complexity with shallow water coral reefs (Hain and Corcoran 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 biological diversity of deep-sea coral communities is high; from an economic perspective, this diversity creates valuable habitat for several commercially fished species (Gass 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 one to tens of meters high (Tucker and Wright 1990; Cairns 1994). Deep-sea coral communities are populated by thousands of sessile and motile species including sponges, polychaetes, 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). These communities are, however, slow growing and fragile, and thus vulnerable to human-induced physical impacts (Freiwald et al. 2004; Roberts and Hirshfield 2004; Brancato 2005; Hyland et al. 2005).

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 have 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; Brancato and Bowlby 2005). It may take decades to centuries for damaged cold-water coral reefs to recover (Freiwald et al. 2004; Roberts and Hirshfield 2004).

Regional Composition and Distribution—There are eight families of habitat-forming deep-sea corals (anthozoans, octocorals, and hydrozoans) in the Northeast Pacific Ocean: Antipathidae, Oculinidae, Caryophllidae, Corallidae, Isididae, Paragorgiidae, Primnoidae, and Stylasteriidae. These corals were documented on seamounts, along the continental shelf, in Puget Sound and the Georgia Strait areas

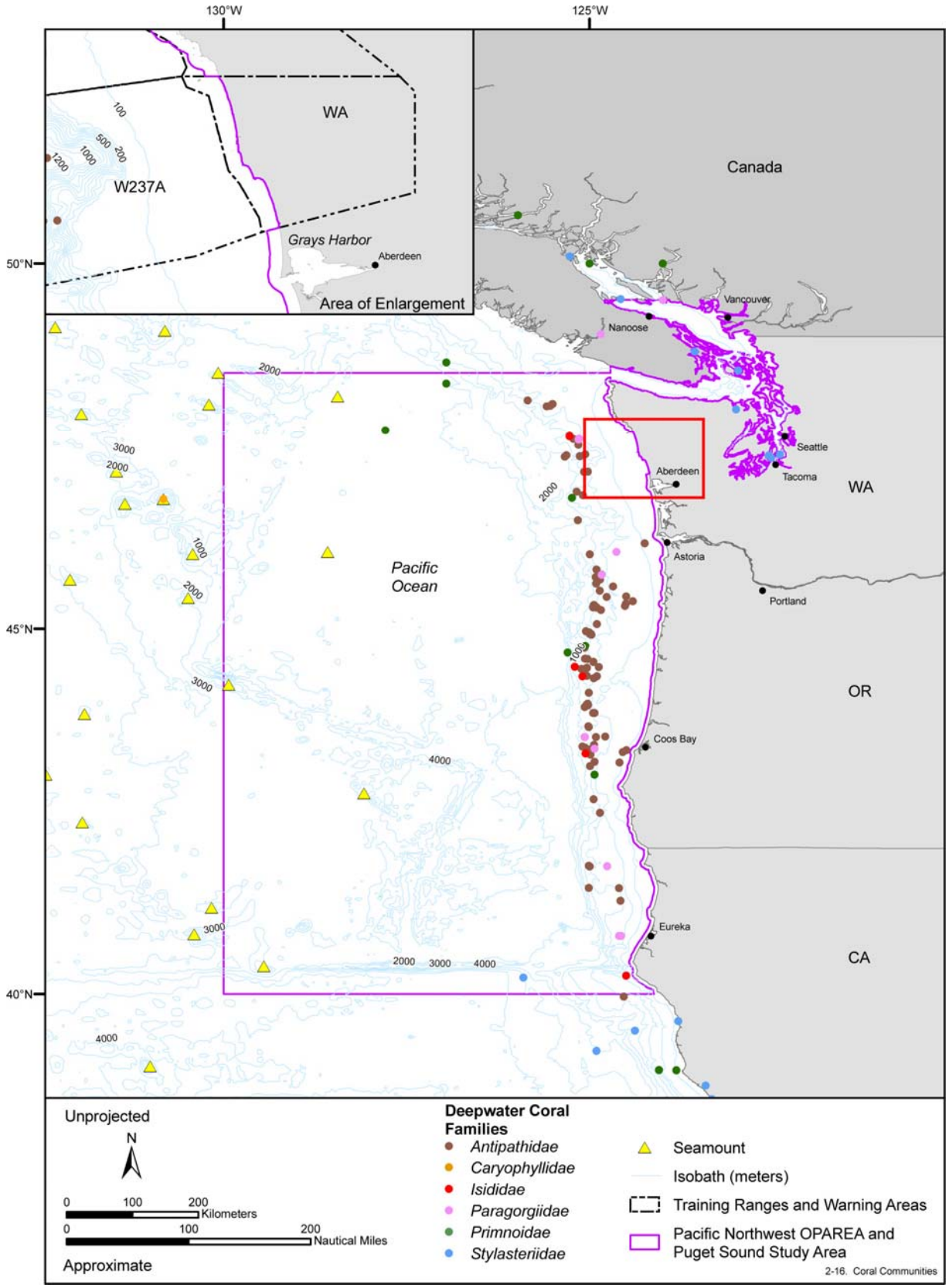

Figure 2-16. Coral communities (hydrozoans and anthozoans) of the Pacific Northwest OPAREA, Puget Sound Study Area, and near vicinity. Source data: MCBI (2003) and Scripps Institution of Oceanography.[4]

(Etnoyer and Morgan 2003; **Figure 2-16**). There are 105 known habitat-forming deep-sea coral species for the Northeast Pacific Ocean. The Primnoidae (anthozoan, octocoral) represent 60% of the regionally-known coral species. The other families documented in the Pacific Northeast region consist of hexacorals (Antipathidae, Oculinidae, Caryophllidae), octocorals (Corallidae, Isididae, Paragorgiidae), and hydrocorals (Stylasteriidae). As mentioned above, the depth range of documented deep-sea corals in the region is 9 to 3,540 m. Except for Corallidae species, all deep-sea coral species of this area can occur in waters as shallow as 9 m. Corallidae are usually found within the 215 to 2,116 m depth range. Corallidae are probably the only true cold-water corals of the Northeast Pacific Ocean. The Isididae (also known as bamboo corals) are the deepest occurring deepwater corals with a known depth range of 107 to 3,880 m (Etnoyer and Morgan 2003). Stylasteriidae corals are found in Puget Sound and Georgia Strait, and on the shelf and shelf slope in waters shallower than 823 m (Etnoyer and Morgan 2003). Additional surveys would probably increase our knowledge of the depth and geographical ranges of corals of the Northeast Pacific Ocean, Puget Sound and Georgia Strait areas.

- Pacific Northwest OPAREA—Corals are found along the entire shelf slope (predominantly within the 500 to 1,500 m water-depth range) of the Pacific Northwest OPAREA including training range W237A and in a few locations along the shelf and within the Puget Sound Study Area (Etnoyer and Morgan 2003; Hyland et al. 2005) (**Figure 2-16**). The most common and abundant corals on the shelf slope are Antipathidae. There are few records of Primnoidae, Stylasteriidae, and Paragorgiidae on the shelf and slope and the rare *Lophelia* (Caryophylliidae) on the Washington shelf (Bowlby et al. 2005; Hyland et al. 2005). In Puget Sound and Georgia Strait, the most common corals are Stylasteriidae. They were found in Sequim Bay, the Commencement Bay region, the areas of Friday Harbor and Saltspring Island, west of Bowen Island, and in the Nanoose Range Area (Etnoyer and Morgan 2003).

2.7.2.5 Sponge Reefs

Hexactinellids (glass or siliceous sponges) typically live in deep oceans (500 to 3,000 m) worldwide (Jamieson and Chew 2002). The hexactinellid sponges on the western Canadian continental shelf are globally unique in that they are reef-building sponges. Hexactinellid reef-building sponges are different from other hexactinellids in that their siliceous skeleton remains intact after the death of the sponge to provide a suitable framework for reef construction. These reefs were discovered during the regional geophysical surveys of 1987 and 1988 (Conway et al. 1991) in the broad glacially scoured troughs of Hecate Strait and Queen Charlotte Sound (Conway et al. 2005). They consist of dense populations of reef-building hexactinellid sponges (three species: *Farrea occa*, *Heterochone calyx*, and *Aphrocallistes vastus*) that have overgrown dead sponges to form a bioconstruction consisting of a strong reef framework (Conway et al. 2002). These bioconstructions form bioherms (mounds) up to 21 m in height and biostromes (beds), which extend for tens of kilometers at depths between 140 and 240 m (F. Whitney et al. 2005).

It is necessary for some hexactinellid sponges to have high dissolved silicate (Si) levels for spicule formation. The Pacific Northwest, and specifically the coastal waters of British Columbia, is enriched with Si from both upwelling and riverine input, making an ideal environment for sponge reef habitat. The sponge reef communities found on the British Columbia coast inhabit areas that are rich in dissolved Si (>40 µM), have relatively high fluxes of opaline detritus (approximately 2 mol Si/m^2/yr), and are subject to moderate bottom currents (to 35 cm/sec) which helps transport nutrients to the sponges and prevent sedimentation smothering of sponges (F. Whitney et al. 2005).

Hexactinellid sponges grow at a rate of approximately 1 cm/yr (Conway et al. 1991). These sponge reefs were believed to have covered much of southern Europe seafloor (a 7,000 km long sponge reef structure) and vanished during the Cretaceous; they were perhaps the largest biotic structure that ever existed on earth (Conway et al. 2002). To date, living hexactinellid sponge reefs have been found only on the western Canadian shelf, where they cover approximately 700 km^2. The sponges require hard substrate for attachment and growth and are therefore normally associated with gravel or bedrock seafloors (Conway et al. 2002).

On the Alaskan and Washington State continental shelves the rockfish trawl fishery has been correlated with sponge by-catch, suggesting that sponge reefs provide important habitat for many species of fishes and invertebrates (Strickland 1983; Conway et al. 2002; F. Whitney et al. 2005).

In areas of sponge reef that have not been affected by bottom trawling, biomass is estimated to be approximately 300 tons/km^2. In areas that have been trawled, there has been nearly complete removal (Conway et al. 1991). Types of damage observed include broken sponges that were removed at the base, crushed sponges, and abraded distal portions of the sponges (Conway et al. 2002).

The four known sponge reef complexes in the Central and North Coasts of British Columbia are thought to be unique in the world. In British Columbia, these reef complexes are presently protected by voluntary shrimp trawl closures and as of July 2002, regulatory groundfish trawl closures (Jamieson and Chew 2002). The Department of Fisheries and Oceans of Canada is currently considering the reefs for potential marine protected areas (Conway et al. 2005).

There are three reef complexes that occur within the Puget Sound Study Area; these three areas all occur in the northern Puget Sound region from 90 to 210 m of water depth at North McCall Bank, South McCall Bank, and Fraser Ridge. At North McCall Bank, 90 reefs have an average reef area of 20,000 m^2, at South McCall Bank, 25 reefs have an average reef area of 92,800 m^2, and at Fraser Ridge, 18 reefs have an average reef area of 5,833 m^2 (Conway et al. 2005). The abundant species at all 3 sites were the chalice or vase sponge (*Heterochone calyx*) and the cloud sponge (*Aphrocallistes vastus*). The communities at Fraser Ridge are densely clustered and brightly colored, unlike other reef areas where these sponges are usually white. The reef complex at North McCall Bank is abundant with large sponges while the reef complex at South McCall Bank has an absence of healthy sponges (Conway et al. 2005).

2.7.2.6 Deep Rocky Substrate

The bottom substrate of the deep-sea is typically covered with silts, clays, and fine sediments; however, there is the occasional hardbottom substrate (e.g., rocky outcroppings, rubble, talus, vertical wall, rocky reef, and seamounts) that support a diverse assemblage of deep-sea invertebrates and fishes. Beyond the depths of kelp beds (>30 m), approximately 3% of the sea floor is comprised of hardbottom substrate.

The type of bottom substrate governs the abundance and diversity of deep-sea organisms. Abundance and diversity are generally higher on hard, irregular substrates than on smooth, hard surfaces (Airamé et al. 2003). Although there have been many descriptive studies detailing the macroflora and macrofauna assemblages associated with these deep rocky substrate habitats, these habitats are challenging to study because they usually lie beyond the range of SCUBA and mechanical sampling is difficult. Characteristically, on deep hard substrate, patterns of species distribution are related to substrate relief. Most deep hardbottom organisms are suspension feeders; for example, corals, anemones, and sea lilies (crinoids) are all common in the Pacific Northwest (Lissner 1988). Two important deep rocky substrate environments, submarine canyons and seamounts, are prominent submarine features that will be discussed in the following sections. Both habitat types may be important in rockfish management (Williams and Ralston 2002b); rockfish occurrence associated with these habitat types is discussed in more detail in Chapter 4.4.3.

2.7.2.6.1 Submarine canyon communities

The Pacific Northwest continental shelf is highly dissected by numerous submarine canyons (**Figure 2-7**). Submarine canyons harbor various habitats, including vertical cliffs, ledges, talus, cobble and boulder fields, and soft mud. Generally, rocky substrate lines the steep canyon walls; whereas, soft substrate (e.g., silt and mud) slope gently and accumulate sediments to form the bottom of the canyon. The organisms that live in submarine canyon habitats must be able to withstand extreme conditions; with depths of more than 500 m, little or no light, cold water temperatures (5º to 12ºC), and tremendous pressure (up to 318 atm; Airamé et al. 2003).

Some of the production in submarine canyons is introduced from adjacent habitats. Drift macroalgae and other organic matter produced in shallow or surface waters may settle and accumulate at the mouth and along the slopes of submarine canyons. This detritus may be washed down the canyon during storms, contributing to productivity in the deep sea. In addition, the soft substrate at the base of the canyons supports a diverse invertebrate community. The rocky substrates of submarine canyons provide cover for numerous fish species (e.g., sole, sablefish, hake, and rockfish). Localized populations of groundfish may take refuge in the structure-forming invertebrate macrofauna that can be found in submarine canyons (Brodeur 2001). For example, a submarine canyon in the North Pacific was observed to have dense aggregations of rockfish associated with sea whips (*Halipteris willemoesi*) while a damaged sea whip "forest" had far fewer rockfish (NMFS-NWR 2005). The complex structure of the rocky substrate in submarine canyons can help to protect these species from over-fishing because they tend to be difficult to locate and target. However, submarine canyons are vulnerable to human activities because submarine canyons extend across a range of depths and may be heavily influenced by the deposition of sediments and pollutants that is associated with coastal development (Airamé et al. 2003).

2.7.2.6.2 Seamounts

Seamounts are isolated mountains rising from 900 to 3,000 m above the surrounding deep soft sandy bottom. 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). Very little research has been conducted on seamounts; they are among the least understood habitats in the ocean-basins (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). Currents generated by seamounts retain rockfish larvae and zooplankton, a principal source for rockfish (Dower and Perry 2001).

A total of 597 invertebrate species have been recorded from seamounts in studies that have been conducted worldwide (Richer de Forges et al. 2000). The most common invertebrates found on seamounts worldwide are cnidarians (i.e., hydroids, jellyfish, anemones, and corals), other abundant and diverse fauna include sponges (including large brilliant-yellow barrel sponges that have been known to support intrinsic communities), brittlestars (ophiuroids), sea lilies (crinoids), seastars, tunicates, sea urchins, sea cucumbers, and octopi (Wilson and Kaufmann 1987; Rogers 1994). The most common fishes are rockfish and morids (codling); seamounts also attract various predators and marine mammals as a result of this relatively high biomass (Wilson and Kaufmann 1987; Airamé et al. 2003). In excess of one third of the species associated with seamounts are endemic. In one study, levels of endemism among 850 macro- and megafaunal species were as high as 29 to 34% (Johnston and Santillo 2004).

Seamount communities are extremely vulnerable to the impacts of fishing. Some seamount fish and benthos are already known to have been seriously impacted by fishing activities; their recovery is complicated by the limited fixed habitat, the extreme longevity of many species (of the order of 100 years and more), and the slow or limited recruitment between seamounts (Richer de Forges et al. 2000; Johnston and Santillo 2004). The global status of seamount benthic communities is unknown; however, the limited distribution of seamount biota greatly increases the threat of extinction making the conservation and protection of seamount habitats necessary (Richer de Forges et al. 2000).

There are several seamounts located in the Pacific Northwest OPAREA; refer to the previous section, 2.3.7, in this chapter for a full description (**Figures 2-7** and **2-13**).

2.7.2.7 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 to 5 km 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 km thick sediment bed that constitutes the largest portion of the

ocean basin (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. In a few places, extinct volcanoes or seamounts, disrupt the monotony of the abyssal plain (Airamé et al. 2003). The abyssal plain is regarded as the true ocean floor and is characterized by extremely cold water, no light, and extremely diverse marine inhabitants (Wilson 1976; Beaulieu 2001a, 2001b; Cunha and Wilson 2003; O'Dor 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.

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 that live within, upon, or associated with the ocean bottom rely upon the primary production in the surface waters; this sinking detritus provides the primary source of nutrients for bathypelagic and deep-sea communities. On average, less than 3% of primary production sinks through the water column to the deep sea; however, in the northeastern Pacific waters, where production is particularly high, approximately 5 to 15% of the surface production eventually reaches the deep sea. Deep benthic fauna living on or in the benthos grow more slowly, live longer, have smaller broods than animals living in shallow waters, and although consumption is slow, once organic matter reaches the sea floor, it is almost entirely consumed, a very small portion of the organic matter may dissolve or become buried in sediments (Airamé et al. 2003).

In spite of these extreme conditions, the deep sea supports a remarkable diversity of organisms (Grassle 1991). Due to the unpredictable and patchy supply of food, organisms in the deep sea use a variety of foraging strategies. Many deep-sea animals are “sit-and-wait” predators, while others are active scavengers that break down carcasses on the sea floor, attracting slower-moving animals, such as mollusks, sea stars, brittlestars, and sea cucumbers. In many areas of the deep sea, brittlestars are the dominant macrofauna; they are often found around sea pen (*Pennatulacea*) beds and are so abundant that their feeding behavior and high activity levels can alter the ecology of benthic soft-bottom communities. Grenadiers and a few large deep-sea squid (e.g., *Architeuthis dux*) are active predators in the deep sea habitat.[18]

The Cascadia abyssal plain or basin is located in the Pacific Northwest OPAREA. It extends from the base of the Cascadia accretionary prism (approximately 700 km off Oregon) westward to the Juan de Fuca Ridge and encompasses a surface area of approximately 170,000 km^2. The total thickness of substrata reaches a maximum 3 km. The abyssal floor widens and slopes to the south with an average gradient of 1:1000 and the maximum water depth is 2930 m. The abyssal floor is contains low-relief channels and two submarine fans. Submarine canyons along the Cascadia shelf function as the principal conduits for sediment transport onto the Cascadia abyssal floor (Underwood and Hoke 2000).

2.7.2.8 Chemosynthetic Ecosystems

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.[6] Chemosynthetic communities are a significant source of biological productivity on the deep-sea floor (**Figure 2-17**). In some locations, vast fields of hydrothermal vents can support benthic communities (Hessler and Lonsdale 1991; Hashimoto et al. 1995; Galkin 1997; Smith et al. 2003). In other locations, gas hydrates in the sediments support extensive chemosynthetic communities (Fisher et al. 2000; Lanoil et al. 2001; Reed et al. 2002).

Chemosynthetic habitats are formed by a variety of geological and biological processes on continental margins, and despite their location in the deep sea, have high biomasses maintained by chemosynthetic bacterial production (Fujikura et al. 2002; Smith et al. 2003) Natural whale falls, hydrothermal vents and seeps, and wood falls provide specific habitat duration and each of these chemosynthetic habitats appears to foster a characteristic fauna (Airamé et al. 2003; JAMSTEC[6]).

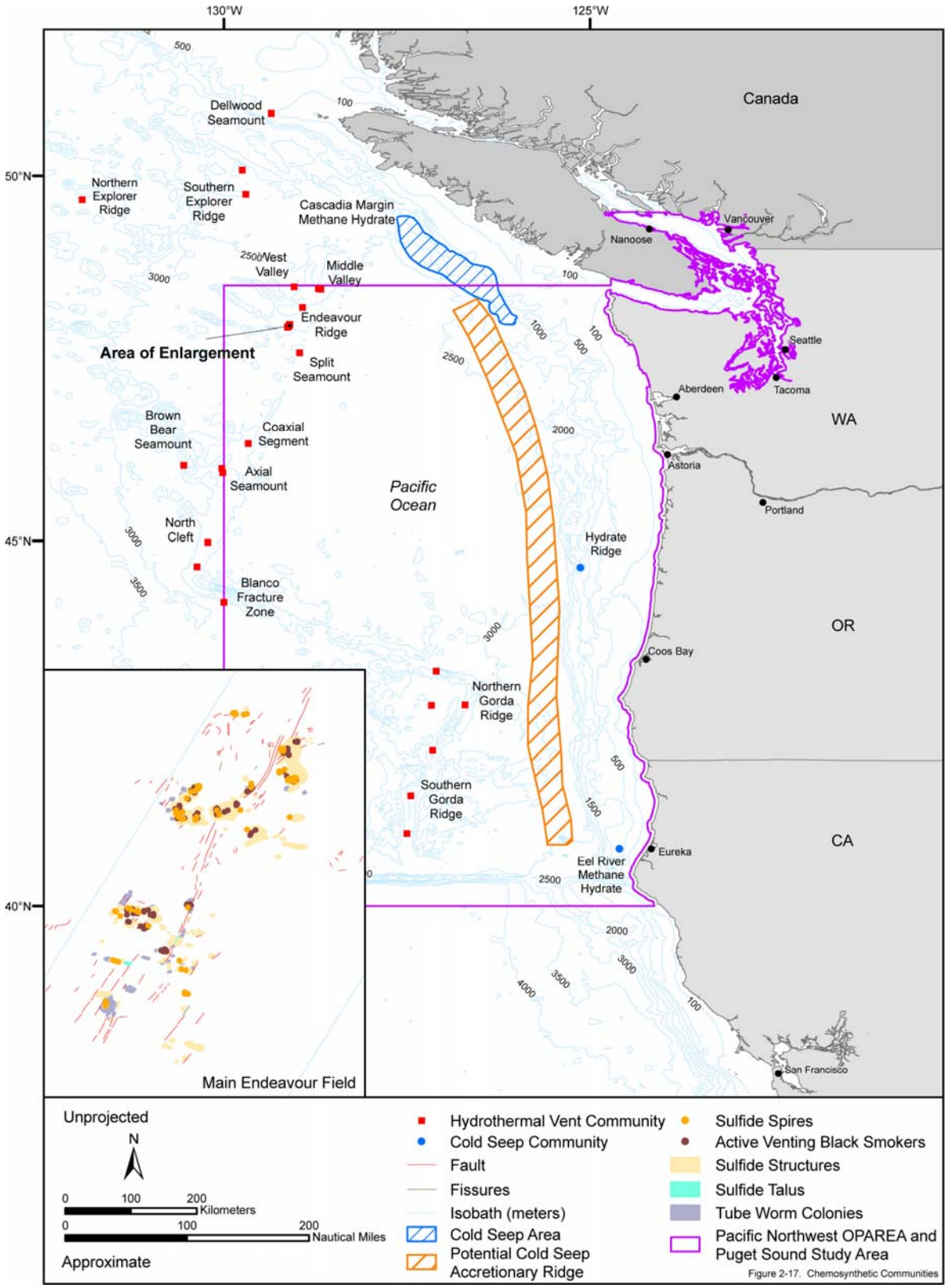

Figure 2-17. Chemosynthetic communities located within the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity, including hydrothermal vent and cold seep communities. General cold seep accretionary areas are also depicted. Source data: Delaney et al. (1992), Interridge (1999), NOAA[26], and Scripps Institution of Oceanography[4]. Source maps (scanned): Levin et al. (2003) and Heeschen et al. (2005). Source information: DoE[21].

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 (Anderson et al. 1993). In general, chemosynthetic communities in the Pacific Northwest OPAREA are characterized by tubeworms, giant white clams, mussels, gastropods, and sponges (Kojima 2002).

2.7.2.8.1 Cold seeps

A cold seep (sometimes referred to as a cold vent) is a region of the seafloor that releases hydrogen sulfide, methane, and other hydrocarbon-rich fluids (Airamé et al. 2003). 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. Typically, cold seeps originate from relatively young sediments and are common along basin margins. However, in recent years many seep communities have been reported in tectonically passive margins, active regions of plate collision, and along marginal basins (Hashimoto et al. 1989; Kvenvolden 1993).

Gas hydrates, also called gas clathrates, are naturally occurring crystalline solids that are comprised of water molecules organized in a rigid polyhedral cage structure; each cage contains a molecule of natural gas, predominantly methane (Kvenvolden 1993; Gornitz and Fung 1994). The gas associated with the hydrates can be carbon dioxide, hydrogen sulfide, methane, or other hydrocarbons; in addition, a hydrate can either be biogenically derived or thermogenically produced (Schmidt 2004). Methane, the most common gas associated with hydrates, accounts for more than 99% of deep ocean hydrates (Schmidt 2004). Gas hydrates are capable of cementing loose sediments into a surface layer several hundred meters thick (Masutani and Coffin 2001). Thus, gas hydrates can alter (1) physical properties of sediments, such as shear strength, porosity, and permeability, (2) geophysical properties, such as acoustic velocity and resistivity, and (3) geochemical properties, such as fluid composition and movement (Kvenvolden 1993). Gas hydrates have formed along much of the Pacific Northwest; they occur along the continental margins of the Pacific Northwest OPAREA where the water is cold and the pressure is sufficient to support hydrate formation.

Gas hydrates occur worldwide on continental margins and have been identified on 10 to 30% of the world's continental shelves (Hovland et al. 1993) (Heeschen et al. 2005), but, fundamentally they are known to occur in polar and deep oceanic regions because of the pressure-temperature and gas volume requirements for formation. In the deep ocean, although not thoroughly explored, gas hydrates are found in the sediments of the continental slope where cold bottom water is present (Kvenvolden 1993).

Sediments containing hydrocarbon seeps are often more productive than the surrounding sediments and seepage into surrounding waters has a profound effect on microbial populations and productivity; increased production is likely due to the increased concentration of sulfides as well as the high alkalinity in the sediments (Montagna et al. 1986). For example, hydrocarbon-degrading microbes often comprise a large percentage of the biota associated with hydrocarbon seeps. These bacteria derive energy from the inorganic chemical compounds that is released (i.e., via free-living bacteria, methane-oxidizing archaea, sulfate reducing bacteria, and a consortia of these metabolic types; Airamé et al. 2003). Recently, high rates of chemosynthesis has been documented from the sediments at methane seeps (Levin and Michener 2002).

Chemosynthetic communities display an astonishing assemblage of macrofauna forming a unique association for the deep sea (Sibuet and Olu 1998). These macrofauna obtain chemosynthetically fixed organic matter by (1) translocation from sulfide- or methane-oxidizing symbionts, (2) feeding on free-living chemoautotrophic bacteria, or (3) consuming another animal that obtains nutrition through (1) or (2) (Levin and Michener 2002). The chemical makeup of the fluids and depth governs the faunal composition, abundance, and diversity of chemosynthetic communities (Airamé et al. 2003). The vesicomyid clam, *Calyptogena kilmeri*, is most common in areas characterized by high sulfide concentrations. In contrast, at the edge of seeps where sulfide levels are lower, *C. pacifica* is abundant. In cold seeps rich in methane

such as brine pools or methane hydrates, mussels (*Bathymodiolus* spp.) are the dominant macrofauna. These mussels have a methane-based symbiosis where intracellular bacteria oxidize the methane and provide energy for the mussels and the bacteria (Nybakken 2001). Various species are attracted to the biological activity around cold seeps (Airamé et al. 2003).

Of the 211 species of macrofauna known from seeps at present, most are endemic and only 13 species are shared between hydrothermal vents and cold seeps (Sibuet and Olu 1998). Diversity at cold seeps is generally higher than at hydrothermal vents. This is possibly due to the fact that hydrothermal 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 hydrothermal vents. Also, cold seeps have a greater depth distribution than hydrothermal vents, displaying a decrease in species richness with depth (Nybakken 2001).

Cascadia Margin—Along the Cascadia subduction zone, the Juan de Fuca plate has been subducting beneath the northwestern margin of the North American plate since the Eocene (55 mya). As this subduction occurs, plumes of gas and fluids travel along faults that cut through sediments and hydrates. These plumes, cold vents, are warm enough to destabilize the hydrate structure, releasing fresh water and methane.[14] Plumes of methane and associated fluids that reach the seafloor are large and can extend hundreds of meters high and several kilometers wide. Upon reaching the seafloor, these fluids, principally methane, hydrogen sulfide, and ammonia are oxidized to carbon dioxide, sulfate, and nitrate – the necessary nutrients for chemosynthetic bacteria. Surrounding the vents on the seafloor, communities of clams and tubeworms feed on the abundant source of chemosynthetic bacteria on an otherwise sparsely inhabited seafloor.[14]

Cold seep sites and hydrates occur throughout a 30 km wide zone parallel to and within the margin of the accretionary wedge off the Cascadia Margin (**Figure 2-17**). There are two sites of cold seeps within the Cascadia Margin that have been studied extensively: (1) the offshore region west of Vancouver Island and (2) Hydrate Ridge, 100 km west of the Oregon coast.[14]

- Hydrate Ridge—Gas hydrates and cold seep areas can be found throughout the Cascadia margin and are especially widespread at the Oregon continental margin. Hydrate Ridge is an accretionary wedge that was created by the subduction of the Juan de Fuca Plate beneath the North American Plate (Trehu 2002). It is located 90 km off the coast of Oregon in the tectonically active Cascadia subduction zone; it is 20 km long and 15 km wide with a northern and a southern summit (Schmidt 2004). In August of 1984, Kulm et al. (1986) discovered a unique biological community along the Oregon margin, at which time, it was noted that tectonic stresses acting along the convergent margin are especially effective in expelling methane and nutrient-rich pore fluids that enable organisms to adapt and evolve in this special ecosystem.

  The northern summit of Hydrate Ridge is covered by extensive carbonate deposits and exists at a depth of about 600 m; the southern summit is predominantly sediment covered and exists at a depth of about 800 m (Torres et al. 2002). Methane bubbles have been observed emanating from both the northern and southern summits, where white and yellow microbial mats have formed over the sediment surface (Trehu 2002). Where no bubbling was observed, aggregations of the vesicomyid clam, *C. pacifica*, were evident (Levin and Michener 2002). At the northern summit, Torres et al. (2002) estimated that methane gas is discharged at a rate of approximately 6×10^4 mol/day.

  The benthic communities of the Oregon subduction zone are characterized by colonies of tube worms (phylum Pogonophora, *Lamellibrachia barhami*) and giant clams (*Calyptogena* spp.) along the crest of the marginal ridge (Kulm et al. 1986). In addition, there are abundant free-living, chemosynthetic bacteria that form filamentous mats on the sediment surface and subsurface (Levin et al. 2003).

- Eel River Margin—Also part of the Cascadia margin subduction zone, along the northern California slope, the Eel River Margin methane seep region is broadly distributed along the tectonically active eastern Pacific margin (**Figure 2-17**); this area boards many methane seep areas located at 520 m water depth (Levin and Michener 2002). The Eel River Margin epifaunal communities are dominated

by cnidarians (*Anthomastus ritteri*), brittlestars (ophiuroids), seastars (*Rathbunaster californicus*), and large demersal populations comprised largely of sablefish (*Anoplopoma fimbria*) (Levin et al. 2003).[16] Microbial mats and vesicomyid clam (*C. pacifica*) beds form distinct microhabitats on the Eel River margin. Large gastropods (*Neptunea* sp.) and filamentous bacteria (*Beggiatoa*-like) are the main components of the microbial mats; in the vicinity of these microbial mats methane bubbles often emanate from the sediments (Levin and Michener 2002).

2.7.2.8.2 Hydrothermal vents

Deep-sea hydrothermal vents occur in areas where new crust is being formed, at or near mid-ocean ridge systems both in fore-arc and back-arc regions (Humphris 1995). Since 1979, more than 200 seafloor vent sites have been located (Wheat et al. 2000). Water temperature at these sites can be quite variable in vent systems and vent macrofauna are distributed with respect to water temperature. 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, heavy metals, and metal sulfides, which include iron, copper, calcium, silicon, and zinc, as well as metalloids (McMullin et al. 2000; Rathgeber et al. 2002). 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, 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. Because vent water is anoxic, organisms that require both oxygen and sulfide survive in the narrow area where vent water and ambient water interact (Nybakken 2001).

Macrofaunal communities associated with chemosynthetic environments are typically characterized by high biomass and low diversity. Fauna can either consume or form symbiotic relationships with the chemosynthetic bacteria (Wheat et al. 2000; Nybakken 2001). In both cases, these animals use numerous morphological, physiological, and behavioral adaptations to flourish in this extreme deep-sea environment; since, 1979, some 500 new species have been found associated with vent systems (Wheat et al. 2000). In addition, hydrothermal vents sustain a variety of microbial habitats including a microbial habitat within the subseafloor whose warm water vents form cracks in the seafloor; this venting brings these microorganisms to the seafloor surface (Mehta et al. 2003). 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).

There are approximately 15 known hydrothermal vent communities in the Pacific Northwest OPAREA (**Figure 2-17**). In January of 1998, a new hydrothermal vent site, Cloud Vent, was created by an eruption at Axial Volcano, on the Juan de Fuca Ridge. Cloud Vent is located 370 km off the British Columbia coast on Juan de Fuca Ridge, South-East of Axial Volcano. Tubeworms (*Ridgea piscesae*) and alvinellid polychaete/limpet assemblages characterize a larger vent field located on the Endeavour Segment of the Juan de Fuca Ridge, Clam Bed (Durand et al. 2002). The main Endeavour Field hydrothermal vent community is complex in that it contains features such as sulfide spires, active venting black smokers, sulfide structures, sulfide talus, and tubeworm colonies.

2.7.2.8.3 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. 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; Smith et al. 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; Smith et al. 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; Smith et al. 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).

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).

2.7.2.9 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, fish aggregating devices (FAD) are suspended in the water column and anchored on the seafloor to attract fish (Klima and Wickham 1971; Bohnsack et al. 1991). 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.

When solid, hard objects with numerous and varied surfaces are introduced to the seafloor, artificial substrates are provided for the settlement and colonization of epibenthic organisms (Bohnsack et al. 1991). The initial colonization of artificial habitats works to build communities that increase marine production as additional epibenthic organisms settle on artificial substrates and provide a biotope suitable for larger motile organisms (Fager 1971; Bohnsack et al. 1991).

Artificial habitat sites are often important nearshore locations for human activities including commerce, navigation, aquaculture, and recreation (Ritter et al. 1999). Fishermen often target these artificial habitats as they tend to provide food, shelter, and nurseries for a variety of demersal and pelagic fishes (including sport fishes) and many invertebrates (Ambrose and Swarbrick 1989; DeMartini et al. 1994).

In the Pacific Northwest, there are a significant number of artificial habitats available for the marine communities (**Figures 2-18** and **2-19**); human activities have severely impacted these areas, especially in highly populated centers such as Puget Sound. Minimization of damage to these nearshore habitats has been identified as an important management action for the region (Ritter et al. 1999).

2.7.2.9.1 Artificial reefs

An artificial reef consists of one or more submerged structures of natural or man-made origin purposefully deployed on the seabed to influence the physical, biological, or socioeconomic processes related to living marine resources (Baine 2001). Artificial reefs are defined both physically by the design and arrangement of materials used in construction and functionally according to their purpose (Seaman and Jensen 2000). A large number of items are used for the creation of artificial reefs including natural objects such as wood (weighted tree trunks) and shells, quarry rock, or man-made objects like vehicles (e.g., automobile bodies and railroad cars), aircraft, ships and boats, home appliances, discarded construction materials (e.g., concrete culverts), tires, oil/gas platforms, ash byproducts (from solid municipal incineration and coal/oil combustion), and prefabricated concrete structures (reef balls; ARS 1997). Artificial reefs are deployed into the marine environment to: (1) enhance commercial fishery production/harvest; (2) enhance recreational activities (fishing, SCUBA diving, and tourism); (3) restore/enhance water and habitat quality;

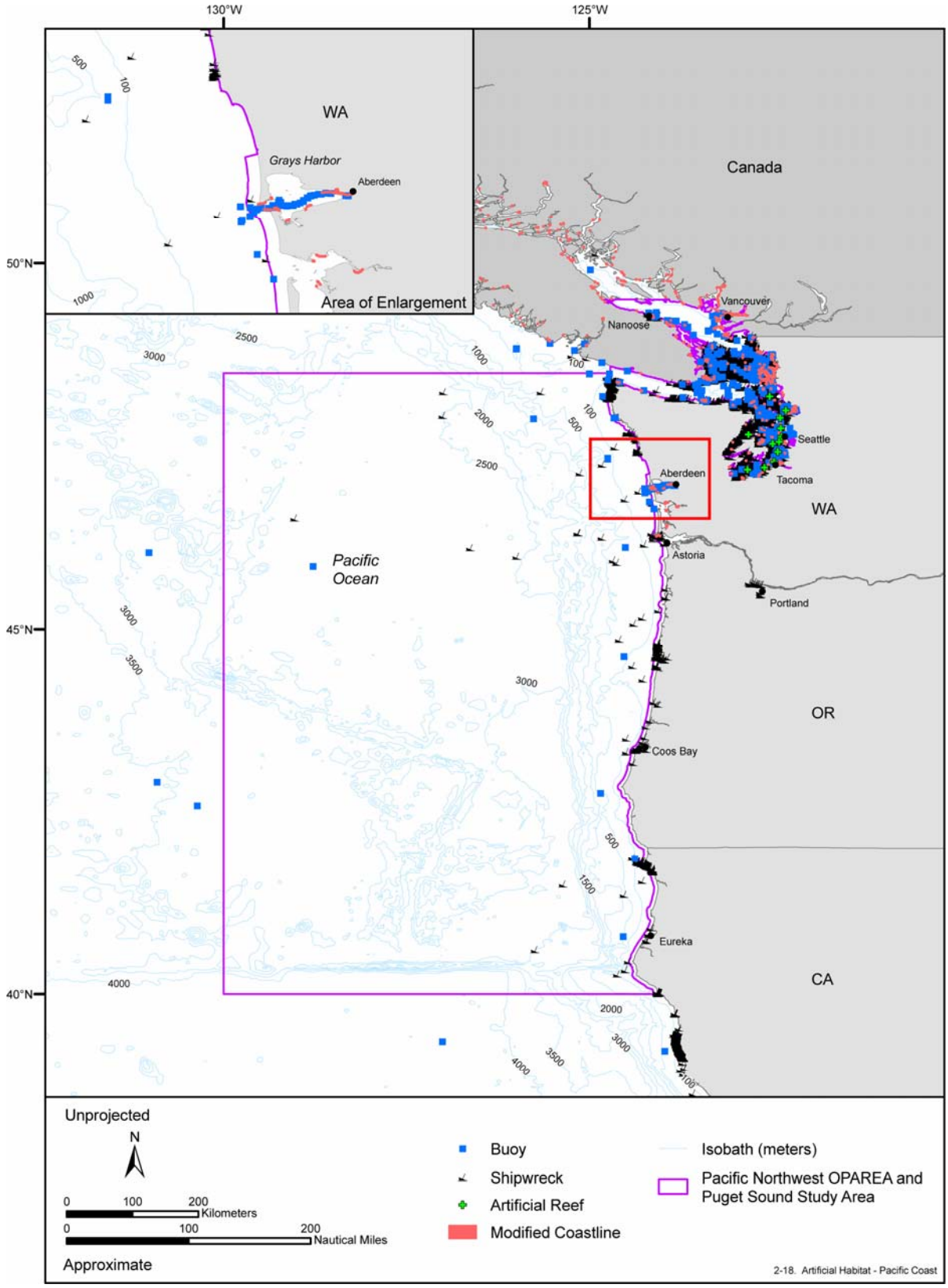

Figure 2-18. Artificial habitats of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Buoys, shipwrecks, artificial reefs, and modified coastline are depicted. Source data: WADNR[22,23,24], Veridian Corporation (2001), Fish-n-Map Co. (2004, 2005), NOAA (2005), USFWS[12], and Province of British Columbia[13].

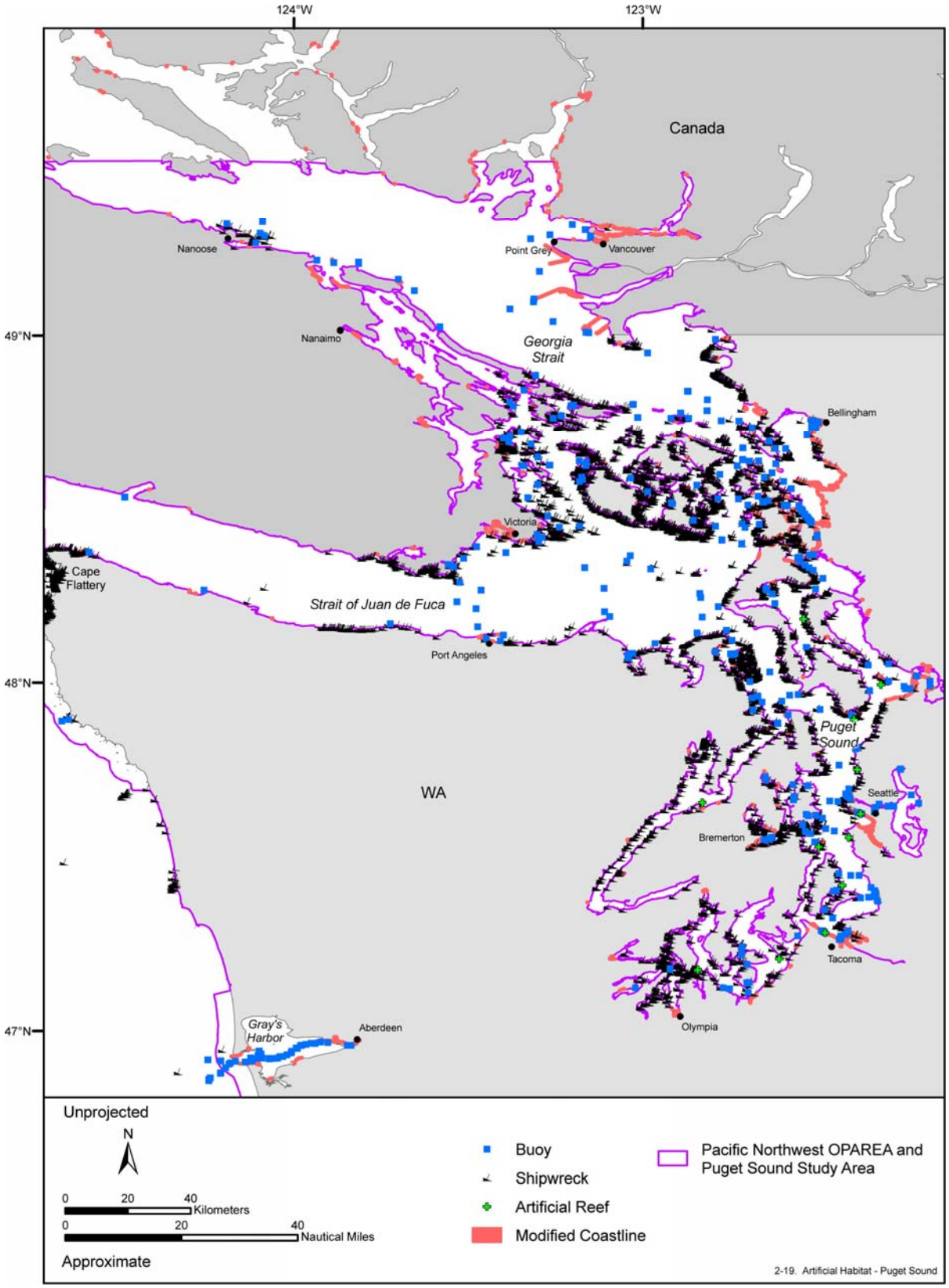

Figure 2-19. Artificial habitats of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Buoys, shipwrecks, artificial reefs, and modified coastline are depicted. Source data: WADNR[22,23,24], Veridian Corporation (2001), Fish-n-Map Co. (2004, 2005), NOAA (2005), USFWS[12], and Province of British Columbia[13].

(4) provide habitat protection and aquaculture production sites; and (5) control fish mortality (Seaman and Jensen 2000). McGurrin et al. (1989) provides a thorough summary of the history of artificial reef development in the U.S.

Artificial reefs can be partially or completely lost in an environment due to several factors including: (1) deterioration of components; (2) burial in sediments; (3) movement of materials due to vandalism or deterioration of the binding and ballast systems; and (4) loss of surface marking buoys and/or changes in onshore landmarks (Wilson et al. 1990; Bedford 2001).

Twelve artificial reefs are currently located within the Pacific Northwest OPAREA and Puget Sound Study Area (**Figures 2-18** and **2-19**). Artificial reefs have been constructed from a variety of materials in the Pacific Northwest including sunken ships, concrete, and rock reefs. The material chosen for construction can influence benthic community development. Historically, 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.

2.7.2.9.2 Shipwrecks

Despite the addition of many navigational aids, the Pacific Northwest remains one of the most treacherous regions for ships to navigate. The combination of fog, rain, sleet, snow, wind, and ocean currents have all contributed to the almost 4,500 wrecks documented for the region (Veridian Corporation 2001; **Figures 2-18** and **2-19**). Near the head of Cape Flattery (at the entrance to the Strait of Juan de Fuca) shipwrecks have resulted in the loss of billions of dollars in ships and precious cargo; over 150 deep-sea ships are known to have sunk near Cape Flattery (Gibbs 1957).

Between Grays Harbor and the Columbia River, more ship strandings have occurred than on any other section of the Washington coast; the entire beach area in this region is composed of long sandy stretches piled up by the deposits from the Columbia River. Smaller rivers and streams also deliver sand to the region, which constantly form dangerous shoals (Gibbs 1957).

The Strait of Juan de Fuca, one of the greatest inland arms of the Pacific, is a deep body of water separating Canada from the U.S. The Strait is one of the most frequented waterways in the northern hemisphere (Gibbs 1957). Nearly all ocean traffic entering and departing Puget Sound and British Columbia ports pass through the Strait of Juan de Fuca. The shorelines of the Strait are heavily wooded, rising abruptly to elevations of considerable height. Within the last century, over 600 major and minor shipwrecks have occurred on Puget Sound and in the Juan de Fuca Strait (Gibbs 1957).

The coast of Oregon has also experienced numerous shipwrecks. For example, a narrow and treacherous sand bar is located near Tillamook County; at one point in its history, ships refused to enter this region, resulting in near starvation for the people of Tillamook County. South to Coos Bay, the coastline remains very rugged. From Coos Bay south to the California border the coastline is very irregular, with numerous headlands, rocky promontories, and beaches (Gibbs 1957).

2.7.2.9.3 Buoys and moorings

A buoy is a floating platform used for navigational purposes or supporting scientific instruments that measure environmental conditions. Currently, eleven buoys are located along the outer coast of the Pacific Northwest OPAREA, while 379 buoys are located within the Strait of Juan de Fuca and Puget Sound (**Figures 2-18** and **2-19**).

2.7.2.9.4 Modified coastline

Zones that are modified and managed for human use and are generally characterized by the continuing presence of man are termed modified coastlines (Proctor et al. 1980a). These regions are prepared and maintained in either an artificial or highly modified state. Modified coastlines are classified by the intensity and type activities conducted and the degree of departure from the surrounding natural zone. The

resulting habitats include lawn grass, shrubs, adaptable local species (e.g., blackberries and sea gulls), and exotic species attracted to activities of the region (Proctor et al. 1980a).

Shorelines in Washington State have been extensively modified. Approximately one-third of all shorelines have some of kind shoreline modification structure.[12] The outer coast has relatively little modification, while Puget Sound is more extensively modified. Areas surrounding Puget Sound have relatively high population densities and a high proportion of unconsolidated shorelines. Much of the shoreline has been altered for agricultural, industrial, and residential uses. Changes include the construction of dams and dikes, establishing new drainage patterns, rerouting and channeling streams, modifying ground cover and soil permeability, tapping and disrupting local aquifers, installing storm and sanitary sewers, and channel dredging (Proctor et al. 1980a). In addition, Washington State has approximately 1,200 boat ramps, 3,600 piers and docks, and 30,000 recreational boat slips.[13]

- Wharves, Pilings, and Docks—Wharves, pilings, and docks are intertidal and/or subtidal structures that modify both the water column and benthic habitats of estuaries. The immense interest in boating and related recreational activities has brought on the development of many floating docks and pilings in nearly all of the protected harbors in Puget Sound (Kozloff 1993). Though man-made, wharves, pilings, and docks provide favorable environments for many flora and fauna by providing a substrate for attachment, shade, and protection. However, these structures are usually constructed of heavy planking supported by floats or wood, Styrofoam, fiberglass, or concrete which can modify the local benthic habitat and introduce additional litter and pollutants to the environment (Proctor et al. 1980a; Kozloff 1993). For instance, wooden pilings are subjected to treatment with creosote and other preservatives that discourage the settlement of benthic communities (Kozloff 1993). Benthic communities surrounding the bottoms of the pilings are different from those in surrounding habitats in that there is a significant detrital input from the pilings above.

2.8 WEBSITES ACCESSED

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3.0 SPECIES OF CONCERN

This chapter provides detailed information for marine mammals, sea turtles, and endangered, threatened, and species of concern birds and fishes. These species are of particular interest to the Navy due to their protected status.

Marine mammals, which include cetaceans (whales, dolphins, and porpoises), pinnipeds (seals, fur seals, and sea lions), and sea otters, are the taxon group with the largest number of federally protected species in the Pacific Northwest OPAREA and Puget Sound Study Area. Section 3.1 of this chapter provides information on the 33 marine mammal species with potential occurrence in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. All marine mammals are protected by the MMPA; nine of these species are also listed as threatened or endangered under the ESA: six cetacean, two pinniped, and one sea otter species. Additionally, the population segment of killer whales known as the southern residents was recently listed as endangered under the ESA. An overview of marine mammals, as well as a brief introduction to acoustics and hearing, which is useful in consideration of any potential anthropogenic impacts to these animals, is included. A detailed narrative has been prepared for each marine mammal species, consisting of a species' description, status, habitat preferences, distribution (including a focus on the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity), behavior and life history, and an account of its vocalizations and hearing capabilities (when available). Maps depicting the seasonal occurrence records and predicted areas of occurrence for each marine mammal species in the OPAREA, Study Area, and vicinity are found in **Appendix B** (**Figures B-1** through **B-52**).

Four sea turtle species are known or have the potential to occur in the Pacific Northwest OPAREA and Puget Sound Study Area, and all are either threatened or endangered. Section 3.2 of this chapter consists of an overview on sea turtle biology and life history and provides basic information on the hearing capabilities of these animals. Each of the sea turtle species is then described in detail by its physical description, status, habitat preferences, distribution (including a focus on the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity), and behavior and life history. Maps depicting the seasonal occurrence records and predicted areas of occurrence for each sea turtle species in the OPAREA, Study Area, and vicinity are found in **Appendix C** (**Figures C-1** through **C-5**).

Five bird species of concern may potentially occur in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Two are listed as endangered and three as threatened. Section 3.3 of this chapter provides information about the physical description, status, habitat preferences, distribution (including a focus on the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity), and behavior and life history of these species. Maps depicting the occurrence records and predicted distributions (e.g., breeding and foraging) of each bird species in the OPAREA, Study Area, and vicinity are found in **Appendix D** (**Figures D-1** through **D-5**).

There are six threatened and endangered fish species with probable occurrence in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Section 3.4 of this chapter includes a discussion of the physical description, status, habitat preferences, distribution (including a focus on the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity), and behavior and life history of each species. Maps depicting the distribution and/or critical habitats for these fish species in the OPAREA, Study Area, and vicinity are embedded in this section (**Figures 3-9** through **3-15**). EFH species are discussed in Section 4-4, and EFH distribution maps are located in **Appendix E**.

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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 majority of the 33 marine mammal species with confirmed or possible occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area are cetaceans (whales and dolphins). Cetaceans are divided into two major suborders: Mysticeti and Odontoceti (baleen and toothed whales, respectively). Toothed whales use teeth to capture prey, while baleen whales use baleen plates to filter their food from the water. Beyond contrasts in feeding methods, there are also life history and social organization differences between baleen and toothed whales (Tyack 1986). Pinnipeds are divided into three families: Phocidae (the “true” or earless seals); Otariidae (sea lions and fur seals); and Odobenidae (walruses). Of the pinnipeds, only phocids and otariids are expected to occur in the study area. 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 blastocyst 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.

3.1.1.1 Adaptations to the Marine Environment: Sound Production and Reception

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

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).

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 cetacean and pinniped sound production and hearing may be found in Richardson et al. (1995), Edds-Walton (1997), Wartzok and Ketten (1999), Au et al. (2000), and Hildebrand (2005). 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 (Bjørge 2002; Bowen et al. 2002; Forcada 2002; Stevick et al. 2002). Most information on marine mammal distribution has been obtained from shipboard and aerial observations, which provide a very limited perspective on their life at or near the surface and little insight into their behavior under the water where some species, particularly cetaceans, spend up to 90% of their time (e.g., Costa 1993).

Our knowledge of marine mammal habitats is often quite limited. Poor definition of spatiotemporal scales is the primary cause for confusion and disagreement among studies about factors that associate with marine mammal (in particular, cetacean) distribution (e.g., Jaquet 1996; Jaquet et al. 1996; Gregr and Trites 2001; Hamazaki 2002; Ferguson 2005). Marine mammals may not respond to instantaneous changes in ocean conditions. Instead, there might be a time lag between the change of oceanographic conditions and top-level predator responses. As noted by Ferguson (2005), time lags are particularly

important when proxies such as chlorophyll data are used to indicate toothed whale habitat. It is not the primary producers themselves that the whales eat, but the squid and mesopelagic fishes several trophic levels higher up. Time lapses before energy and nutrients from the primary producers climb the food chain up to cetacean prey species. For baleen whales feeding on zooplankton, which are trophically close to primary production, this lag may be on the order of several weeks, whereas the lag might be considerably greater for sperm whales where the primary prey (cephalopods) are removed from primary production by approximately four months (Gregr and Trites 2001). Integrated approaches are underway in some areas to examine the temporal and spatial relationship of marine mammals to the structure and variability of their habitat (e.g., Croll et al. 1998). Efforts are also underway in habitat modeling, which predicts potential habitat in unsurveyed areas based on the relationships between species' presence and the environmental parameters observed in surveyed areas (e.g., Gregr and Trites 2001; Hamazaki 2002; Ferguson 2005; Hastie et al. 2005; Redfern et al. 2006).

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 (e.g., Forney 2000; Gregr and Trites 2001; MacLeod and Zuur 2005). For example, though topography might increase primary productivity and, as a result, provide a local increased availability of prey, not every marine mammal species is necessarily concentrated in that area. Additional factors may be involved, such as habitat segregation between other species that share the same ecological niche (MacLeod and Zuur 2005). The degree of similarity in diet between two or more predators that occur in the same habitat will affect the level of competition between these predators. Competition between predators can result in the exclusion of one or more of them from a specific habitat. For example, MacLeod et al. (2003) suggested that an example of niche segregation might be that *Mesoplodon* spp. occupy a separate dietary niche from bottlenose whales (*Hyperoodon*) and Cuvier's beaked whales (*Ziphius*) although these species 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.

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). Pregnant females are believed to lead the migration to and from northern feeding grounds. However, not all baleen whales migrate. Some individual gray, 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 density differences between two different water masses aggregate phytoplankton and zooplankton (Etnoyer et al. 2004). High concentrations of fish and invertebrate larvae along with high rates of primary productivity are associated with shelf break and pelagic frontal features (Roughgarden et al. 1988; Munk et al. 1995). Oceanographic frontal features along the Pacific coast tend to be ephemeral in space and time, shifting to the north and south by 10 to 1,000 km depending on the season, the year, and the state of the El Niño (Etnoyer et al. 2004).

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 (Etnoyer et al. 2004). 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). Not all pinniped species are migratory. For example, the harbor seal is littoral in distribution and non-migratory; this species breeds and feeds in the same area throughout the year (Bigg 1981; Jeffries et al. 2000).

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 (I. 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 affect 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 (Schneider and Payne 1983; Moulton et al. 2000).

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). Responses of marine mammals to climate change are difficult to interpret due to the confounding effects of natural responses and human influences. Additionally, the time scale on which marine mammals respond to direct or indirect effects of climate change may be diluted or muted. 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. Reduced foraging success, increased nutritional stress, and higher mortality have been reported for various pinniped species during cyclic warming periods (e.g., Feldkamp et al. 1991; Hayward 2000; 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 disappeared from the Santa Catalina Island area and were 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 due an influx of warm-water species coupled with the persistence of temperate species typically found off central California (Benson et al. 2002). Cerchio et al. (2005) noted negative impacts on individual condition and reproduction for humpback whales, notably, a low reproductive success. Climate variation may also influence social organization through changes in prey availability, as noted in Pacific Northwest killer whales that tended to occur in smaller groups when there was less salmon available (Lusseau et al. 2004). Recent work on common dolphins in the eastern tropical Pacific also suggests that animals cross stock boundaries during periods of significant environmental change (e.g., El Niño), moving to areas of higher quality habitat when preferred habitat is reduced (Danil and Chivers 2005).

Marine Mammals of the Pacific Northwest OPAREA and Puget Sound Study Area

The species that occur in this area are either primarily cosmopolitan (occurring worldwide), or associated with the temperate/sub-Arctic, or mixed-water oceanographic regions (Leatherwood et al. 1988). Some species are resident year-round, while others are here only seasonally, making migrations through the area. Thirty-three marine mammal species have confirmed or possible occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area, including 26 cetacean (whales, dolphins, and porpoises), six pinniped (seals, sea lions, and fur seals), and one fissiped (the sea otter) species (**Table 3-1**). Information on acoustics and hearing abilities of the marine mammals occurring in the Pacific Northwest OPAREA and Puget Sound Study Area is presented in **Table 3-2**.

For both the beluga (*Delphinapterus leucas*) and the pantropical spotted dolphin (*Stenella attenuata*), the Pacific Northwest OPAREA and Puget Sound Study Area are clearly well outside their normal range. An individual beluga was sighted a few times during 1940 near Tacoma, Washington State (Scheffer and Slipp 1948). The consensus is that these are extralimital records (Scheffer and Slipp 1948; Rugh, D.J., NMFS-NWR, pers. comm., 22 August 2005). There are few records of the pantropical spotted dolphin, a species which prefers much warmer waters, north of the California-Mexico border. These records include a stranding in central California (Worthy et al. 1993) and in Alaska (Jefferson, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005). The dolphin found stranded in Alaska is thought to have probably been transported there by human intervention (Jefferson, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005). Therefore, these two before-mentioned species will not be discussed further in this MRA.

Temperate and warm-water toothed whales often change their distribution and abundance as oceanographic conditions vary both seasonally (Forney and Barlow 1998) and internannually (Forney 2000). Forney and Barlow (1998) noted significant north/south shifts in distribution for Dall's porpoises, common dolphins, and Pacific white-sided dolphins, and they identified significant inshore/offshore differences for northern right whale dolphins and humpback whales. Unusual marine mammal distributions may be observed during incursions of warm water related to ENSO events, allowing some species to move temporarily into more northerly latitudes. Several authors have noted the impact of the El Niño events on marine mammal occurrence patterns and population dynamics in the waters off the Pacific Coast (e.g., Wells et al. 1990; Forney and Barlow 1998; Benson et al. 2002; Norman et al. 2004). Norman et al. (2004) remarked that most of the stranding events for species that have a more extralimital occurrence in Washington State and Oregon occurred during or within a year of an El Niño event.

The Pacific Northwest coastal zone is embedded within the California Current System, a system of currents with strong variability that extends from British Columbia, Canada to Baja California, Mexico (Hickey 1998; Hickey and Banas 2003; MacCall et al. 2005); the physical oceanography of the region is largely controlled by this circulation within the California Current System, the Columbia River plume, the

Table 3-1. Marine mammal species of the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Taxonomy follows IWC (2005) for cetaceans and Rice (1998) for the other marine mammal species.

	Scientific Name	Status	Occurrence[a]
Order Cetacea			
Suborder Mysticeti (baleen whales)			
Family Balaenidae (right whales)			
North Pacific right whale	*Eubalaena japonica*	Endangered	Regular
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
Family Eschrichtiidae (gray whale)			
Gray whale	*Eschrichtius robustus*	[b]	Regular
Suborder Odontoceti (toothed whales)			
Family Physeteridae (sperm whale)			
Sperm whale	*Physeter macrocephalus*	Endangered	Regular
Family Kogiidae (pygmy sperm whales)			
Pygmy sperm whale	*Kogia breviceps*		Regular
Dwarf sperm whale	*Kogia sima*		Extralimital
Family Ziphiidae (beaked whales)			
Cuvier's beaked whale	*Ziphius cavirostris*		Regular
Hubbs' beaked whale	*Mesoplodon carlhubbsi*		Regular
Stejneger's beaked whale	*Mesoplodon stejnegeri*		Regular
Baird's beaked whale	*Berardius bairdii*		Regular
Family Delphinidae (dolphins)			
Rough-toothed dolphin	*Steno bredanensis*		Extralimital
Bottlenose dolphin	*Tursiops truncatus*		Extralimital
Striped dolphin	*Stenella coeruleoalba*		Rare
Short-beaked common dolphin	*Delphinus delphis*		Regular
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*		Regular
Northern right whale dolphin	*Lissodelphis borealis*		Regular
Risso's dolphin	*Grampus griseus*		Regular
False killer whale	*Pseudorca crassidens*		Rare
Killer whale	*Orcinus orca*	[c]	Regular
Short-finned pilot whale	*Globicephala macrorhynchus*		Rare
Family Phocoenidae (porpoises)			
Harbor porpoise	*Phocoena phocoena*		Regular
Dall's porpoise	*Phocoenoides dalli*		Regular
Order Carnivora			
Family Mustelidae (otters)			
Sea otter	*Enhydra lutris*	Threatened	Regular
Suborder Pinnipedia (seals, sea lions, walruses)			
Family Phocidae (true seals)			
Harbor seal	*Phoca vitulina*		Regular
Northern elephant seal	*Mirounga angustirostris*		Regular
Family Otariidae (sea lions and fur seals)			
Northern fur seal	*Callorhinus ursinus*		Regular
Guadalupe fur seal	*Arctocephalus townsendi*	Threatened	Rare
Steller sea lion	*Eumetopias jubatus*	Threatened[d]	Regular
California sea lion	*Zalophus californianus*		Regular

[a] **Regular** = A species that occurs as a regular or normal part of the fauna of the area, regardless of how abundant or common it is; **Rare** = A species that only occurs in the area sporadically; **Extralimital** = A species that does not normally occur in the area, but for which there are one or more records that are considered beyond the normal range of the species.

[b] Only the population which occurs in the western North Pacific is listed as endangered.

[c] The Southern Resident Killer Whale population that occurs here is listed as endangered while the other three populations that also occur here are not listed.

[d] The species as a whole is listed as threatened; the eastern population that is expected here is listed as threatened while the western population which is not expected to occur here is listed as endangered.

Table 3-2. Acoustics and hearing characteristics of marine mammals in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Information compiled primarily from Richardson et al. (1995) and Ketten (1998) (and references within). *based on the North Atlantic right whale

Common Name	Acoustics		Hearing
	Frequency Range (kHz)	Source Level (dB re 1 µPa-m)	Frequency Range (kHz)
Baleen whales			
North Pacific right whale	0.050 - 0.6	137 - 192*	0.010 - 22 (predicted)
Humpback whale	0.020 - 10	144 - 192	0.7 - 10 (predicted)
Minke whale	0.060 - 20	150 - 175	Not Available
Sei whale	0.433 (+/- 0.192) - 3.5	156 +/- 3.6	Not Available
Fin whale	0.010 - 0.75	155 - 186	Not Available
Blue whale	0.012 - 0.4	188 (maximum)	Not Available
Gray whale	0.020 - 20	142 - 185	<2
Toothed whales			
Sperm whale	0.1 - 30	140 - 236	5 - 20 (measured from 1 neonatal sperm whale)
Pygmy sperm whale	60 - 200	Not Available	90 - 150
Dwarf sperm whale	13-33	Not Available	Not Available
Cuvier's beaked whale	0.3 - 135	214 (maximum)	Not Available
Hubb's beaked whale	0.3 - 80	Not Available	Not Available
Stejneger's beaked whale	Not Available	Not Available	Not Available
Baird's beaked whale	4 - 42	Not Available	Not Available
Rough-toothed dolphin	0.1 - 200	Not Available	Not Available
Bottlenose dolphin	0.8 - 130	125 - 228	0.01 - 150
Striped dolphin	6 - 24+	Not Available	29 - 123
Short-beaked common dolphin	0.2 - 150	180 (maximum)	5 - 150
Pacific white-sided dolphin	0.002 - 80	170 (peak amplitude)	0.075 - 150
Risso's dolphin	0.1 - 65	222 (maximum)	1.6 - 150
Northern right whale dolphin	1 - 16+	170 (maximum)	Not Available
False killer whale	4 - 130	220 - 228	16 - 64
Killer whale	0.1 - 35	137 - 224	<0.5 - 105
Short-finned pilot whale	0.5 - >20	180 (maximum)	Not Available
Harbor porpoise	0.04 - 160	135 - 177	16 - 140
Dall's porpoise	0.04 - 160	120 - 175	Not Available
Pinnipeds			
Harbor seal	0.1 - 150	Not Available	1 - 180
Northern elephant seal	0.2 - 1	Not Available	0.075 - 45
Northern fur seal	Not Available	Not Available	0.5 - 60
Guadalupe fur seal	Not Available	Not Available	Not Available
Steller sea lion	0.03 - 3 (female calls only)	Not Available	1 - 25
California sea lion	0.25 - 6	Not Available	1 - 40
Fissipeds			
Sea otter	0.2-12.8 (in-air)	Not Available	Not Available

formation of large eddies (e.g., the Juan de Fuca Eddy), and seasonal wind stress (Barth and Smith 1997; Hickey and Banas 2003). The combination of these forces creates an ecosystem of diverse oceanographic conditions. Occurrence patterns (the presence or absence) of cetaceans in the Pacific Northwest are often related to the regionalized differences in hydrographic and oceanographic variables, with sea surface temperature, salinity, chlorophyll, and location of the thermocline explaining the majority of distribution variability (Tynan et al. 2005). In addition, circulation in the Strait of Juan de Fuca follows the typical patterns of estuarine flow with fresher surface water flowing seaward above the colder, saltier seawater. This deep seawater flows landward resulting in the presence of cold oceanic water far inland of the Pacific Coast (Ebbesmeyer et al. 1991; Thomson 1994; Ott and Garrett 1998); the presence of deep, cold oceanic water inshore allows for deepwater marine mammals to enter the shallower basins of the Puget Sound Study Area.

In the Pacific Northwest, the distribution and movement patterns of some marine mammal species are driven by occurrences of salmon, an important prey source. Pinnipeds haul out and aggregate near areas where migrating salmon run. For example, in the San Juan Islands, harbor seals congregate near a constricted channel in which migrating salmon are funneled through by the incoming tidal currents (Zamon 2001). In Oregon, harbor seals also aggregate near a constriction in Netarts Bay and wait for chum salmon (*Oncorhynchus keta*) runs during the incoming tide (Brown and Mate 1983). These constrictions in tidal flow represent important foraging habitat for pinnipeds due to the predictability of salmon in these areas (Zamon 2001). Resident killer whale distribution, in particular, is also often dependent on salmon. Resident killer whales congregate during the summer at particular coastal locations that are in association with high densities of migrating salmon (Heimlich-Boran 1986; Nichol and Shackleton 1996; Olson 1998; NMFS 2005i). Their strong preference for chinook salmon (*Oncorhynchus tshawytscha*) may influence the year-round distribution patterns of resident killer whales in coastal British Columbia and adjacent waters (Ford and Ellis 2005). For instance, northern resident killer whale occurrence in Johnstone Strait has been strongly tied to the large seasonal runs of sockeye and pink salmon (*Oncorhynchus nerka and Oncorhynchus gorbuscha*, respectively), as well as chum salmon (Nichol and Shackleton 1996).

3.1.1.3 Marine Mammal Occurrences

The distribution of marine mammal records is presented for the upwelling season (defined as April through September) and the relaxed season (October through March) in the maps in **Appendix B**. An occurrence record does not reflect the number of marine mammals; due to the social nature of cetaceans, multiple individuals of a species are often sighted at the same time at the same location. It should be noted that the number of marine mammal observations in this area is partially a function of the level of effort to collect this information, rather than just the actual marine mammal abundance in the area.

A listing and description of data sources used to determine each species' occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area is found in **Appendix A-2**, while the process used to create the map figures is described in Section 1.4.2.2. On the map figures, various types of shading and terminology designate the occurrence of marine mammals in the Pacific Northwest OPAREA and Puget Sound Study Area. "Area of primary occurrence" (area shaded in dark blue) is defined as the areas and habitats where the species is primarily found. "Area of secondary occurrence" (area shaded in medium blue) is the areas and habitats where the species may be found, especially during "anomalous" environmental conditions. "Area of rare occurrence" (light blue area) is the areas and habitats where the species is not expected to be found regularly. "No systematic survey effort" (hatched) is the areas and habitats for which insufficient information is available to establish occurrence due to lack of systematic survey effort (best judgment follows then whether the area would be anticipated to be of primary or secondary occurrence).

Each marine mammal species is listed below with its description, status, habitat preference, distribution (including location and seasonal occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area), 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**.

3.1.1.4 Threatened and Endangered Marine Mammals of the Pacific Northwest OPAREA and Puget Sound Study Area

There are ten marine mammal species (or population segments) with confirmed or possible occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area that are listed as threatened or endangered under the ESA; these are the North Pacific right whale, humpback whale, sei whale, fin whale, blue whale, sperm whale, the recently listed SRKW population segment, Guadalupe fur seal, Steller sea lion, and the sea otter. While the SRKW is discussed here, the other stocks of killer whales (that are not listed) are discussed in detail in Section 3.1.1.5.

A combined map of the threatened and endangered cetacean species occurring in the Pacific Northwest OPAREA and Puget Sound Study Area is located in **Appendix B**. This map does not include the SRKW, since SRKW sighting data was not available from the NMFS-AFSC, and NMFS' occurrence pattern determination of threatened and endangered cetacean species did not include the SRKW.

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—There is a primary occurrence of threatened and endangered cetacean species along the entire outer coast of the Pacific Northwest OPAREA, from the shore to seaward of the OPAREA boundaries (**Figure B-1**). Occurrence of this cetacean grouping within Puget Sound Study Area is driven by the humpback whale. Within the Study Area, there is a band of secondary occurrence in the Strait of Juan de Fuca and around the San Juan Islands and Whidbey Island (**Figure B-2**). There is a rare occurrence north and south of the area of secondary occurrence in the Puget Sound Study Area.

- Relaxed season—As in the upwelling season, there is a primary occurrence of threatened and endangered cetacean species along the entire outer coast of the Pacific Northwest OPAREA, from the shore to seaward of the OPAREA boundaries (**Figure B-1**). During the relaxed season, there is a rare occurrence for this group of cetaceans within the Puget Sound Study Area (**Figure B-2**).

- **North Pacific Right Whale (*Eubalaena japonica*)**

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

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

Status—The North Pacific right whale is one of the world's most endangered large whale species (Perry et al. 1999; IWC 2001). North Pacific right whales are classified as endangered under the ESA. There are insufficient genetic or resighting data to address whether there is support for the traditional separation into eastern and western stocks (Brownell et al. 2001); however, Clapham et al. (2004) noted that north-south migratory movements support the hypothesis of two largely discrete populations of right whales in the eastern and western North Pacific. No reliable population estimate presently exists for this species (Angliss and Outlaw 2005); the population in the eastern North Pacific is considered to be very small, perhaps only in the tens of animals (Clapham et al. 2004; NMFS 2005b). In the western North Pacific, the population may number at least in the low hundreds (Brownell et al. 2001; Clapham et al. 2004). Designated critical habitat was recently designated for

the North Pacific right whale, and it includes an area in the western Gulf of Alaska and in the southeastern Bering Sea (NMFS 2006h; **Figure 3-1**). Neither of these areas is within the OPAREA or Study Area.

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 apparent 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 m to 80 m; Tynan et al. 2001). Recently, however, a tagged individual moved between the middle and outer portions of the continental shelf in the Bering Sea, which is consistent with historical distribution patterns (Wade et al. 2006). Additionally, sightings of some other right whale individuals during the 2004 survey were made on the outer continental shelf (Wade et al. 2006). North Pacific right whales have been sighted in even deeper waters, as evidenced by a sighting off California in waters with a bottom depth as deep as 1,700 m (Carretta et al. 1994). The IWC (2001) noted a surprising absence of evidence for coastal calving grounds, since right whales in the North Atlantic and in the Southern Hemisphere have calving grounds located in shallow bays, lagoons, or in waters over the continental shelf.

Distribution—Right whales occur in subpolar to temperate waters. They are generally migratory, with at least a portion of the population moving between summer feeding grounds in temperate or high latitudes and winter calving areas in warmer waters (Kraus et al. 1986; Clapham et al. 2004).

Right whales were probably never particularly common along the west coast of North America (Scarff 1986; Brownell et al. 2001). Current distribution patterns and migration routes of the North Pacific right whale are not known (Scarff 1986; NMFS 2005b). Historical whaling records provide virtually the only information on North Pacific right whale distribution. 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, Okhotsk Sea, and the Sea of Japan (Omura et al. 1969; Scarff 1986; Clapham et al. 2004). Presently, sightings are extremely rare, occurring primarily in the Okhotsk Sea and the eastern Bering Sea (Brownell et al. 2001; Shelden et al. 2005; Shelden and Clapham 2006; Wade et al. 2006). Prior to 1996, right whale sightings were very rare in the eastern North Pacific (Scarff 1986; Brownell et al. 2001). Recent summer sightings and acoustic detections of right whales in the eastern Bering Sea represent the first reliable, consistent observations in this area since the 1960s (LeDuc et al. 2001; Tynan et al. 2001; Wade et al. 2006). 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; Wade et al. 2006). The area of densest concentration in the Gulf of Alaska is roughly east from 170°W to 150°W and south to 52°N (Shelden and Clapham 2006).

Clapham et al. (2004) noted the following 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); diminished sightings and occurrence further south in fall (September through October); and few animals recorded anywhere during the winter (November through February). It is unclear whether the entire population undertakes a predictable seasonal migration. During the summer, whales were found in the Gulf of Alaska, along both coasts of the Kamchatka Peninsula, the southeastern Bering Sea, and in the Okhotsk Sea (Clapham et al. 2004). The whales were most widely dispersed in fall and spring, with whales occurring in mid-ocean waters and extending from the Sea of Japan to the eastern Bering Sea. In the winter, right whales were found in the Ryukyu Islands (south of Kyushu, Japan), the Bonin Islands, the Yellow Sea, and the Sea of Japan. Historical concentrations of sightings in the Bering Sea,

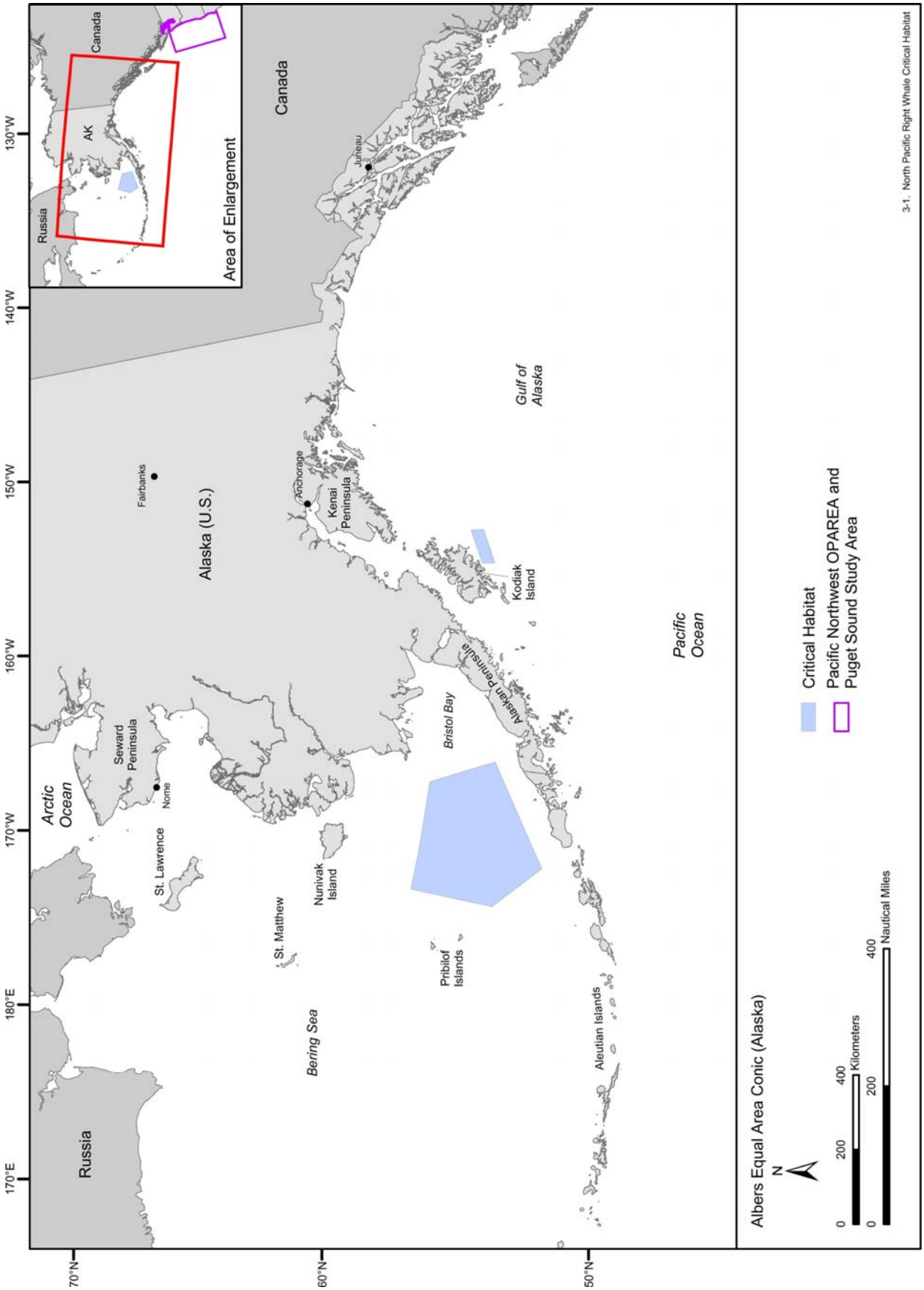

Figure 3-1. Designated critical habitat for the North Pacific right whale. Source data: NMFS (2005h, 2005l).

together with the recent sightings indicate that this region remains an important summer foraging habitat for eastern North Pacific right whales (Tynan et al. 2001; Shelden et al. 2005). Scarff (1986) hypothesized those right whales that summer in the eastern North Pacific mate, calve, and overwinter in the mid-Pacific or in the western North Pacific.

The location of calving grounds for the eastern North Pacific population is unknown (Scarff 1986; Clapham et al. 2004; NMFS 2005b), which appears to reflect a true absence of coastal calving grounds, at least within historic times (Scarff 1986). 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. There were no records in the last 100 years of newborn or very young calves in the eastern North Pacific until 2004 when the presence of at least two calves was documented in the eastern Bering Sea (Wade et al. 2006).

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).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

  - Upwelling season—The highly endangered status of the North Pacific right whale necessitates an extremely conservative determination of this species' occurrence in the Pacific Northwest OPAREA. There is a secondary occurrence in the Pacific Northwest OPAREA to account for the possibility of encountering this species anywhere in coastal and offshore waters (**Figure B-3**). There is a rare occurrence within the Puget Sound Study Area. There was a May 1992 sighting over Quinault submarine canyon (Green et al. 1992; Rowlett et al. 1994).

  - Relaxed season—The occurrence patterns for the relaxed season are expected to be similar to the upwelling season (**Figure B-3**).

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

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

North Pacific right whales probably feed almost exclusively on calanoid copepods (*Canalus marshallae*), a type of zooplankton. High concentrations of copepods have been recorded in zooplankton samples collected in 1997 and 1999 near right whales in the North Pacific. North Pacific right whales have also been observed feeding in 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).

There is almost nothing known of North Pacific right whale diving abilities. Dives of 5 to 15 min or even longer have been reported for North Atlantic right whales (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 m 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 sec (McDonald and Moore 2002; Wiggins et al. 2004). Right whales commonly produce calls in a series of 10 to 15 calls lasting 5 to 10 min, followed by silence lasting an hour or more. Some individuals do not call for periods of at least 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). Baumgartner et al. (2005) noted that downsweep calls by North Atlantic right whales in the 16 to 160 Hz frequency band exhibited a diel pattern (fewer calls at night) that corresponded strongly to the diel vertical migration of zooplankton.

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 have been estimated only for pulsive calls of North Atlantic right whales, which are 172 to 187 decibels (dB), with a reference pressure of one micropascal (µP) at one meter (dB re 1 uP a-m; Thomson and Richardson 1995; Parks and Tyack 2005). Other sound types produced by North Atlantic right whales have source levels 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 that are produced only by males (Parks et al. 2005; Parks and Tyack 2005).

Morphometric analyses of the inner ear of right whales resulted in an estimated hearing frequency range of approximately 0.01 to 22 kHz, based on established marine mammal models (Parks et al. 2004; Parks, S., Woods Hole Oceanographic Institution, pers. comm., 11 January 2006). Research by Nowacek et al. (2004) on North Atlantic right whales suggests that received sound levels of only 133 to 148 dB re 1 µPa-m for the duration of the sound exposure are likely to disrupt feeding behavior; the authors did note, however, that a return to normal behavior within minutes of when the source is turned off would be expected.

- **Humpback Whale (*Megaptera novaeangliae*)**

Description—Adult humpback whales 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 at least partially white (Jefferson et al. 1993; Clapham and Mead 1999). The head is larger than in other rorquals. The flukes have a concave, serrated trailing edge; the ventral side is variably patterned in black and white. Individual humpback whales may be identified using these patterns (Katona et al. 1979).

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

Recent information from photo-identification studies and genetic work suggest that there are probably three stocks or populations in the North Pacific: the Eastern (the California/Oregon/Washington-Mexico stock), Central, and Western North Pacific stocks (Baker et al. 1998; Calambokidis et al. 2001; Carretta et al. 2006). Calambokidis et al. (2001) further suggested that up to six subpopulations of humpback whales in the North Pacific Ocean might be recognized. The minimum population estimate for the Eastern North Pacific stock of humpback whales is 1,158 individuals (Carretta et al. 2006).

Habitat Preferences—Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (Clapham and Mead 1999). Shallow banks or ledges with high sea-floor relief characterize feeding grounds (Payne et al. 1990; Hamazaki 2002). The habitat requirements of wintering humpbacks appear to be determined by the conditions necessary for calving. Breeding grounds are in tropical or subtropical waters, generally with shelter created by islands or reefs. Optimal calving conditions are warm water (24° to 28°C) and relatively shallow, low-relief ocean bottom in protected areas (behind reefs), apparently to take advantage of calm seas, to minimize the possibility of predation by sharks, or to avoid harassment by males (Smultea 1994; Clapham 2000; Craig and Herman 2000). Females with calves occur in significantly shallower waters than other groups of humpback 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 are generally 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), the Hawaiian Islands, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). There is known to be some interchange of whales among different wintering grounds, and matches between Hawai'i and Japan and Hawai'i and Mexico have been found (Salden et al. 1999; Calambokidis et al. 2000b). 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; **Figure 3-2**).

There is also some trans-oceanic interchange between the North Pacific and South Pacific breeding populations (Medrano-González 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 (EPO). 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.

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 3-2**). There is much interchange of whales among different feeding grounds, although some site fidelity is the rule. The U.S./Canada border is an approximate geographic boundary between the California and Alaska feeding groups (Carretta et al. 2006). Humpback whales off California, Oregon, and Washington State form a discrete feeding aggregation. Their feeding ground ranges between 32°N and 48°N, and there is limited interchange with areas north of Washington State (Calambokidis et al. 1996; 2004a). Individuals of the Eastern North Pacific stock migrate along the west coast of the continental U.S., between the Mexican breeding ground and feeding grounds in southern British Columbia, using a corridor along the coast of Baja California (**Figure 3-2**). Some humpback whales remain in some higher latitude feeding grounds through the

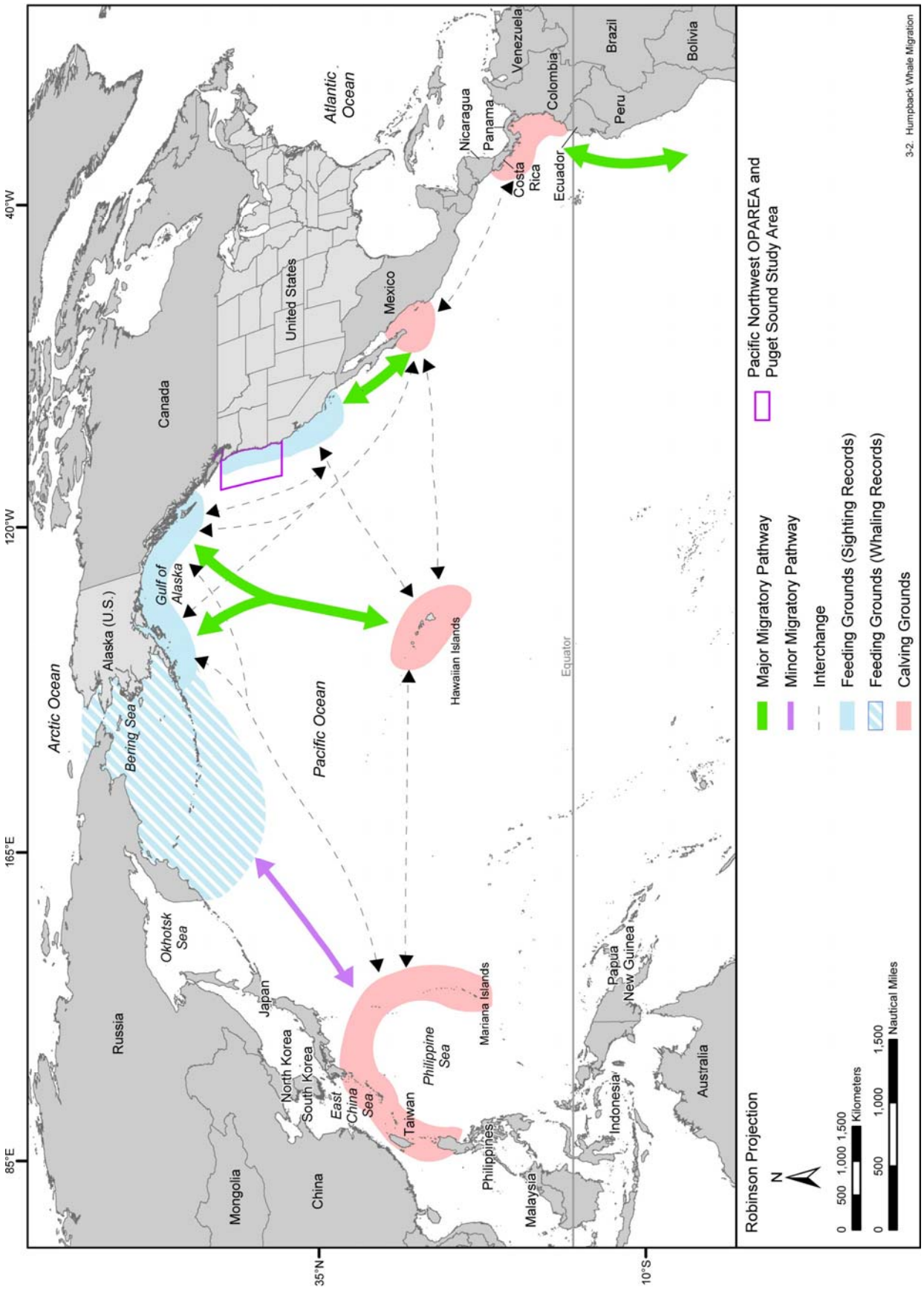

Figure 3-2. General major and minor migratory patterns of humpback whales in the North Pacific Ocean. Regions depicted with solid shading are defined by current observations of seasonal return by naturally marked individuals. Regions depicted with striped shading are defined by historical patterns of distribution during periods of commercial whaling. Source information: Baker et al. (1990) and Calambokidis et al. (2000, 2001).

breeding season, or perhaps individual variability in the timing of migrations results in the presence of some individuals in high latitude areas during all months of the year (Straley 1990).

The humpback whale has one of the longest migrations known for any mammal; individuals can travel nearly 8,000 km between feeding and breeding areas (Clapham and Mead 1999). Migratory transits between the Hawaiian Islands and southeastern Alaska have been documented to take as little as 36 to 39 days (Gabriele et al. 1996; Calambokidis et al. 2001).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Humpback whales feed in the Pacific Northwest OPAREA during the non-breeding season. They are present in northern California between April and December and may be found off Oregon and Washington State from May through November (Dohl et al. 1983; Green et al. 1992; Forney and Barlow 1998). Humpback whales were common in inland Washington State waters in the early 1900s; however, there have only been a few sightings in this area since the whales were heavily hunted in the eastern North Pacific (Scheffer and Slipp 1948; Calambokidis and Steiger 1990; Pinnell and Sandilands 2004). Today, humpback whales occasionally occur in the Puget Sound Study Area but do not remain there for long periods (Everitt et al. 1980; Osborne and Ransom 1988). Calambokidis and Steiger (1990) recorded the movements of at least two humpback whales in southern Puget Sound in June and July 1988.

  Humpback whales primarily feed along the shelf break and continental slope (Green et al. 1992; Tynan et al. 2005). Off Washington State, they are known to concentrate between Juan de Fuca Canyon and the outer edge of the shelf break in a region called “the Prairie,” near Barkley and Nitnat canyons, and near Swiftsure Bank (Calambokidis et al. 2004b). Humpback whales also tend to congregate near Heceta Bank off the coast of Oregon (Green et al. 1992). These locations represent important feeding areas for humpback whales in the OPAREA.

  - Upwelling season—The area of primary occurrence is a band along the outer coast from the shore to about the 3,000 m isobath (**Figure B-4**). Primary occurrence branches off somewhat near the Strait of Juan de Fuca to account for feeding aggregations near this area. The area of secondary occurrence is an additional 100 NM (185 km) buffer that accounts for the possibility of encountering some individuals that might migrate further offshore from the main migratory corridor. There is a rare occurrence seaward of this secondary buffer.

    There is an area of secondary occurrence in the Strait of Juan de Fuca and in the central part of the Puget Sound Study Area (to around the San Juan and west side of the Whidbey islands) and near Nanaimo (west coast of the Strait of Georgia) based on historical whaling records (**Figure B-5**). There is a rare occurrence in the southern part of Puget Sound, east of the Whidbey islands, and north of Nanaimo.

  - Relaxed season—Occurrence along the outer coast is similar to that of the upwelling season (**Figure B-4**). Occurrence throughout the Puget Sound Study Area is expected to be rare (**Figure B-5**). Humpback whales are expected to be in the OPAREA during the beginning of the relaxed season. Between January and March, most whales are further south on their breeding grounds and not in the OPAREA.

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

Humpback whales feed on a wide variety of invertebrates and small schooling fishes. The most common invertebrate prey are euphausiids (krill); the most common fish prey are herring, mackerel, sand lance, sardines, anchovies, and capelin (Clapham and Mead 1999). These whales are lunge feeders, taking in huge batches of prey items as they lunge laterally, diagonally, or vertically through patches of prey (Clapham 2002). Feeding behavior is highly diverse, and humpbacks employ unusual behaviors, such as bubble netting, to corral prey (Jurasz and Jurasz 1979; Weinrich et al. 1992). This is the only species of baleen whale that shows some evidence of cooperation when feeding in large groups (D'Vincent et al. 1985). Humpback whales are not typically thought to feed on the breeding grounds; however, some feeding behavior has been observed there (Salden 1989; Gendron and Urbán R. 1993).

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 two to three years, although females occasionally give birth to calves in successive years (Clapham 1996). Males compete for access to receptive females by aggressive, sometimes violent interactions, as well as vocal displays (Clapham 1996; Pack et al. 1998).

Humpback whale diving behavior depends on the time of year (Clapham and Mead 1999). In summer, most dives last less than 5 min; those exceeding 10 min are atypical. In winter (December through March), dives average 10 to 15 min; dives of greater than 30 min have been recorded (Clapham and Mead 1999). Although humpback whales have been recorded to dive as deep as 500 m (Dietz et al. 2002), on the feeding grounds they spend the majority of their time in the upper 120 m of the water column (Dolphin 1987; Dietz et al. 2002). Humpback whales on the wintering grounds do dive deeply; Baird et al. (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) sounds made within groups on the wintering (calving) grounds; and (3) social 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 (Mattila et al. 1987; Gabriele et al. 2001; Gabriele and Frankel 2002; Clark and Clapham 2004). Humpback song is an incredibly elaborate series of patterned vocalizations, which are hierarchical in nature (Payne and McVay 1971). There is geographical variation in humpback whale song, with different populations singing different songs and all members of a population using the same basic song. However, the song evolves over the course of a breeding season but remains nearly unchanged from the end of one season to the start of the next (Payne et al. 1983).

Social calls are from 50 Hz to over 10 kHz, with dominant frequencies below 3 kHz (Silber 1986). Female vocalizations appear to be simple; Simão and Moreira (2005) noted little complexity. The male song, however, is complex and changes between seasons. Components of the song range from under 20 Hz to 4 kHz and occasionally 8 kHz, with source levels of 144 to 174 dB re 1 µPa-m, with a mean of 155 dB re 1 µPa-m. Au et al. (2001) recorded high-frequency harmonics (out to 13.5 kHz) and source level (between 171 and 189 dB re 1 µPa-m) of humpback whale songs. Songs have also been recorded on feeding grounds (Mattila et al. 1987; Clark and Clapham 2004). The main energy lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz. “Feeding” calls, unlike song and social sounds, are highly stereotyped series of narrow-band trumpeting calls. They are 20 Hz to 2 kHz, less than 1 sec in duration, and have source levels of 162 to 192 dB re 1 µPa-m. The fundamental frequency of feeding calls is approximately 500 Hz (D'Vincent et al. 1985; Thompson et al. 1986).

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

- **Sei Whale (*Balaenoptera borealis*)**

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

Status—Sei whales are listed as endangered under the ESA. The International Whaling Commission (IWC) designates the entire North Pacific Ocean as one sei whale stock unit (Donovan 1991), although some evidence exists for multiple stocks (NMFS 1998a). The minimum population estimate for the Eastern North Pacific stock of the sei whale is 35 individuals (Carretta et al. 2006), and the best estimate is 56 individuals (Barlow 2003).

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

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

Distribution—Sei whales have a worldwide distribution but are found primarily in cold temperate to subpolar latitudes, rather than in the tropics or near the poles (Horwood 1987). Sei whales are also known for occasional irruptive occurrences in areas followed by disappearances for sometimes decades (Horwood 1987; Schilling et al. 1992; Clapham et al. 1997; Gregr et al. 2005).

Sei whales spend the summer months feeding in the subpolar higher latitudes and return to the lower latitudes to calve in the 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; Gregr et al. 2000). 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). Whaling data suggest that the northern limit for this species is about 55°N (Gregr et al. 2000). In the east, they range as far south as Baja California, Mexico, and in the west, to at least Japan and Korea (NMFS 1998a).

➢ <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

- <u>Upwelling season</u>—Sei whales are known for occasional irruptive occurrences in areas followed by disappearances for sometimes decades. There is a secondary occurrence in the Pacific Northwest OPAREA to reflect the current situation with sei whales seldom being found here (**Figure B-6**). Due to the many British Columbia whaling catches in the early to mid 1900s depicted in **Figure B-6**, sei whales have clearly utilized this area in the past (Pike and MacAskie 1969; Gregr et al. 2000). There is a rare occurrence in the Puget Sound Study Area since sei whales are not expected to occur there. Of interest, a sei whale washed ashore west of Port Angeles during September 2003 (Preston 2003).

- Relaxed season—Occurrence patterns are assumed to be similar to the upwelling season (**Figure B-6**).

Behavior and Life History—Sei whales are typically found in groups of two to five individuals (Leatherwood et al. 1988). The sei whale is atypical of rorquals in that it primarily "skims" its food (although 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). The dominant food for sei whales off California during June through August is the northern anchovy, while in September and October they eat mainly krill (Rice 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. Recordings from the North Atlantic consisted of paired sequences (0.5 to 0.8 sec, separated by 0.4 to 1.0 sec) of 10 to 20 short (4 milliseconds [msec]) FM sweeps between 1.5 and 3.5 kHz; source level was not known (Thomson and Richardson 1995). These mid-frequency calls are distinctly different from low-frequency tonal and frequency swept calls recently recorded in the Antarctic; the average duration of the tonal calls was 0.45±0.3 sec, with an average frequency of 433±192 Hz and a maximum source level of 156±3.6 dB re 1 µPa-m (McDonald et al. 2005).

While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- **Fin Whale (*Balaenoptera physalus*)**

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

Status—Fin whales are classified as endangered under the ESA. There is no designated critical habitat for this species in the North Pacific. The minimum population estimate for the California/Oregon/Washington stock of the fin whale is 2,541 individuals (Carretta et al. 2006).

Habitat Preferences—The fin whale is found in continental shelf, slope, 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. 1999). They have been observed during the summer in the central Bering Sea (Moore et al. 2000). During the winter (November through April), fin whales are sparsely distributed from 60°N, south to the northern edge of the tropics, near which it is assumed that mating and calving take place (Mizroch et al. 1999). However, some fin whales have been sighted as far north as 60°N all winter (Mizroch et al. 1999). Recoveries of marked whales demonstrate long migrations from low-latitude winter grounds to high-latitude summer grounds and extensive longitudinal movements both in-season and between years within and between the main summer concentration areas (Mizroch et

al. 1999). There is also some evidence of a resident population of fin whales in the Gulf of California, Mexico (Tershy et al. 1993). Such cases indicate that not all members of the species necessarily make the long, north/south migrations that are typical of the species.

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—The area of primary occurrence for the fin whale is the entire OPAREA (**Figure B-7**). This is based on the distribution of sighting records, acoustic detections, and the high number of British Columbia whaling catch records to the north. Occurrence of fin whales is rare within the Puget Sound Study Area; fin whales are extremely rare here (Wade, P., NMFS-NMML, pers. comm., 3-6 October 2005). Prior to commercial whaling off British Columbia, fin whales were occasional visitors to the inland waters (Osborne et al. 1988). Of note, strandings reported within Puget Sound have all been individuals struck by ships and presumably carried on the bow into the Sound (Norman et al. 2004).

- Relaxed season—Occurrence patterns are assumed to be similar to that of the upwelling season (**Figure B-7**).

Behavior and Life History—Fin whales feed by lunge-feeding and "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, but they do gather in groups at times, especially when good sources of prey are aggregated.

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

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

Acoustics and Hearing—Fin and blue whales produce calls with the lowest frequency and highest source levels of all cetaceans. Infrasonic, pattern sounds have been documented for fin whales (Watkins et al. 1987; Clark and Fristrup 1997; McDonald and Fox 1999). Fin whales produce a variety of sounds with a frequency range up to 750 Hz. The long, patterned 15 to 30 Hz vocal sequence is most typically recorded; only males are known to produce these (Croll et al. 2002). The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an FM sweep from about 23 to 18 Hz) with durations of about 1 sec and can reach source levels of 184 to 186 dB re 1 µPa-m (maximum up to 200; Thomson and Richardson 1995; Charif et al. 2002). Croll et al. (2002) recently suggested that these long, patterned vocalizations might function as male breeding displays, much like those that male humpback whales sing. The source depth, or depth of calling fin whales, has been reported to be about 50 m (Watkins et al. 1987).

While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- **Blue Whale (*Balaenoptera musculus*)**

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

Status—Blue whales are classified as endangered under the ESA. 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; as many as five populations of blue whales might occur (NMFS 1998a). There is a minimum population estimate of 1,384 individuals in the Eastern North Pacific blue whale stock (Carretta et al. 2006). This is the most abundant large whale off southern California (Smith et al. 1986). There is some indication that blue whale abundance in California coastal waters has increased; it is not known if this is due to an increase in the stock itself, or if it is a result of an increased use of California as a feeding area (Barlow 1994; Carretta et al. 2006).

Habitat Preferences—Blue whales inhabit both coastal and oceanic waters in temperate and tropical areas (Yochem and Leatherwood 1985). Important foraging areas include the edges of continental shelves and upwelling regions (Reilly and Thayer 1990; Schoenherr 1991). 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) and Baja California, Mexico (Reilly and Thayer 1990). Blue whales off the coast of southern California appear to feed exclusively on dense euphausiid schools between 100 m to 200 m (Croll et al. 1998; Fiedler et al. 1998). These concentrations form downstream from upwelling centers in close proximity to regions of steep topographic relief off the continental shelf break (Croll et al. 1999). Migratory movements of the blue whale in California probably reflect seasonal patterns and productivity (Croll et al. 2005). 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 year-round in low latitudes, 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). A discovery tag shot into a blue whale by whalers off Vancouver Island in May 1963 was recovered a year later in June 1964 just south of Kodiak Island, supporting the idea that blue whales taken off British Columbia were en route to and from feeding areas in the Gulf of Alaska (COSEWIC 2002).

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). Blue whale vocalizations have been detected in many portions of the North Pacific (e.g., McDonald et al. 1995; Watkins et al. 2000a; 2000b; Stafford et al. 2001; Stafford 2003), even those areas where sighting reports are rare (e.g., central North Pacific; Northrop et al. 1971; Thompson and Friedl 1982; McDonald and Fox 1999).

In the North Pacific, blue whales may be found as far north as the Gulf of Alaska, Aleutian Islands, Kuril Islands, and the Kamchatka Peninsula during the spring and summer months (Yochem and Leatherwood 1985) and as far south as approximately 1,300 km off the coast of Guatemala in the fall and winter months. Photographic identification effort has revealed extensive movements from the Gulf of California and the west side of Baja California in late winter and spring to California in summer and fall (Calambokidis et al. 1990). Off the coast of southern California, blue whales tend to be more

common at the western end of the Santa Barbara Channel (Fiedler et al. 1998). Some blue whales are found year-round off the coast of California and Baja California (Reilly and Thayer 1990). One individual blue whale was photo-identified off the Queen Charlotte Islands in British Columbia and resighted off the Santa Barbara Channel in California, representing the first match between California and waters further north (COSEWIC 2002). A blue whale photographed south of Prince William Sound in the Gulf of Alaska and determined to be an individual that was identified five previous times in 1995 and 1998 off southern California (Calambokidis, J., Cascadia Research Collective, pers. comm., 1 December 2005).

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—Primary occurrence for the blue whale is south of 44°N, from the shore to seaward of the OPAREA boundary (**Figure B-8**). This takes into consideration both sighting and acoustic data, as well as the fact that blue whales are known to feed in the southern part of the Pacific Northwest OPAREA. There is an area of secondary occurrence between 44°N and 48°N. The dividing line of 44°N is based on the available sighting data. There is an additional area of primary occurrence north of 48°N based on whaling records off British Columbia. This area is presumably a known feeding area. The Puget Sound Study Area is an area of rare occurrence for the blue whale.

- Relaxed season—The coast of the Pacific Northwest OPAREA is an area of primary occurrence for the blue whale during the relaxed season (**Figure B-8**). October is still a time of year during which blue whales are feeding. Less individuals are seen during the end of this season since the majority of the population migrates south at this time. Analyses of acoustic data collected by SOSUS hydrophones reveal that males are calling at this time of the year in this area (Stafford et al. 2001). The Puget Sound Study Area is an area of rare occurrence for the blue whale.

Behavior and Life History—Blue whales are found singly or in groups of two or three (Yochem and Leatherwood 1985). As noted by Wade and Friedrichsen (1979), apparently solitary whales are likely part of a large dispersed group. Blue whales, like other rorquals, feed by "gulping" (Pivorunas 1979) almost exclusively on krill (Nemoto and Kawamura 1977). Two species of euphausiids were consumed by blue whales in the Channel Islands—*Thysanoessa spinifera* and *Euphausia pacifica*, with evidence of preference for the former, a larger and more coastal species (Fiedler et al. 1998; Larkman and Veit 1998). Female blue whales reach sexual maturity at 5 to 15 years of age (Yochem and Leatherwood 1985). There is usually a two-year interval between calves. Calving occurs primarily during the winter (Yochem and Leatherwood 1985).

Blue whales spend greater than 94% of their time below the water's surface (Lagerquist et al. 2000). Croll et al. (2001) determined that blue whales dived to an average of 140.0 m (S.D.=±46.01 m) and for 7.8 min (S.D.=±1.89 min) when foraging and to 67.6 m (S.D.=±51.46 m) and for 4.9 min (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 and fin whales produce calls with the lowest frequency and highest source levels of all cetaceans. Sounds are divided into two categories: short-duration or long duration. Blue whale vocalizations are typically long, patterned low-frequency sounds with durations up to 36 sec (Thomson and Richardson 1995) repeated every 1 to 2 min (Mellinger and Clark 2003). Their frequency range is 12 to 400 Hz, with dominant energy in the infrasonic range at 12 to 25 Hz (Ketten 1998; Mellinger and Clark 2003). These long, patterned, infrasonic call series are sometimes referred to as "songs." The short-duration sounds are transient, frequency-modulated calls having a higher frequency range and shorter duration than song notes, and often sweeping down in frequency (Di Iorio et al. 2005; Rankin et al. 2005). Short-duration sounds appear to be common; however, they are underrepresented in the literature (Rankin et al. 2005). These short-duration sounds are less than 5 sec in duration (Di Iorio et al. 2005; Rankin et al. 2005) and are high-intensity, broadband (858±148 Hz) pulses (Di Iorio et al. 2005). Source levels of blue whale vocalizations 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). Stafford et al. (2005) recorded the highest calling rates when blue whale prey was closest to the surface during its vertical migration.

While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- **Sperm Whale (*Physeter macrocephalus*)**

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

Status—Sperm whales are listed as endangered under the ESA. It should be noted that the sperm whale's ESA status as endangered is somewhat political, and the species is actually in no immediate danger of global extinction. Although many sperm whale populations have been depleted to varying degrees by past whaling activities, sperm whales remain one of the more globally common great whale species. In fact, in some areas, they are actually quite abundant. As just a single example, there are estimated to be about 21,200 to 22,700 sperm whales in the eastern tropical Pacific (Wade and Gerrodette 1993). There is no designated critical habitat for this species in the North Pacific. Mesnick et al. (1999) found evidence to suggest that California, Oregon, and Washington State may contain a stock of sperm whales that is separate from those off Hawai'i and those in the Gulf of California. There is a minimum population estimate of 885 individuals in the California/ Oregon/Washington stock of the sperm whale. Sperm whale abundance in the eastern temperate North Pacific is estimated to be 32,100 individuals and 26,300 individuals by acoustic and visual detection methods, respectively (Barlow and Taylor 2005).

Habitat Preferences—Sperm whales show a strong preference for deep waters (Rice 1989), especially areas with high sea floor relief. Globally, sperm whale distribution is associated with waters over the continental shelf break, over the continental slope, and into deeper waters (Hain et al. 1985). 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; Waring et al. 2002). Worldwide, females rarely enter the shallow waters over the continental shelf (Whitehead 2003).

Sperm whale concentrations have been correlated with high secondary productivity and steep underwater topography (Jaquet and Whitehead 1996). Sperm whales are more frequently found in certain geographic areas, which whalers learned to exploit (e.g., whaling "grounds" such as the Azores Islands) encompassing 300 to 1,500 km^2 (Townsend 1935). These main sperm whaling grounds are usually correlated with areas of increased primary productivity caused by upwelling (Jaquet et al. 1996). Sperm whales in the Gulf of Mexico aggregate along the continental slope in or near cyclonic (cold-core) eddies (Biggs et al. 2000; Davis et al. 2002). These eddies are mesoscale features with locally enhanced plankton stocks (Wormuth et al. 2000). Data suggest that sperm whales appear to adjust their movements to stay in or near cold-core rings (Davis et al. 2000; 2002). This would demonstrate that sperm whales shift their movements in relation to prey concentrations. Off the eastern U.S., sperm whales are found in regions of pronounced horizontal temperature

gradients, along the edges of the Gulf Stream and warm-core rings (Waring et al. 1993; Jaquet et al. 1996; Griffin 1999). 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°C to 24.9°C and a bottom depth of 325 to 2,300 m (Waring et al. 2003). In the Eastern Tropical Pacific (ETP), sperm whale habitat use is significantly related to SST and depth of the thermocline (Polacheck 1987). Gregr and Trites (2001) reported that female sperm whales off British Columbia were relatively unaffected by the surrounding oceanography. Tynan et al. (2005) reported an increased density of sperm whales with strong turbulence associated with rough topography along the slope near Heceta Bank.

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 SST greater than approximately 15°C, whereas males, and especially the largest males, can be found in waters as far poleward as the pack ice with temperatures close to 0° (Rice 1998). The thermal limits on female distribution correspond approximately to the 40° parallels (50° in the North Pacific; Whitehead 2003).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—There are two noteworthy sperm whale stranding events in this area. During November 1970, there was an infamous incident (well-publicized by the media) of attempts to dispose of a decomposed sperm whale carcass on an Oregon beach by using explosives.[1] Second, there was a mass stranding of 47 individuals in Oregon during June 1979 (Rice et al. 1986; Norman et al. 2004).

  - Upwelling season—Based on known habitat preferences, the primary area of occurrence for the sperm whale is seaward of the 1,000 m isobath in the Pacific Northwest OPAREA (**Figure B-9**). There is an area of secondary occurrence between the 200 m and 1,000 m isobaths, which accounts for the possibility of sightings in more shallow waters. Sperm whale occurrence in waters between the shore and the 200 m isobath is expected to be rare since this species prefers deep waters. Sperm whales would have a rare occurrence within the Puget Sound Study Area.

  - Relaxed season—Occurrence patterns are expected to be the same as during the upwelling season (**Figure B-9**).

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 have a highly diverse diet, preying on large mesopelagic squid and other cephalopods as well as demersal fishes and occasionally benthic invertebrates (Fiscus and Rice 1974; Rice 1989; Clarke 1996).

Sperm whales forage during deep dives that routinely exceed a depth of 400 m and 30 min duration (Watkins et al. 2002). They 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/sec (Watkins et al. 2002). Dive descents averaged 11 min at a rate of 1.52 m/sec, and ascents averaged 11.8 min at a rate of 1.4 m/sec (Watkins et al. 2002).

Acoustics and Hearing—Sperm whales produce short-duration (generally less than 3 sec), broadband clicks. These clicks range in frequency from 100 Hz to 30 kHz, with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). Generally, most of the acoustic energy is present at frequencies below 4 kHz, although diffuse energy up to past 20 kHz has been reported (Thode et al. 2002). The source levels can be up to 236 dB re 1 µPa-m (Møhl et al. 2003). Thode et al. (2002) suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region. The clicks of neonate sperm whales are very different from usual clicks of adults in that they are of low directionality, long duration, and low-frequency (dominant frequencies around 0.5 kHz) 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. 2005b). These may be echolocation clicks used in feeding, contact calls (for communication), and orientation during dives. When sperm whales are socializing, they tend to repeat series of clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared between individuals of a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead 1997; Rendell and Whitehead 2004).

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

- **Southern Resident Killer Whale (population segment of *Orcinus orca*)**

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

There are at least three ecotypes in the eastern North Pacific: "residents," "transients," and "offshores." Resident animals have a dorsal fin that is more curved and rounded at the tip, especially among mature females (Ford et al. 1994). Residents also exhibit five patterns of saddle patch pigmentation (Baird and Stacey 1988).

Status—The SRKW stock (or population segment) was recently listed as endangered under the ESA (NMFS 2005f); it is also designated as depleted under the MMPA.

Most cetacean taxonomists agree that multiple killer whale species or subspecies occur worldwide (Krahn et al. 2004; Waples and Clapham 2004). Krahn et al. (2004) concluded that all North Pacific resident killer whales should be treated as a single unnamed subspecies distinct from offshore and transient whales.

The term "residents" is a colloquial term and is not particularly descriptive of site-fidelity and actual movement patterns of the animals (e.g., NFMS 2005i). Some researchers instead refer to this ecotype as "fish-eaters". There are two populations of resident killer whales in the Washington State/British Columbia area: northern resident killer whales (NRKW) and SRKW; it is primarily the SRKW that occur in the Pacific Northwest OPAREA and Puget Sound Study Area, although NRKW (discussed later in the general killer whale section) occasionally venture into the area. Genetic analyses using nuclear (microsatellite) and mitochondrial DNA indicate that the two populations are most likely reproductively isolated from each other (Hoelzel et al. 1998b; Barrett-Lennard 2000).

The Eastern North Pacific SRKW stock is one of five killer whale stocks (Carretta et al. 2006). The SRKW population is estimated at 84 individuals (Carretta et al. 2006). This estimate is a direct count of individually identifiable animals. The SRKW stock experienced an almost 20% decline from 1996 to 2001 (NMFS 2005i). The SRKW population consists of three pods: J, K, and L (NMFS 2005i) which are very familiar to the general public. The J and K pods are currently comprised of four matrilines each, while the L pod (the largest of the three SRKW pods) is currently composed of 12 matrilines (Wiles 2004). J and K pods have generally maintained their numbers during the decline; however, L pod, which comprises about half of the southern resident population, has been in sharp decline since 1994. This pod's decline is especially worrisome since it involves both increased mortality of members and a reduction in birth rates.

Designated critical habitat was recently proposed for three specific areas: The Summer Core Area in Haro Strait and waters around the San Juan Islands; Puget Sound; and the Strait of Juan de Fuca, which comprise approximately 6,641 sq km of marine habitat (NMFS 2006g; **Figure 3-3**)[8]. Eighteen military sites would be excluded (NMFS 2006g).

Habitat Preferences—Killer whales have the most ubiquitous distribution of any species of marine mammal, 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). In the eastern North Pacific, killer whales are found in protected inshore waters, as well as offshore waters off the outer coast (Wiles 2004). Killer whales in the eastern North Pacific occasionally enter the lower reaches of rivers in Washington State and Oregon while feeding (Wiles 2004). In fact, in October 1931, a killer whale made its way up the Columbia River and was killed in the Oregon Slough, a branch of Portland Harbor, 95.6 NM (110 mi) inland from the Pacific Ocean (Shepherd 1932).

Several studies have reported that southern residents feed heavily in areas characterized by high-relief underwater topography, such as subsurface canyons, seamounts, ridges, and steep slopes (Heimlich-Boran 1988; Felleman et al. 1991). Such features may concentrate prey, thereby resulting in greater prey availability, and be used by the whales as underwater barriers to assist in herding fish (Heimlich-Boran 1988).

Distribution—The SRKW population is a transboundary population that resides for part of the year in the protected inshore waters of the Strait of Georgia and Puget Sound (especially in the vicinity of Haro Strait, west of San Juan Island, and off the southern tip of Vancouver Island) principally during the late spring, summer, and fall (Ford et al. 1994; Krahn et al. 2004). Pods have visited coastal sites off Washington State and Vancouver Island (Ford et al. 1994) and are known to travel as far south as central California and as far north as the Queen Charlotte Islands. During September and October, they can often be found off the mouth of the Fraser River in the Strait of Georgia, intercepting salmon before they enter the river. Little is known of where the SRKWs go when they leave Puget Sound, particularly from November to May, although there are occasional sightings within this area during November through March. The overall range of the SRKW in winter is unknown. During the winter J pod is commonly seen in inshore waters, while K and L pods apparently spend more time in offshore waters. In late Jan 2000, whales from K and L pods were sighted in Monterey Bay; this was the first sighting of residents in waters south of Washington State. Members of L pod were also sighted in Monterey Bay during March 2003.[5]

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

  - <u>Upwelling season</u>—Residents are most often seen during May through October when they are found in inland waters around the San Juan Islands, including Haro Strait, Boundary Passage, and the eastern portion of the Strait of Juan de Fuca (Heimlich-Boran 1988; Ford et al. 1994; Olson 1998; Wiles 2004).

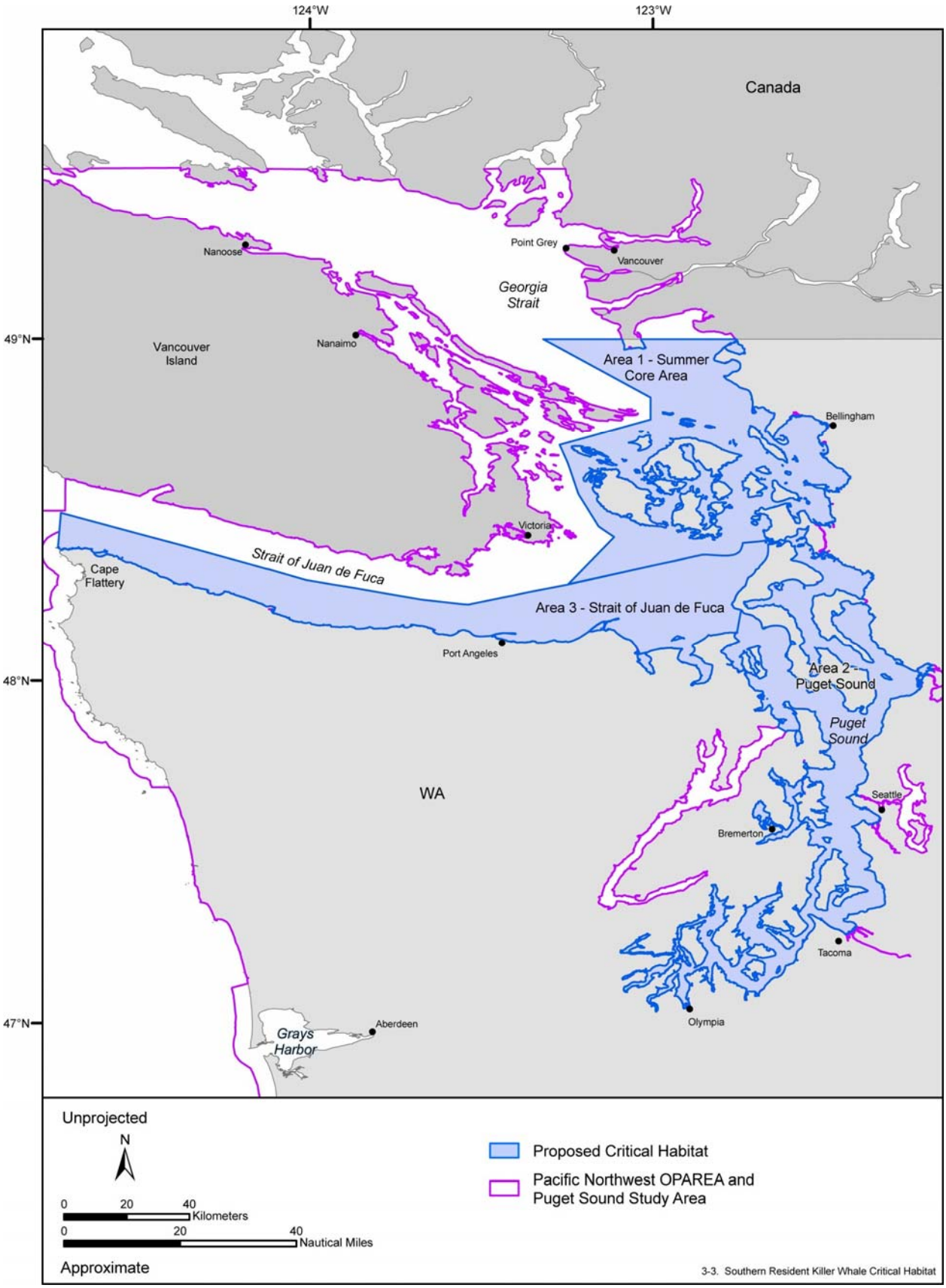

Figure 3-3. Proposed critical habitat for the southern resident killer whale. Source data: NMFS (2006a).

The area of primary occurrence for the SRKW is north of 47° and inshore of the shelf break, including all of Puget Sound (**Figures B-10** and **B-11**). The area of secondary occurrence north of 47° is between the shelf break and the 1,000 m isobath, while south of 47° it is waters shallower than the 1,000 m isobath. There is a rare occurrence in waters seaward of the 1,000 m isobath. K pod migrates into Washington State inland waters as early as March, and L pod joins in June. During summer (the peak feeding time), the pods tend to make a circuit between the mouth of the Fraser River and the Strait of Juan de Fuca, traveling up to a hundred miles a day and swimming through the San Juan Islands to feed on migrating salmon. SRKW are common throughout the summer and congregate at particular coastal locations at this time of year in association with high densities of migrating salmon (Heimlich-Boran 1986; Nichol and Shackleton 1996; Olson 1998; NMFS 2005i).

- Relaxed season—Occurrence patterns during the relaxed season are anticipated to be similar to that of the upwelling season (**Figures B-10** and **B-11**). Little is known about the movements and distribution of SRKW in the winter months. In Washington State inland waters, L pod typically departs around October and K pod in October or November, while J pod stays here, ranging as far south in Puget Sound as Olympia. Noteworthy is that in late October 1997, 19 southern resident killer whales spent 30 days in Dyes Inlet near Bremerton, Washington State, likely having followed a chum salmon run to Chico Creek. Of interest, L pod was sighted in outer coast waters, about 18.5 km off Westport, Washington State on 13 March 2004 (Hanson, B., NMFS-NWFSC, pers. comm., 29 November 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 (Bigg et al. 1990; Baird 2000).

Residents are organized into a series of social units from small to large on the basis of maternal genealogy (e.g., Ford et al. 1994). The maternal relatedness of the whales diminishes as one goes from the smallest kin unit, the mother and her offspring, through increasingly larger units: the matriline, the pod, and the clan. Residents occur in small highly stable social units known as matrilines in which all individuals are maternally related. Pods are larger social groups comprised of several matrilines and typically hold about 10 to 60 whales. The clan is comprised of pods that have similar vocal dialects or acoustic behavior. It may be that clans are linked through a common maternal ancestor but one that is more ancient than that which links pods within clans. The top level of social structure is the community which is made up of pods that regularly associate with one another.

Among resident killer whales in the northeastern Pacific, births occur largely from October to March, although births can occur year-round (Olesiuk et al. 1990; Stacey and Baird 1997). Females typically give birth for the first time at 11 to 15 years of age (Ford and Ellis 1999). Maximum life span is estimated to be 80-90 years for females and 50 to 60 years for males (Olesiuk et al. 1990).

Salmon are the principle prey for resident killer whales during spring, summer, and fall (Heimlich-Boran 1986; Felleman et al. 1991; Ford et al. 1998; Baird and Hanson 2004; Ford and Ellis 2005; Hanson et al. 2005). Current data suggest that chinook salmon (the area's largest salmonid) are the most commonly targeted species. Other salmonids appear to be eaten less frequently, as are rockfish, halibut, lingcod, and herring. The SRKW's annual presence in the vicinity of the San Juan Islands and the Fraser River mouth from late spring to early fall suggests a dependence on salmon returning to this river system (Osborne 1999). Chinook is the predominant prey species taken by SRKW during May through August. Autumn movements of SRKW into Puget Sound roughly correspond with chum and chinook salmon runs (Osborne 1999), as illustrated by the presence of whales in Dyes Inlet during a strong run of chum in 1997. Over the years, the fish-eating SRKW have been seen harassing Dall's and harbor porpoise on a number of occasions.[6]

The maximum depth recorded for free-ranging killer whales diving off British Columbia is 264 m (Baird et al. 2005a). On average, however, for seven tagged individuals, less than 1% of all dives examined were to depths greater than 30 m (Baird et al. 2003b). 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—Killer whales produce a wide-variety of clicks and whistles, but most of this species social sounds are pulsed, with frequencies ranging from 0.5 to 25 kHz (dominant frequency range: 1 to 6 kHz) (Thomson and Richardson 1995). Echolocation clicks recorded for this species indicate source levels ranging from 195 to 224 dB re: 1 µPa-m peak-to-peak, dominant frequencies ranging from 20 to 60 kHz, and durations of 80 to 120 µs (Au et al. 2004). Source levels associated with social sounds have been calculated to range from 131 to 168 dB re 1 µPa-m and have been demonstrated to vary with vocalization type (e.g., whistles: average source level of 140.2 dB re 1 µPa-m, variable calls: average source level of 146.6 dB re 1 µPa-m, and stereotyped calls: average source level 152.6 dB re 1 µPa-m) (Veirs 2004). Additionally, killer whales modify their vocalizations depending on social context or ecological function (i.e., short-range vocalizations [<10 km range]) are typically associated with social and resting behaviors and long-range vocalizations [10 to 16 km range] associated with travel and foraging) (Miller 2006).

Resident killer whales are very vocal, making calls during all types of behavioral states. Acoustic studies of resident killer whales in the Pacific Northwest have found that there are dialects in their highly stereotyped, repetitive discrete calls, which are group-specific and shared by all group members (Ford 1991, 2002b). 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 1991, 2002b). Dialects have been documented in northern Norway (Ford 2002a) and southern Alaskan killer whales populations (Yurk et al. 2002) and are likely occur in other regions as well. Residents do not need to alter their sounds (i.e., frequency or amplitude) when hunting fishes, since most of their prey (i.e., salmonids) are not capable of hearing in this frequency range (i.e., >20 kHz) (Hawkins and Johnstone 1978; Au et al. 2004). Transient killer whales, conversely, appear to use passive listening as a primary means of locating prey, call less often, and frequently vocalize or use high-amplitude vocalizations only when socializing (i.e., not hunting), trying to communicate over long distances, or after a successful attack, as a result of their prey's ability (i.e., primarily other marine mammal species) to hear or "eavesdrop" on their sounds (Barrett-Lennard et al. 1996; Deecke et al. 2005; Saulitis et al. 2005).

Both behavioral and ABR techniques indicate killer whales can hear a frequency range of 1 to 100 kHz and are most sensitive at 20 kHz, which is one the lowest maximum-sensitivity frequency known among toothed whales (Szymanski et al. 1999).

- **Guadalupe Fur Seal (*Arctocephalus townsendi*)**

Description—Guadalupe fur seals are sexually dimorphic. Maximum length and weight for males is 1.93 m and 170 kg (Reeves et al. 1992; Jefferson et al. 1993). Adult females attain lengths of 1.37 m and can weigh 55 kg (Reeves et al. 1992; Jefferson et al. 1993). Both sexes are dark brown or dusky black. Older males also have tan to yellowish hairs on the back of the neck, while females are generally paler on the chest and underside of the neck (Reeves et al. 1992).

Status—All Guadalupe fur seal individuals are considered to belong to a single stock, since all are recent descendants from one breeding colony at Guadalupe Island, Mexico (Carretta et al. 2006). The minimum population estimate in Mexico is 3,028 individuals and the population is increasing at an annual rate of 13.7% (Carretta et al. 2006). The Guadalupe fur seal is listed as threatened under the ESA.

Habitat Preferences—Guadalupe fur seals prefer rocky habitat for breeding and hauling out. They generally haul out at the base of towering cliffs on shores characterized by solid rock and large lava blocks (Peterson et al. 1968), although they may also inhabit caves and recesses (Belcher and Lee

2002). On Guadalupe Island, cliffs and overhanging rocks offer shaded, cool areas necessary for temperature regulation, especially during the warm breeding period (May to July; Peterson et al. 1968). Volcanic caves on the east side of the island also provide shelter from prevailing winds, launching spots for a cool swim, as well as suitable breeding habitat (Fleischer 1978).

Distribution—Formerly, Guadalupe fur seals ranged from Monterey Bay, California, to the Revillagigedo Islands, Mexico (Hanni et al. 1997; Aurioles-Gamboa et al. 1999). Currently, Guadalupe fur seals are most common at Guadalupe Island, Mexico, their primary breeding ground (Melin and DeLong 1999). In 1997, a second rookery was discovered at Benito del Este, Baja California (Maravilla-Chavez and Lowry 1999), and a pup was recently born at San Miguel Island, California (Melin and DeLong 1999). A few Guadalupe fur seals are known to inhabit California sea lion rookeries in the Channel Islands, primarily San Nicolas and San Miguel islands (Stewart et al. 1987). Sightings have also been made at Santa Barbara and San Clemente islands (Stewart et al. 1987). Distribution at sea is largely unknown (Reeves et al. 1992), but Guadalupe fur seals may migrate at least 600 km from the rookery sites, based on pelagic observations of individuals in the Southern California Bight (Seagars 1984). The movements of Guadalupe fur seals at sea are unknown, but strandings have been reported in northern California and even as far north as Washington State (Hanni et al. 1997; DeLong, R., NMFS-NMML, pers. comm., 3-6 October 2005). Etnier (2002) reported on a dead yearling specimen stranded on a beach just north of the Columbia River in 1992 and the presence of fur seal remains in archeological site from Ozette Village on the northern Washington Coast which dated 300 to 500 years before present.

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area —The highly endangered status of the Guadalupe fur seal necessitates an extremely conservative determination of this species' occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area. Guadalupe fur seals are expected to be rare in the OPAREA and Study Area based on their known distribution. Strandings have been recorded in the Pacific Northwest (Hanni et al. 1997). The northernmost stranding was recorded in May 2005 near Ocean Shores, Washington State (Norman, S., NMFS-NWR, pers. comm., 22 December 2005). Guadalupe fur seals are capable of traveling long distances from rookery sites in California and Mexico, particularly during El Niño events, so sightings in the OPAREA are possible (Hanni et al. 1997; Lander et al. 2000).

  - Upwelling season—Guadalupe fur seals have a rare occurrence throughout the OPAREA and Study Area except for a 20 NM (37 km) wide strip of secondary occurrence seaward of the shelf break and south of 47°N (**Figure B-12**). This area of secondary occurrence is based on feeding habitat preferences.

  - Relaxed season—Occurrence during the relaxed season is similar to that of the upwelling season (**Figure B-12**).

Behavior and Life History—Groups size and composition of Guadalupe fur seals changes seasonally. Adult males, juveniles, and nonparous females may live at sea during some seasons or for part of a season (Reeves et al. 1992). Females with pups are restricted to rookery areas because they must return to nurse their pups. Males typically undertake some form of seasonal movement either after the breeding season or during the winter months when prey availability is reduced (Arnould 2002). Several observations suggest that this species travels alone or in small groups of less than five individuals (Seagars 1984).

Males are very territorial during the breeding season. A territory usually consists of one dominant adult male, several nonterritorial fringe males, and two or three females with pups (Fleischer 1978). Females give birth from mid-June through July, 3 to 6 days after hauling out. Seven to ten days after giving birth, females mate and begin a series of trips (average of 7 days) to sea to feed (Carranza 1994). Between these feeding bouts, they return to shore to nurse their pups for about 5 to 6 days (Ronald and Gots 2003). During the winter, adult males are absent from the rookeries, but females may continue to haul out and nurse their pups through the following spring (Reeves et al. 1992). Both

the gestation and lactation periods last for 8 to 12 months (Seagars 1984; Arnould 2002). The age at sexual maturity is not known (Reeves et al. 1992).

The Guadalupe fur seal's diet consists of squid, lampfish, sanddab, and lanternfish (Reeves et al. 1992; Hanni et al. 1997). Guadalupe fur seals predominately forage at night to take advantage of prey migrating vertically through the water column (Arnould 2002; Ronald and Gots 2003). Females have been observed feeding in the California Current south of Guadalupe Island, making an average round trip of 2,375 km (Ronald and Gots 2003).

Foraging dives are usually shallow (50 to 60 m) and of short duration (Arnould 2002; Ronald and Gots 2003). Lander et al. (2000) tracked a rehabilitated female whose dives were less than 20 m and lasted 2 to 4 min.

Acoustics and Hearing—Guadalupe fur seals produce a variety of airborne sounds. Younger animals produce barks, roars, and coughs, adult males most often make barks and puffs, and females with pups used bawls (Peterson et al. 1968). Many of these sounds consist of multiple harmonics with frequencies less than 7 kHz and dominant frequencies below 1 kHz (Peterson et al. 1968).

There is no published information on the hearing ability of this species.

- **Steller Sea Lion (*Eumetopias jubatus*)**

Description—The Steller sea lion, or northern sea lion, is the largest eared seal species. The average male is 282 cm long and weighs 566 kg. Females are quite a bit smaller with an average length and weight of 228 cm and 263 kg, respectively (Loughlin 2002). 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 as a species is listed as threatened under the ESA. 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 (also known as the Western stock) includes animals at and west of Cape Suckling, Alaska (144°W), while the Eastern U.S. stock (also known as the Eastern stock) includes all the animals east of Cape Suckling (NMFS 1997c; Loughlin 2002; Angliss and Outlaw 2005). In 1997, NMFS reclassified Steller sea lions as two subpopulations, listing the Western stock as endangered under the ESA, while maintaining the threatened status for the Eastern stock (NMFS 1997c). The minimum population estimate for the Eastern stock of the Steller sea lion is 43,728 individuals (Angliss and Outlaw 2005). The Eastern stock is the one that occurs in the Pacific Northwest OPAREA and Puget Sound Study Area.

Designated critical habitat includes a 37 km buffer around all major haulout sites and rookeries; 3,000 ft (914 m) zones landward, seaward, and skyward of all major haulout sites and rookeries; and three large offshore foraging areas in Alaska (NMFS 1997c; **Figure 3-4**). There is no critical habitat for this species in the Pacific Northwest OPAREA or the Puget Sound Study Area.

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, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005). 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, rocky shorelines, and jetties throughout their range (Jeffries et al. 2000; NRC 2003; Call and Loughlin 2005). Steller sea lions also haul out on buoys, rafts, floats, and U.S. Navy submarines in the Puget Sound Study Area (Jeffries et al. 2000; DoN 2001b).

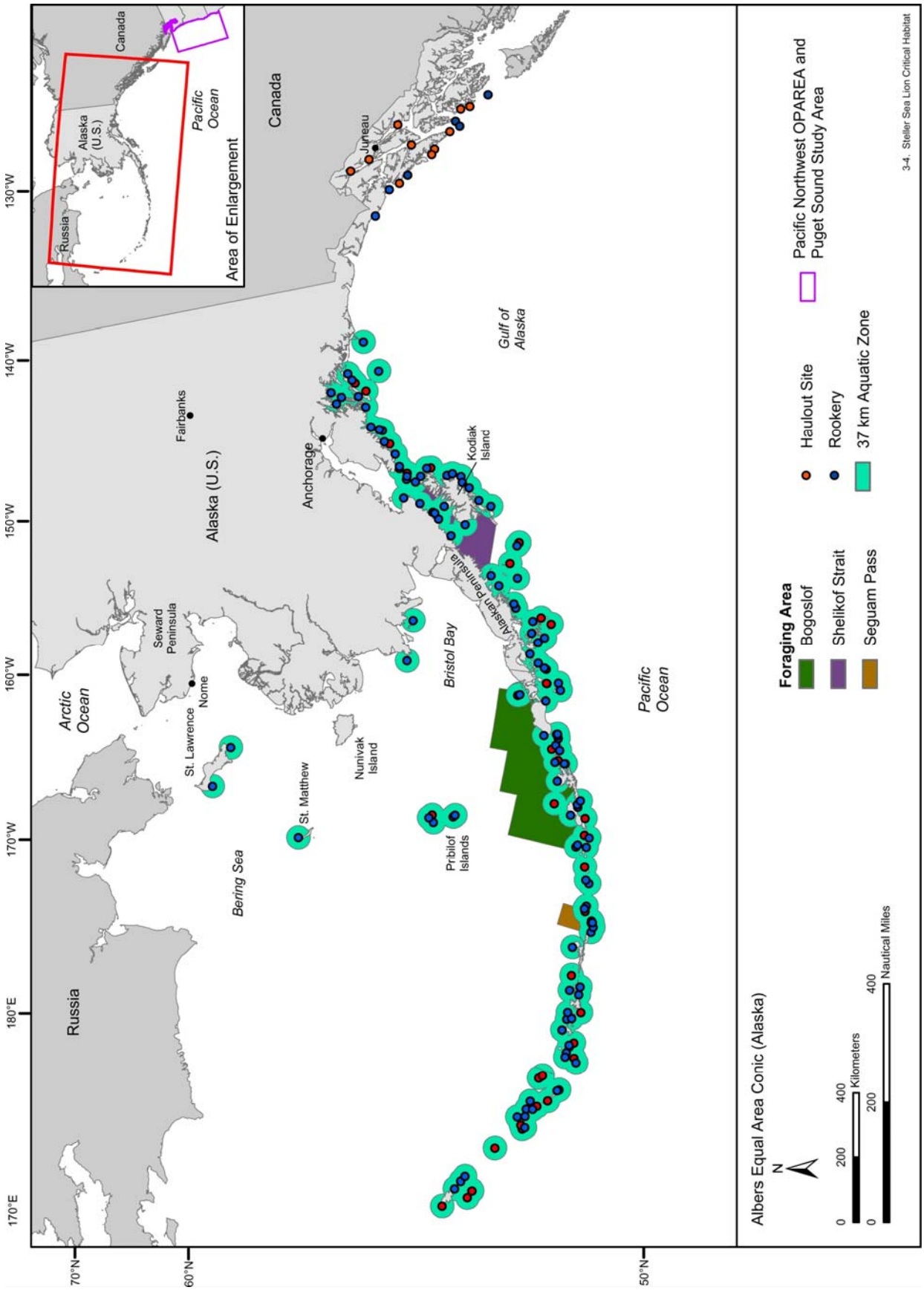

Figure 3-4. Major rookeries, haulout sites, and associated terrestrial and aquatic zones designated as critical habitat for the Steller sea lion. Source data: NMFS (1993b).

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 (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 3-3**). In the Pacific Northwest, rookeries are located in British Columbia, Oregon, and northern California; there are no rookeries in Washington State (NMFS 1992; Angliss and Outlaw 2005).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Steller sea lions regularly occur in the Pacific Northwest OPAREA and Puget Sound Study Area year-round. Peak abundance occurs on land during the spring breeding season and at sea during the fall (Bonnell et al. 1992). Steller sea lion haulout sites and rookeries range widely throughout the OPAREA and Study Area (**Figure B-13**). In Washington State, Steller sea lions primarily haul out along the coast from the Columbia River to Cape Flattery and on the southern coast of Vancouver Island near the Strait of Juan de Fuca (Jeffries et al. 2000). Primary rookery sites in Oregon are located along the southern coast at Orford and Rogue Reefs, while main haulout sites are also in Sea Lion Caves, Three Arch Rocks, Ecola Point, and the Columbia River jetty (Bonnell et al. 1992; Brown 1997). St. George Reef is the primary haulout and rookery site in the northern California part of the OPAREA (Loughlin et al. 1992).

  In the Pacific Northwest region, Steller sea lions mostly occur in shallow waters (<200 m) but have been sighted in water depths as great as 2,250 m off the coast of California (Bonnell et al. 1983). During the summer, Steller sea lions are common in cold, upwelled waters off southern Oregon; they tend to remain near rookeries (<30 km), Heceta and Stonewall Banks, and the mouth of the Umpqua River (Bonnell et al. 1992). Steller sea lions are widely-distributed throughout Washington State inland waters; they are frequently observed over deep water in the Strait of Georgia (Keple 2002).

  - Upwelling season—The area of primary occurrence extends from the shore to the 500 m isobath along the outer coast of the OPAREA (**Figure B-14**). Secondary occurrence is a band between the 500 m and 1,000 m isobaths. Steller sea lions are rare seaward of this secondary occurrence band.

    An area of primary occurrence extends into the Strait of Juan de Fuca, around San Juan and Whidbey islands, and through the Strait of Georgia (**Figure B-15**). The southern part of the Puget Sound Study Area is an area of secondary occurrence.

  - Relaxed season—Occurrence patterns are expected to be similar to that of the upwelling season.

Behavior and Life History—In general, Steller sea lions do not migrate but often disperse widely during the nonbreeding season (Loughlin 2002). Steller sea lions are gregarious animals. They often haul out in large groups. Steller sea lions in the Pacific Northwest are known to haul out in groups up to 45 individuals (Keple 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 non-breeding 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 breeding 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). Pups in Oregon are weaned in late spring (Hamblen et al. 2005). Females reach sexual maturity between 4 and 5 years of age; most males become sexually mature by the age of eight (Pitcher and Calkins 1981).

Steller sea lions are opportunistic predators, feeding primarily on fishes and cephalopods. They feed near land or in relatively shallow water (Pitcher and Calkins 1981). The diet varies geographically and

seasonally (Merrick et al. 1997). In Alaska, Steller sea lion diet includes capelin, sand lance rockfishes, sculpins, and flatfishes. In the Pacific Northwest, Steller sea lions feed on flatfishes, rockfishes, and lampreys (Schusterman 1981; Roffe and Mate 1984).

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, females make long trips of around 130 km and dive deeply 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-hour cycles (NRC 2003). Steller sea lions tend to make shallow dives of 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). Young Steller sea lions make shallow (70 to 140 m) and short dives (one to two min) 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 3000 Hz with peak frequencies from 150 to 1000 Hz; typical duration is 1000 to 1500 msec (Campbell et al. 2002). Pups produce bleating sounds.

Underwater sounds are like the in-air signals (Loughlin et al. 1987). The underwater hearing sensitivity of two Steller sea lions was recently tested; the hearing thresholds of the male were significantly higher than those of the female (Kastelein et al. 2005). The range of best hearing for the male was from 1 to 16 kHz, with maximum sensitivity (77 dB re 1 µPa-m) at 1 kHz. The range of best hearing for the female was from 16 to above 25 kHz, with maximum sensitivity (73 dB re 1 µPa-m) at 25 kHz. It is not known whether the differences in hearing sensitivity are due to individual differences in sensitivity or due to sexual dimorphism in hearing (Kastelein et al. 2005).

- **Sea Otter (*Enhydra lutris*)**

Description—The sea otter is among the least derived of all marine mammals and looks very much like its terrestrial relatives. The sea otter is the largest mustelid species. Male sea otters reach maximum mean lengths of 1.5 m and maximum weights of 50 kg (Sea Otter Recovery Team 2004); females are smaller, measuring maximum mean lengths of 1.3 m and maximum mean weights of 25.2 kg (Lance et al. 2004). The sea otter has a short broad head and a short blunt snout (Kenyon 1981). The upper lip and cheeks are well-developed and densely covered by stiff whiskers. The hindpaws are large, flipper-like and webbed (Kenyon 1981). The forepaws are rounded. The tail is long, flattened, and oar-like. Insulation from cold environmental temperatures is provided entirely by air trapped in the dense fur. This dark brown fur covers almost the entire body, except for the pads on the bottom of the feet and the tip of the nose.

Status—There are three recognized subspecies of sea otter: two northern sea otter subspecies (*Enhydra lutris lutris* is found in the western North Pacific from the Kamchatka Peninsula through the Kuril Islands; *Enhydra lutris kenyoni* is distributed in the Commander Islands, the Aleutian Islands, and throughout central and southeastern coastal Alaskan waters, as well as off British Columbia, Washington State, and occasionally, Oregon) and one southern sea otter subspecies (Enhydra lutris nereis, which primarily occupies waters off central California; Wilson et al. 1991; Cronin et al. 1996; USFWS 2003b).

The USFWS recognizes five stocks in U.S. waters under the MMPA guidelines (USFWS 2005c); these include single stocks in California and Washington State and three in Alaska (Southeast, Southcentral, and Southwest). The southern sea otter (California stock) is listed as threatened under the ESA; the northern sea otter is not listed under the ESA. The southwest Alaska stock of the northern sea otter recently received threatened status under the ESA (USFWS 2005c). Both the California and southwest Alaska stocks are also designated as depleted under the MMPA.

Harvesting for pelts during the 1700s and 1800s decimated sea otter numbers throughout their range (Kenyon 1975). From about 1911 to 1969, sea otters were absent from Washington State. Reintroduction efforts dating back to 30 years ago are largely responsible for the recovery of northern sea otters in Washington State, Canada, and parts of southeast Alaska. Between 1965 and 1972, 700 northern sea otters were captured at Amchitka, an island in the Aleutian chain, and Prince William Sound and were translocated to other sites in Alaska as well as British Columbia, Washington State, and Oregon (Jameson et al. 1982). In 1969 and 1970, 59 otters were reintroduced to the Washington State and Oregon coast from Amchitka Island, Alaska (Jameson et al. 1982). Only the Washington State reintroduction was successful. After a decade of questionable status, the Washington State sea otter population began to increase steadily. The most recent survey during 2004 in Washington State counted 743 sea otters, an 11% increase over the 2003 estimate (Jameson and Jeffries 2004; Lance et al. 2004). Disease-caused mortality in the Washington State population is currently under investigation (Lance et al. 2004).

Habitat Preferences—Sea otters occupy nearly all coastal marine habitats from fine sediment bays and estuaries to rocky shores exposed to oceanic swells (Riedman and Estes 1990; Bodkin 2003; USFWS 2003b; 2005c). Sea otters prefer rocky shoreline with kelp beds, although this is not an essential habitat requirement (Riedman and Estes 1990; USFWS 2003b). Lower numbers of individuals also use soft-sediment areas where kelp is absent. Beds of giant and bull kelp and shallow rocky substrata provide sheltered resting and feeding areas during all weather conditions (e.g., Jameson et al. 1986). Historically, the Washington State sea otter occurred in estuarine and sandy habitats and along the rocky outer coast. This population currently occupies primarily rocky habitats (Lance et al. 2004). Sea otters in Washington State occasionally haul out at low tide on offshore rocks and islands.

Individuals seldom range more than 1 to 2 km from shore, although some individuals, particularly juvenile males, travel farther offshore (Riedman and Estes 1990; Ralls et al. 1995; 1996; USFWS 2003b; Lance et al. 2004). The width of habitat they occupy is defined by the intertidal zone and extends offshore to about the 100 m isobath (Bodkin 2003). Most individuals occur between the shore and the 20 m isobath (Riedman and Estes 1990; USFWS 2003b). Female areas tend to be in areas protected from weather and strong seas, while male areas tend to be in more exposed regions (Lance et al. 2004). Sea otters primarily forage in habitats where the bottom depth is less than 40 m, although foraging in southeast Alaska can occur in water as deep as 100 m (Bodkin et al. 2004). Sometimes non-foraging individuals can be found in waters with a bottom depth up to 200 m (Bodkin and Udevitz 1999).

Distribution—Sea otters are found in shallow, nearshore waters of the North Pacific, from northern Japan north to the coast of the Kamchatka Peninsula, east throughout the Aleutians, and south through the Gulf of Alaska and along the Pacific coast of North America, historically to Baja California (Reeves et al. 2002). The northward limits for this species appear related to the southern limits of sea ice, which can preclude access to foraging habitat (Bodkin 2003). Southern range limits are less well-understood but appear to coincide with the southern limits of coastal upwelling, associated canopy-forming kelp forests, and the 20° to 22°C isotherm (Bodkin 2003). The southernmost extent of the range of *Enhydra lutris kenyoni* is considered to be Washington State and British Columbia (Raum-Suryan et al. 2004; Sea Otter Recovery Team 2004; USFWS 2005c). However, in recent years, sea otter sightings have become increasingly common off the Oregon coast (Lynch, D., USFWS, pers. comm., 29 November 2005). These individuals are considered to be far-ranging animals from the Washington State population (Lynch, D., USFWS, pers. comm., 29 November 2005).

Sea otters will shift their distribution seasonally to areas where there is food or sheltered water to avoid exposure to storms and rough seas (Kenyon 1975; Riedman and Estes 1990). Individual sea otters in Washington State have demonstrated such distributional shifts (Lance et al. 2004) though it should be noted that the entire population itself does not shift since otters continue to range along the outer Washington State coast.

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—There is an area of primary occurrence for the sea otter between the shore and the 40 m isobath from Neah Bay, wrapping around the Olympic Peninsula to Grays Harbor, which takes into account sighting and live-stranding data as well as the fact that most feeding takes place inshore of the 40 m isobath (**Figure B-16**). There is a secondary occurrence between the 40 m and 100 m isobaths in this same area based on the possibility of encountering sea otters foraging further offshore. The Oregon coast is also an area of secondary occurrence, from the shore to the 100 m isobath. This takes into account the historical range of the species, as well as recent sightings as the species is possibly expanding its range. There is a rare occurrence offshore, as well as south of the area of secondary occurrence. All of the Puget Sound Study Area is considered to be an area of secondary occurrence for sea otters (**Figure B-17**; Lynch, D., USFWS, pers. comm., 29 November 2005).

  The current population in Washington State is spread out along about 100 mi (185 km) of coastline from Destruction Island in the south to Pillar Point (Neah Bay) in the north, with concentrations in the vicinities of Duk Point, Cape Alava, Sand Point, Cape Johnson, Perkins Reef, and Destruction Island (Lance et al. 2004). Almost half of the Washington State population occurs at Destruction Island (Lance et al. 2004). Recent sightings in Washington State have been made as far south as Cape Elizabeth (Calambokidis et al. 2004b; Doughton 2004). The sea otter is not usually seen in the Puget Sound Study Area (Osborne et al. 1988), although there are some confirmed sightings and movements of tagged individuals in the eastern Strait of Juan de Fuca, around the San Juan Islands, and within Puget Sound near Olympia (Calambokidis et al. 1987; Lance et al. 2004). The Strait of Juan de Fuca is new habitat for Washington State sea otters, not having been occupied by sea otters for over 100 years (Jeffries et al. 2005). One sea otter was even sighted about 9 km inland up McAllister Creek (Jeffries and Allen 2001). The current distribution differs from the pre-exploitation range, which extended south to the Columbia River with a major concentration off Point Grenville (Lance et al. 2004).

  Most of Oregon's sea otter habitat occurs in the southern half of the state, where the only extensive nearshore rocky reef systems are found. There were sporadic reports in Oregon waters since the population was extirpated (e.g., Pedersen and Stout 1963). Unfortunately, the reintroduction efforts in Oregon were not successful. Out of 93 sea otters translocated to Oregon in 1970 and 1971, they failed to establish for unknown reasons (Jameson et al. 1982). Confirmed sightings of sea otters along the Oregon coast have noticeably increased over the past decade.[2] In particular, sea otters have been spotted at Cape Blanco, Yachats, and Yaquina Bay, as well as on Simpson Reef at Cape Arago (Lynch, D., USFWS, pers. comm., 29 November 2005; Quinn[2]).

  In the last 10 years there have only been two confirmed sightings of sea otters in northern California; these were in August 2005 on consecutive days (Hatfield, B., USGS, pers. comm., 7 September 2005). It is uncertain whether this animal (assuming it is the same otter) wandered north from central California or south from Washington State (Hatfield, B., USGS, pers. comm., 7 September 2005).

- Relaxed season—Occurrence during the relaxed season is anticipated to be similar to the upwelling season (**Figures B-16** and **B-17**).

Behavior and Life History—Sea otters may be sighted alone or in groups, often called “rafts” (Riedman and Estes 1990). Adult males establish territories, with females moving freely amongst the territories (Jameson 1989). Groups of male and female sea otters generally rest separately. During summer and fall, males are found within female areas and are often associated with rafts of females. Breeding occurs throughout the year, with a peak in late autumn in Washington State (Lance et al. 2004). Pupping occurs throughout the year, although most births occur from late February to early

April (USFWS 2003b; Lance et al. 2004). Most adult female sea otters give birth to a single pup each year (Jameson and Johnson 1993). Females attain sexual maturity after three years of age, while it appears to be approximately five years for males (USFWS 2003b). Gestation in the sea otter involves two phases: a delayed implantation phase of 2 to 3 months, and an implanted phase of 4 to 5 months (Jameson and Johnson 1993; Da Silva and Larson 2005).

The diet varies with the physical and biological characteristics of the habitats in which they live (see reviews by (Riedman and Estes 1990; Estes and Bodkin 2002). Sea otters feed on or near the bottom in shallow waters. Major prey items in Washington State are invertebrates such as crustaceans, bivalves, urchins, and sea cucumbers (Lance et al. 2004). Sea otters also prey on cephalopods, fishes, and even seabirds (Riedman and Estes 1990). Preferred prey is large sea urchins until urchin density and large size classes are depleted, hereafter there is a diversification in diet that includes bivalves (Kvitek et al. 1989; Kvitek et al. 1998; Kvitek et al. 2001; VanBlaricom and Chambers 2003; Laidre et al. 2004). Sea otters exhibit individual differences not only in prey choice but also in choice and method of tool use, area in which they tend to forage, and water depth (Riedman and Estes 1990; Estes et al. 2003). In rocky-bottom habitats, sea otters generally forage for large-bodied prey offering the greatest caloric reward. In softbottom habitats, prey is smaller and more difficult to find; sea otters feed on a variety of burrowing invertebrates. Sea otters occupying an established population range on the outer coast of Washington State feed heavily on bivalves and have a diverse diet (Bowlby et al. 1988; Jeffries et al. 2005), in contrast to sea otters occupying new habitat in the Strait of Juan de Fuca, and have a more restricted diet dominated by red urchins (Jeffries et al. 2005). The record dive depth occurred in the Aleutian Islands, where a sea otter drowned in a king crab pot set at a bottom depth of approximately 100 m (Riedman and Estes 1990). Mean dive duration for Washington State sea otters is 55±25 sec (Jeffries et al. 2005). Mean dive duration exceeds 125 sec (Ralls et al. 1995).

Acoustics and Hearing— Sea otter produce a variety of airborne sounds (underwater sounds have not been studied), including screams; whines or whistles; hisses; deep-throated snarls or growls; soft cooing sounds; grunts; and barks that are considered to be primarily used for short-range communication among individuals (Kenyon 1975; McShane et al. 1995). These sounds typically range in frequency from 0.2 to 12.8 kHz with various harmonics and a dominant frequency of 0.2 to 4.9 kHz (McShane et al. 1995). The screams (dominant frequency range 3 to 5 kHz) of pups and their mothers can travel over distances of greater than 1 km, and it is believed that these sounds vary enough to potentially allow for individual recognition between mother and pup (Sandegren et al. 1973; McShane et al. 1995).

There are no hearing data available for this species.

3.1.1.5 Non-Threatened and Non-Endangered Marine Mammal Species of the Pacific Northwest OPAREA and Puget Sound Study Area

There are 24 non-endangered/non-threatened marine mammal species that occur in this area: 2 baleen whale species, 18 toothed whale species, and 4 pinniped species.

- **Minke Whale (*Balaenoptera acutorostrata*)**

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

Status—The IWC recognizes three stocks of minke whales in the North Pacific: one in the Sea of Japan/East China Sea, one in the rest of the western Pacific west of 180°N, and one in the remainder

of the Pacific (Donovan 1991). The NMFS recognizes three stocks of minke whales within the Pacific U.S. EEZ: a California/Oregon/Washington stock, an Alaskan stock, and a Hawaiian stock (Carretta et al. 2006). The minimum population estimate for the California/Oregon/Washington stock of the minke whale is 585 individuals (Carretta et al. 2006). Horwood (1990) noted that densities of minke whales throughout the North Pacific are low.

Habitat Preferences—In general, throughout its distribution the minke whale occupies waters over the continental shelf, including inshore bays and some estuaries (Mitchell and Kozicki 1975; Ivashin and Votrogov 1981; Murphy 1995; Mignucci-Giannoni 1998; Calambokidis et al. 2004a). 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). Dorsey et al. (1990) noted minke whales feeding in locations of strong tidal currents in inland waters of Puget Sound. Hoelzel et al. (1989) reported that 80% of feeding observations in the San Juans were over submarine slopes of moderate incline at a depth of about 20 m to 100 m. Off the California outer coast, they foraged along the edge of kelp beds and out to the shelf break (Dorsey et al. 1990) in contrast to other locales where minkes forage from closer to shore to the edge of the shelf break (Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 11 November 2005).

Distribution—Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 1993); they are less common in the tropics than in cooler waters. Minke whales are present in the North Pacific from near the equator to the Arctic (Horwood 1990). The summer range extends to the Chukchi Sea (Perrin and Brownell 2002). In the winter, minke whales are found south to within 2° of the equator (Perrin and Brownell 2002). The distribution of minke whale vocalizations (specifically, "boings") suggests that the winter breeding grounds are the offshore tropical waters of the North Pacific Ocean (Rankin and Barlow 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 State and along central California (Dorsey 1983; Dorsey et al. 1990) and exhibit site fidelity to these areas between years (Dorsey et al. 1990).

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

  - <u>Upwelling season</u>—Minke whales are observed year-round in Puget Sound, with a peak in abundance between July and September (Everitt et al. 1979; Osborne et al. 1988; Dorsey et al. 1990). There is a band of primary occurrence on the outer coast that captures all of the depicted sightings in **Figure B-18**. A 50 NM buffer of the area of secondary occurrence captures the area where individuals might be seen since the exact distribution of this species is unknown. There is an area of rare occurrence seaward of these areas.

    Within the Puget Sound Study Area, there is an area of primary occurrence around the San Juan Islands that captures the depicted sightings (**Figure B-19**). In the San Juan Islands, three feeding grounds were identified: the Strait of Juan de Fuca (this includes all the submarine banks); San Juan Channel and the Waldron Island Area, including Cowlitz Bay, President's Channel, and Rosario Strait; and between Sucia, Patos, and Waldron islands (Osborne et al. 1988; Hoelzel et al. 1989; Dorsey et al. 1990; Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 11 November 2005). The Channel and Waldron areas were abandoned in the late 1980's, but in 2005, individuals were seen feeding in these areas again (Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 11 November 2005). There are probably other feeding areas in the Puget Sound Study Area, and there is some year-to-year variation in the use of some of these areas (Osborne et al. 1988; Dorsey et al. 1990). There is also an area of primary occurrence in the Strait of Juan de Fuca since minkes are seen most consistently there. Primary occurrence extends into Admiralty Inlet on the west side of Whidbey Island. Within this area, individuals move within and between specific feeding areas, those areas around submarine banks (Stern, J., Northeast Pacific Minke

Whale Project, pers. comm., 11 November 2005). Primary occurrence also includes the upper part of Haro Strait and Boundary Pass and extends as far east as East Point on Saturna Island. There is an area of rare occurrence in central and southern Puget Sound as evidenced by the few sightings (Osborne et al. 1988; **Figure B-19**). There is an area of secondary occurrence north of the San Juan Islands, including the Waldron Island area. Sightings in the Strait of Georgia (e.g., Baird and Guenther 1991; Keple 2002) are likely of individuals moving from the northern San Juan Island area.

- Relaxed season—The minke whale is known to be a migratory species; however, the patterns are not as well-known or defined as for some other species such as gray and humpback whales. There are both areas of secondary and rare occurrence along the outer coast; the dividing line between these areas is based on available sighting records for this season (**Figure B-18**). The inland waters of the Puget Sound Study Area are an area of secondary occurrence to account for sparse survey effort in this area during this season (**Figure B-19**). The frequency of sightings of minke whales in inland waters is very low in winter months (Everitt et al. 1979; Dorsey et al. 1990). Dorsey et al. (1990) noted that this is due, in part, to poor weather and low search effort.

Behavior and Life History—Minke whales are sighted alone or in small groups (Perrin and Brownell 2002). Mating is thought to occur in winter or early spring but has never been observed (Stewart and Leatherwood 1985). Stern (1992) described a general surfacing pattern of minke whales consisting of about four surfacings interspersed by short-duration dives averaging 38 sec. After the fourth surfacing, there was a longer duration dive ranging from approximately 2 to 6 min. Minke whales are lunge-feeding "gulpers," like the other rorquals (Pivorunas 1979). In the North Pacific, major food items include krill, Japanese anchovy, Pacific saury, herring, sand lance, and walleye pollock (Perrin and Brownell 2002; Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 31 July 2006). In the San Juans, two distinct types of foraging are observed – feeding under flocks of feeding seabirds and lunge feeding without seabirds. Individuals tend to specialize on one of these types which are influenced by bottom topography (Hoelzel et al. 1989). Prey taken in the San Juans includes juvenile herring (*Clupea harengus*) and probably sand lance (Ammodytes hexapterus; Hoelzel et al. 1989).

Acoustics and Hearing—Recordings of minke whale sounds indicate the production of both high- and low-frequency sounds (range: 0.06 to 20 kHz) (Beamish and Mitchell 1973; Winn and Perkins 1976; Thomson and Richardson 1995; Mellinger et al. 2000). Minke whale sounds have dominant frequency range of 0.06 to greater than 12 kHz, depending on sound type (Thomson and Richardson 1995). Mellinger et al. (2000) described two basic forms of pulse trains: a "speed-up" pulse train (dominant frequency range: 0.2 to 0.4 kHz) with individual pulses lasting 40 to 60 msec, and a less-common "slow-down" pulse train (dominant frequency range: 50 to 0.35 kHz) lasting for 70 to 140 ms. Source levels for this species have been estimated to range from 151 to 175 dB re 1 µPa-m (Ketten 1998). Source levels for some minke whale sounds have been calculated to range from 150 to 165 dB re 1 µPa-m (Gedamke et al. 2001). 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 display, consist of a brief pulse at 1.3 kHz followed by an amplitude-modulated call with greatest energy at 1.4 kHz, with slight frequency modulation over a duration of 2.5 sec (Rankin and Barlow 2005).

While no empirical data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes are most adapted to hear low to infrasonic frequencies.

- **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 six to twelve 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 weakly 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 western (Korean-Okhotsk) and the eastern (California-Chukchi) Pacific populations (LeDuc et al. 2002). The western Pacific population is critically endangered and shows no apparent signs of recovery (Weller 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. It is not classified as a strategic stock by NMFS. The minimum population estimate for the eastern Pacific stock of the gray whale is 17,752 individuals, and the best estimate is 18,813 whales (Angliss and Outlaw 2005). The population still appears to be increasing in size, despite the 1999 mortality event in which an unusually large number of gray whales stranded along the coast from Mexico to Alaska (Gulland et al. 2005).

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 are generally less than 68 m deep (Nerini 1984; Jones and Swartz 2002). The breeding grounds consist of subtropical lagoons, which are protected from the open ocean by narrow entrances marked by lines of whitewater over barrier sand bars (Jones and Swartz 2002). These warm-water, protected lagoons are more conducive to the rearing of calves and mating and offer protection from predation by killer whales (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 Sea of Japan in the south to the Sea of Okhotsk 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).

There is a pronounced seasonal north-south migration (**Figure 3-5**). The eastern Pacific population summers in the shallow waters of the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea (Rice and Wolman 1971). Some individuals spend the summer feeding along the Pacific coast from southeastern Alaska to central California (Sumich 1984; Calambokidis et al. 1987; 2002). Photo-identification studies indicate that gray whales move widely along the Pacific coast and are often not sighted in the same area each year (Calambokidis et al. 2002). In October and November, the whales begin to migrate southeast through Unimak Pass and follow the shoreline south to breeding grounds on the west coast of Baja California and the southeastern Gulf of California (Braham 1984; Rugh 1984). The average gray whale migrates 7,500 to 10,000 km at a rate of 147 km/d (Rugh et al. 2001; Jones and Swartz 2002). Although some calves are born along the coast of California, most are born in the shallow, protected waters on the Pacific coast of Baja California from Morro de Santo Domingo (28°N) south to Isla Creciente (24°N; Urbán R. et al. 2003). The main calving sites are Laguna Guerrero Negro, Laguna Ojo de Liebre, Laguna San Ignacio, and Estero Soledad (Rice et al. 1981).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Gray whales occur in the Pacific Northwest OPAREA and Puget Sound Study Area throughout the year. They transit along the coast of Washington State, Oregon, and California during migrations between breeding and feeding grounds from January through April. During the southbound migration to breeding grounds in Mexico, gray whales pass along the coasts of Washington State

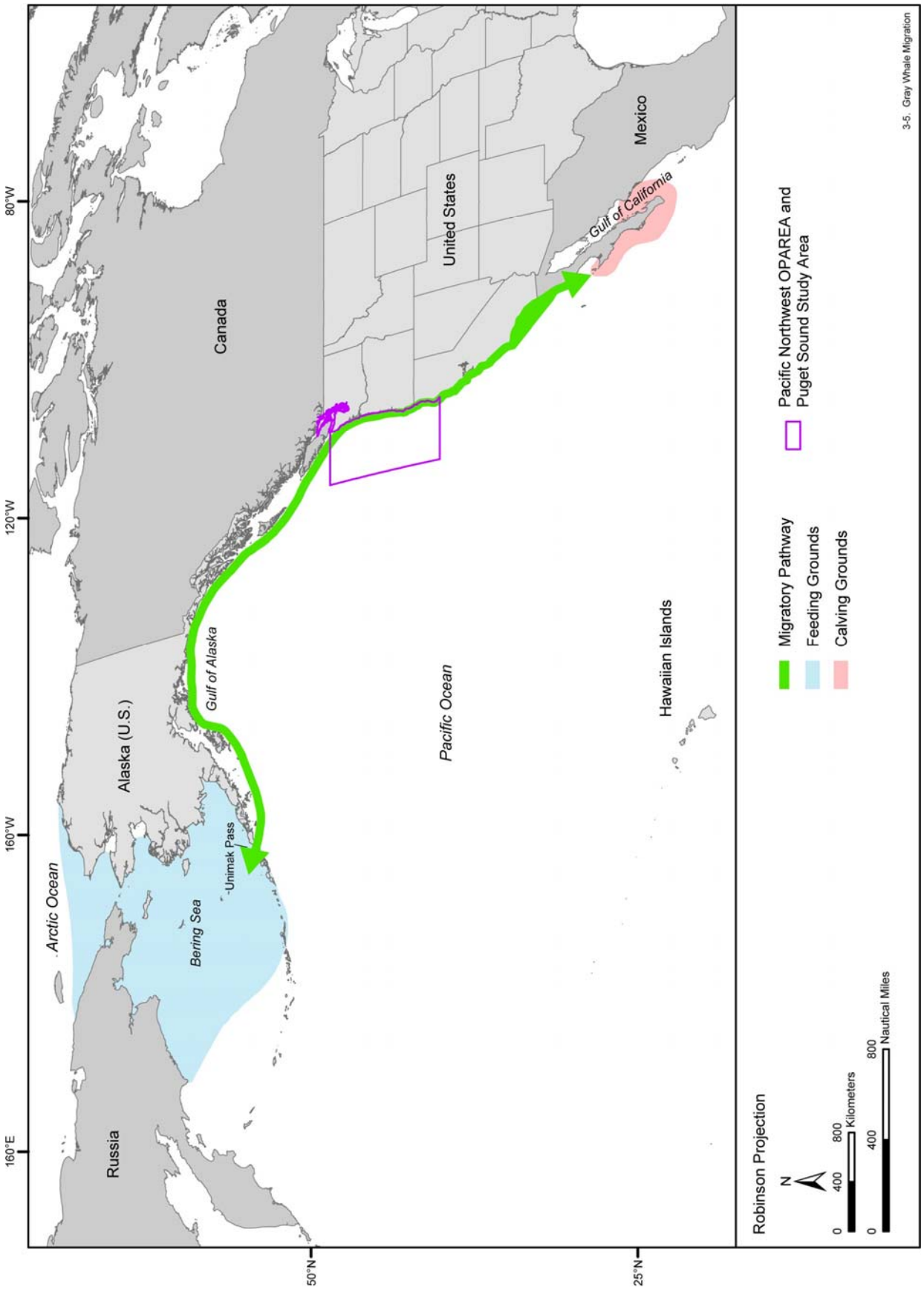

Figure 3-5. General major migratory routes of gray whales in the eastern North Pacific Ocean. Gray whales migrate along the U.S. west coast between summer feeding grounds (April to November) in the Bering and Chukchi Seas and the Pacific Northwest and winter calving grounds (December to April) in the shallow, tropical waters off Baja California. Map adapted from: Jones et al. (1984) and Findley and Vidal (2002).

and Oregon between early December and mid-February (Herzing and Mate 1984). Peak sightings in the OPAREA and Study Area during the southbound migration occur in January (Rugh et al. 2001). There are two phases of the northbound migration to feeding grounds in the Bering, Chukchi, and Beaufort seas. The first phase passes along the coasts of Washington State and Oregon from mid-February through April; the second phase, which consists of mostly cows and calves, passes through these areas from late April through May (Herzing and Mate 1984).

Some whales enter Willapa Bay, Grays Harbor, the Strait of Juan de Fuca, and Puget Sound during migration (Richardson 1997b; Calambokidis et al. 2004b). In recent years gray whales have been sighted in the southern part of Puget Sound, particularly in Elliott Bay.[3] Gray whales are known to enter the Puget Sound Study Area in spring and remain there through the early summer months; some are present in the region as early as January (Calambokidis et al. 1994). Most sightings in the Puget Sound Study Area are between March and May (Calambokidis et al. 1994; DoN 2002a). Gray whales typically feed in Puget Sound in March (Calambokidis, J., Cascadia Research Collective, pers. comm., 16 December 2005).

A group of gray whales known as the Pacific Coast Feeding Aggregation (PCFA) feeds along the Pacific coast between southeastern Alaska and southern California throughout the summer and fall (NMFS 2001; Calambokidis et al. 2002). The gray whales in this feeding aggregation are a relatively small proportion (few hundred individuals) of the overall eastern gray whale population and typically arrive and depart from these feeding grounds concurrently with the migration to and from the wintering grounds (Calambokidis et al. 2002). Although some site fidelity is known to occur, particularly in the feeding site near Whidbey Island, there is generally considerable interannual variation since many individuals do not return to the same feeding site in successive years (Calambokidis et al. 2000a). Many whales observed feeding along the coast of Washington State are known to range throughout the summer along the British Columbia coast to north of Vancouver Island (Calambokidis et al. 2002).

There is some concern that the resumption of whaling by the Makah Indian Tribe of Washington State may negatively impact the PCFA since it is often difficult to determine which whales are migratory individuals and which are part of the small PCFA (Calambokidis et al. 2002). Based on the 1855 Treaty of Neah Bay, the Makah Indian Tribe has the right to hunt gray whales at usual and accustomed grounds off the coast of Washington State (NMFS 2005d). The Makah hunted gray whales until the 1920s when the eastern population was drastically reduced. After the eastern population was delisted from the ESA in 1994, the Makah hunted one gray whale in 1999 but have since been prevented from whaling (NMFS 2005d). The Makah recently submitted a request to hunt 20 gray whales within a 5-year period. The Makah's proposal includes time and area restrictions to avoid intentional harvest of PCFA whales and management measures to ensure that any incidental harvest of PCFA whales remains at or below the annual strike limit (NMFS 2005d).

- Upwelling season—The area of primary occurrence in the OPAREA is from the shore to a generalized 200 m isobath (**Figure B-20**). The area of secondary occurrence is an additional 10 NM (18.5 km) buffer that accounts for the possibility of encountering some individuals that might migrate further offshore from the main migratory corridor. There is a rare occurrence seaward of this secondary buffer.

  Within the Puget Sound Study Area, the area of primary occurrence from the outer coast extends into the Strait of Juan de Fuca (since individuals are either migrating by the mouth of Puget Sound or even moving into it) to north of the Kitsap Peninsula (about 47°N), including around Whidbey Island to account for regular sightings of this species (**Figure B-21**). Primary occurrence also includes Boundary Bay, which is often occupied by gray whales between March and June (Ford, J., DFO, pers. comm., 9 January 2006). This is a high-use area by gray whales during March through April and also possibly into May during the northward migration. There is an area of secondary occurrence south of the Kitsap Peninsula to account for possible sightings of this species in southern Puget Sound. There is an additional area of

secondary occurrence north of the San Juan Islands that takes into consideration historic whaling catches in the Strait of Georgia.

- Relaxed season—During January through March, there are lower densities of gray whales along the outer coast since the majority of the population has already migrated through this area on its way to the breeding lagoons in Mexico. The occurrence patterns along the outer coast are expected to be similar to those in the upwelling season, also with an area of primary occurrence capturing the deep waters of the Strait of Juan de Fuca to north of the Kitsap Peninsula, including around Whidbey Island (**Figure B-20**). This pattern takes into account migrating individuals (in particular, juveniles) that wander into the Puget Sound Study Area during this time of the year. Primary occurrence also includes Boundary Bay, which is often occupied by gray whales between March and June (Ford, J., DFO, pers. comm., 9 January 2006). The rest of the Puget Sound Study Area is an area of secondary occurrence during the relaxed season (**Figure B-21**).

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). During migration, gray whales are predominantly solitary; groups of more than six are rare (Rice and Wolman 1971; Leatherwood et al. 1988). 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 eight years (Rice et al. 1984). The gestation period is around 13.5 months (Rice et al. 1984). The calving season is from January through March; weaning occurs within nine months (Rice and Wolman 1971).

Gray whales are predominantly bottom feeders. They filter amphipods and other crustaceans by sucking-up and 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 (Sund 1975; Braham 1984). Gray whales that summer in Washington State waters feed on benthic invertebrates; they are also known to feed on dense aggregations of ghost shrimp in the Puget Sound Study Area (Callianassa californiensis; Weitkamp et al. 1992; Richardson 1997b).

When foraging, gray whales typically dive to 50 to 60 m for five to eight minutes. In the breeding lagoons, 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 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 (2000) reviewed the characteristics of gray whale vocalizations. Gray whales produce broadband signals ranging from 0.1 kHz 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 0.1 kHz to 2 kHz (dominant frequency range: 0.327 to 0.825 kHz (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 (predominantly below 1.5 kHz) bonging sounds and 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 (as low as 0.8 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 in these studies include startle responses (i.e., water disturbances, tail-lobbing); 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). It was determined the threshold for inducing feeding interruptions from air gun noise was a received level of 173 dB re 1 µPa-m, and for continuous industrial noise, the threshold for inducing avoidance was a received level of approximately 120 dB re 1 µPa-m (Malme et al. 1986).

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

Description—There are two species of *Kogia*: the pygmy sperm whale and the dwarf sperm whale. Recent genetic evidence suggests that there might even be two separate species of dwarf sperm whales; however, more data are needed to make such a determination (Chivers et al. 2005b).

Pygmy sperm whales have a shark-like head with a narrow underslung lower jaw (Jefferson et al. 1993). The flippers are set high on the sides near the head. The small falcate dorsal fin of the pygmy sperm whale is usually set well behind the midpoint of the back (Jefferson et al. 1993). The dwarf sperm whale is similar in appearance to the pygmy sperm whale, but it has a larger dorsal fin, generally set nearer the middle of the back (Jefferson et al. 1993). The dwarf sperm whale also has a shark-like profile but with a more pointed snout than the pygmy sperm whale. Pygmy and dwarf sperm whales reach body lengths of around 3 and 2.5 m, respectively (Plön and Bernard 1999).

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

Status—The minimum population estimate for the California/Oregon/Washington stock of the pygmy sperm whale is 119 individuals (Carretta et al. 2006). There is no information available to estimate the population size of the dwarf sperm whale off the Pacific coast of the U.S. since there are no confirmed and documented sightings of this species there (Carretta et al. 2006).

Habitat Preferences—Both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope (McAlpine 2002). *Kogia* are found predominantly along the shelf break and upper continental slope in the Hawaiian Islands and the Gulf of Mexico (Baumgartner et al. 2001; 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). Green et al. (1992) reported a *Kogia* sighting over the Juan de Fuca Canyon.

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

break, while dwarf sperm whales tend to occur closer to shore, often over the OCS (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 ETP (Wade and Gerrodette 1993). There, the pygmy sperm whale was not seen in truly tropical waters south of the southern tip of Baja California, but the dwarf sperm whale was common in those waters. This idea is also supported by the distribution of strandings in South American waters (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 break 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, the lack of incorporation of age class effects, and possibly the local adaptation of each species to the conditions of specific areas.

Distribution—Both *Kogia* species apparently have a worldwide distribution in tropical and temperate waters (Jefferson et al. 1993) and are known to occur in eastern North Pacific waters from Washington State in the north (e.g., Scheffer and Slipp 1948; Hubbs 1951; Roest 1970; Everitt et al. 1979). Baird et al. (1996) noted that there are several unconfirmed sighting reports for pygmy sperm whales in British Columbia waters.

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—All eight confirmed stranding records of *Kogia* spp. from Oregon and Washington State are of the pygmy sperm whale (Norman et al. 2004). There is one stranding record of the dwarf sperm whale from British Columbia (Nagorsen and Stewart 1983; Willis and Baird 1998a), but this is considered to be an extralimital stray. In fact, Osborne et al. (1988) did not even include a species account for dwarf sperm whale in their guide to marine mammals of the Puget Sound Study Area. So, while it is apparent that the dwarf sperm whale does sometimes reach the Pacific Northwest area, these are probably mostly extralimital records, and it seems likely that some of the past reports of the species from this area were actually misidentifications of the pygmy sperm whale.

  - Upwelling season—Based on the known preference of *Kogia* spp. for deep waters, waters deeper than the 1,000 m isobath are of primary occurrence in the Pacific Northwest OPAREA (**Figure B-22**). The area of secondary occurrence is between the 200 m and 1,000 m isobaths. There is a rare occurrence for *Kogia* spp. in waters shallower than the 200 m isobath on the outer coast, as well as in all the waters of the Puget Sound Study Area.

  - Relaxed season—Occurrence is expected to be the same as during the upwelling season (**Figure B-22**).

Behavior and Life History—*Kogia* species have small group sizes (mean group size is usually two individuals; Willis and Baird 1998a). A recent study of *Kogia* in South Africa has determined that these two species have a much earlier attainment of sexual maturity and shorter life span than other similarly-sized toothed whales (Plön and Bernard 1999). Sexual maturity is attained at around 4 years in both sexes of both species. *Kogia* feed on cephalopods and, less often, on deep-sea fishes and shrimps (Everitt et al. 1979; Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998a). Willis and Baird (1998a) reported that whales of the genus *Kogia* make dives of up to 25 min. Median

dive times of around 11 min are documented for *Kogia* (Barlow 1999). 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 (DSL; Scott et al. 2001). Most sightings of *Kogia* are brief; these whales are often difficult to approach and they sometimes actively avoid aircraft and vessels (Würsig et al. 1998).

Acoustics and Hearing—The only sound recordings for the pygmy sperm whale are from a stranded individual that produced echolocation clicks ranging from 60 to 200 kHz, with a dominant frequency of 120 to 130 kHz (Marten 2000). Recently, a dwarf sperm whale was recorded producing clicks at 13 to 33 kHz with durations of 0.3 to 0.5 sec (Jérémie et al. 2006).

An ABR study completed on a stranded pygmy sperm whale indicated a hearing range of 90 to 150 kHz (Ridgway and Carder 2001). No information on sound production or hearing is available for the dwarf sperm whale.

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

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

Status—The minimum population estimate for the California/Oregon/Washington stock of the Cuvier's beaked whale is 1,121 individuals (Carretta et al. 2006). Little else is known about the status of Cuvier's beaked whales in this area. However, a recent study of global phylogeographic structure of Cuvier's beaked whales suggested at least that groups in different ocean basins show a high level of differentiation (Dalebout et al. 2005). However, in that study it was not possible to discern finer-scale population differences within the North Pacific (Dalebout et al. 2005).

Habitat Preferences—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; MacLeod et al. 2004; Ferguson et al. 2006; MacLeod and Mitchell 2006). Beaked whales are only occasionally reported in waters over the continental shelf (Pitman 2002). Cuvier's beaked whales generally are 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). As noted by MacLeod and D'Amico (2006), in many locales, occurrence patterns have been linked to physical features, in particular, the continental slope, canyons, and escarpments, and oceanic islands. The authors noted that more research was needed to determine how surface and deep water currents, levels of local productivity, and distribution of prey species may influence habitat usage. In the eastern tropical Pacific, beaked whales are found in waters over the continental slope to the abyssal plain, ranging from well-mixed to highly stratified (Ferguson et al. 2006). MacLeod et al. (2004) reported that Cuvier's beaked whales occur in deeper waters than Blainville's beaked whales in the Bahamas. Beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200 to 2,000 m) and only rarely stray over the continental shelf (Pitman 2002). Willis and Baird (1998b) reported an incidental catch record for a Cuvier's beaked whale, just north of the Pacific Northwest OPAREA boundary, in offshore waters with a bottom depth of approximately 3,300 m. Willis and Baird (1998b) also reported a Cuvier's beaked whale sighting in waters with a bottom depth of less than 90 m in British Columbia waters. Tynan et al. (Tynan et al. 2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank off Oregon.

Distribution—The Cuvier's beaked whale is the most widely distributed of all beaked whale species, occurring in all three major oceans and most seas (Heyning 1989). This species occupies almost all temperate, subtropical, and tropical waters, as well as subpolar and even polar waters in some areas (MacLeod et al. 2006).

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—Waters deeper than the 1,000 m isobath are the area of primary occurrence for the Cuvier's beaked whale in the Pacific Northwest OPAREA (**Figure B-23**). The area of secondary occurrence is between the 500 m and 1,000 m isobaths, while there is a rare occurrence in waters shallower than the 500 m isobath. The majority of the Puget Sound Study Area is an area of rare occurrence for this species, with the exception of the deeper waters of the Strait of Juan de Fuca where there is an area of secondary occurrence.

- Relaxed season—Occurrence of the Cuvier's beaked whale is expected to be the same as during the upwelling season (**Figure B-23**).

Behavior and Life History—Most beaked whales are difficult to approach and tend to actively avoid aircraft and vessels (Würsig et al. 1998; Barlow et al. 2006). There are limited data on the life history of Cuvier's beaked whales. Cuvier's beaked whales are found alone or in groups of up to 15 individuals (MacLeod and D'Amico 2006). Until recently, it was thought that all beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey was encountered or was locally abundant, by suction-feeding (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003). However, based on recent tagging data from Cuvier's and Blainville's beaked whales, Baird et al. (2005b) suggested that feeding might actually occur at mid-water rather than only at or near the bottom. Stomach contents of Cuvier's beaked whales primarily contain cephalopods and, rarely, fish (MacLeod et al. 2003). Tagged Cuvier's beaked whale dive durations as long as 87 min and dive depths of up to 1,990 m are recorded (Baird et al. 2004; Baird et al. 2005b; Tyack, P., Woods Hole Oceanographic Institution, pers. comm., 16 December 2005).

Acoustics and Hearing—Sounds recorded from beaked whales are divided into two categories: whistles and pulsed sounds (clicks), with whistles likely serving a communicative function, and pulsed sounds being important in foraging and/or navigation (Johnson et al. 2004; Madsen et al. 2005; MacLeod and D'Amico 2006). Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz, however, as noted by MacLeod and D'Amico (2006), higher frequencies may not be recorded due to equipment limitations. Whistles recorded from free-ranging Cuvier's beaked whales off Greece ranged in frequency from 8 to 12 kHz, with an upsweep of about 1 sec (Manghi et al. 1999). Frantzis et al. (2002) recorded pulsed sounds have a narrow peak frequency of 13 to 17 kHz, lasting 15 to 44 sec in duration. An acoustic recording tag attached to two Cuvier's beaked whales in the Ligurian Sea recorded at depth, echolocation clicks with center frequencies at around 42 kHz and source levels up to 214 dB re 1 µPa-m peak-to-peak (Zimmer et al. 2005a).

There are no hearing data available for the Cuvier's beaked whale. In fact, there is no direct information available on the exact hearing abilities of most beaked whales (MacLeod 1999), except for some recent information for the Gervais' beaked whale (*Mesoplodon europaeus*). A stranded juvenile was found to be most sensitive to high frequency signals between 40 and 80 kHz but produced smaller evoked potentials to 5 kHz (Cook et al. 2006). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no direct evidence to confirm this idea (MacLeod 1999).

- **Hubbs' Beaked Whale (*Mesoplodon carlhubbsi*)**

Description—The body and head shape of the Hubbs' beaked whale is typical of all *Mesoplodon* species. *Mesoplodon* species have a relatively small head, large thorax and abdomen, and short tail.

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

Status—Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 645 individuals (Carretta et al. 2006).

Habitat Preferences—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; MacLeod et al. 2004; Ferguson et al. 2006; MacLeod and Mitchell 2006). As noted by MacLeod and D'Amico (2006), in many locales, occurrence patterns have been linked to physical features, in particular, the continental slope, canyons, and escarpments, and oceanic islands. The authors noted that more research was needed to determine how surface and deep water currents, levels of local productivity, and distribution of prey species may influence habitat usage. Beaked whales are only occasionally reported in waters over the continental shelf (Pitman 2002). Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank. Along the Pacific coast of the North America, the distribution of the Hubbs' beaked whale corresponds with the dilute and upwelling domains on the surface and with the confluence of the subarctic current and the California Current systems at depth (Mead et al. 1982).

Distribution—The Hubbs' beaked whale appears to be restricted to the North Pacific Ocean (Mead et al. 1982; Houston 1990; MacLeod et al. 2006). Nearly all records to date have been strandings along the west coast of North America and in Japan, with one live sighting made off La Jolla, California (Hubbs 1946; Mead et al. 1982). However, there have also been several sightings in relatively nearshore waters of the Pacific Northwest, and MacLeod et al. (2006) speculated that the distribution might actually be continuous across the North Pacific between about 30° and 45°N. This, however, remains to be confirmed. The northernmost record of this species in the eastern North Pacific is a stranding that occurred at Prince Rupert (54.3°N) in northern British Columbia (Mead et al. 1982; MacLeod et al. 2006).

➢ <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

- <u>Upwelling season</u>—Based on the known preference of *Mesoplodon* spp. for deep, oceanic waters, the area of primary occurrence for the Hubb's beaked whale is in waters deeper than the 500 m isobath in the Pacific Northwest OPAREA (**Figure B-24**). The area of secondary occurrence is between the 200 m and 500 m isobaths, and there is a rare occurrence in waters shallower than the 200 m isobath. The majority of the Puget Sound Study Area is an area of rare occurrence for this species, with the exception of the deeper waters of the Strait of Juan de Fuca where there is an area of secondary occurrence.

- <u>Relaxed season</u>—Occurrence of the Hubb's beaked whale is expected to be the same as during the upwelling season (**Figure B-24**).

Behavior and Life History—Life history data on beaked whale species are extremely limited. Calving in this species most probably takes place in summer (Mead et al. 1982; Willis and Baird 1998b). Group sizes are generally small, ranging from one to 15 individuals, as in other species in the genus *Mesoplodon* (MacLeod and D'Amico 2006).

Until recently, it was thought that all beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey was encountered or was locally abundant, by suction-feeding (Heyning 1989; Heyning and Mead 1996; MacLeod et al. 2003). However, based on recent tagging data from Cuvier's and Blainville's beaked whales, Baird et al. (2005b) suggested that feeding might actually occur at mid-water rather than only at or near the bottom. Stomach contents of a stranded Hubbs' beaked whale consisted of squid beaks, fish otoliths, and fish bones (Mead et al. 1982). Durations of long dives for *Mesoplodon* species are over 20 min (Barlow 1999; Baird et al. 2005b; Tyack, P., Woods Hole Oceanographic Institution, pers. comm., 16 December 2005).

Acoustics and Hearing—Sounds recorded from beaked whales are divided into two categories: whistles and pulsed sounds (clicks), with whistles likely serving a communicative function, and pulsed sounds being important in foraging and/or navigation (Johnson et al. 2004; Madsen et al. 2005; MacLeod and D'Amico 2006). Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz, however, as noted by MacLeod and D'Amico (2006), higher frequencies may not be recorded due to equipment limitations. Vocalizations recorded from two juvenile Hubbs' beaked whales consisted of low and high frequency click trains ranging in frequency from 300 Hz to 80 kHz and whistles with a frequency range of 2.6 to 10.7 kHz and duration of 156 to 450 msec (Lynn and Reiss 1992; Marten 2000).

There are no hearing data available for the Hubbs' beaked whale. In fact, there is no direct information available on the exact hearing abilities of most beaked whales (MacLeod 1999), except for some recent information for the Gervais' beaked whale (*Mesoplodon europaeus*). A stranded juvenile was found to be most sensitive to high frequency signals between 40 and 80 kHz but produced smaller evoked potentials to 5 kHz (Cook et al. 2006). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no empirical evidence to support this idea (MacLeod 1999).

- **Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)**

Description—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).

Status—Until reliable methods are developed for distinguishing the different *Mesoplodon* species from one another, the management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 645 individuals (Carretta et al. 2006).

Habitat Preferences—The Stejneger's beaked whale appears to prefer cold-temperate and sub-polar waters (Loughlin and Perez 1985; MacLeod et al. 2006). 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). Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank.

World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; MacLeod et al. 2004; Ferguson et al. 2006; MacLeod and Mitchell 2006). As noted by MacLeod and D'Amico (2006), in many locales, occurrence patterns have been linked to physical features, in particular, the continental slope, canyons, and escarpments, and oceanic islands. The authors noted that more research was needed to determine how surface and deep water currents, levels of local productivity, and distribution of prey species may

influence habitat usage. Beaked whales are only occasionally reported in waters over the continental shelf (Pitman 2002).

Distribution—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, Japan (Loughlin and Perez 1985; MacLeod et al. 2006).

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—Based on the known preference of *Mesoplodon* spp. for deep, oceanic waters, the area of primary occurrence for the Stejneger's beaked whale is in waters deeper than the 500 m isobath in the Pacific Northwest OPAREA (**Figure B-24**). The area of secondary occurrence is between the 200 m and 500 m isobaths, and there is a rare occurrence for the Stejneger's beaked whale in waters shallower than the 200 m isobath. The majority of the Puget Sound Study Area is an area of rare occurrence for this species, with the exception of the deeper waters of the Strait of Juan de Fuca where there is an area of secondary occurrence.

- Relaxed season—Occurrence of the Stejneger's beaked whale is expected to be the same as during the upwelling season (**Figure B-24**).

Behavior and Life History—Stejneger's beaked whales have been observed in groups of 5 to 15 individuals, often containing individuals of mixed sizes (Jefferson et al. 1993). 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. Stejneger's beaked whale stomach contents include squids and pelagic fish (Nishiwaki and Kamiya 1958; Walker and Hanson 1999; Yamada and Yamada 1999). Until recently, it was thought that all beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey was encountered or was locally abundant, by suction-feeding (Heyning 1989; Heyning and Mead 1996; MacLeod et al. 2003). However, based on recent tagging data from Cuvier's and Blainville's beaked whales, Baird et al. (2005b) suggested that feeding might actually occur at mid-water rather than only at or near the bottom. Dive durations for *Mesoplodon* species are typically over 20 min (Barlow 1999; Baird et al. 2005b; Tyack, P., Woods Hole Oceanographic Institution, pers. comm., 16 December 2005).

Acoustics and Hearing—There is no information available for Stejneger's beaked whale vocalizations. Sounds recorded from beaked whales are divided into two categories: whistles and pulsed sounds (clicks), with whistles likely serving a communicative function, and pulsed sounds being important in foraging and/or navigation (Johnson et al. 2004; Madsen et al. 2005; MacLeod and D'Amico 2006). Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz, however, as noted by MacLeod and D'Amico (2006), higher frequencies may not be recorded due to equipment limitations.

There is no empirical information available on the hearing abilities of Stejneger's beaked whales (MacLeod 1999). In fact, there is no direct information available on the exact hearing abilities of most beaked whales (MacLeod 1999), except for some recent information for the Gervais' beaked whale (*Mesoplodon europaeus*). A stranded juvenile was found to be most sensitive to high frequency signals between 40 and 80 kHz but produced smaller evoked potentials to 5 kHz (Cook et al. 2006). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no direct evidence to confirm this idea (MacLeod 1999).

- **Baird's Beaked Whale (*Berardius bairdii*)**

Description—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 III 1989). Body weight for an average whale 10 m in length is 8,000 to 10,000 kg (Balcomb III 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 III 1989). Two pairs of teeth are located near the tip of the lower jaw. The forward pair (these teeth are large and triangular) in adults is visible at the tip of the lower jaw, even when the mouth is closed, and the second pair is smaller and peg-like in shape (Balcomb III 1989).

Status—The minimum population estimate for the California/Oregon/Washington stock of the Baird's beaked whale is 152 individuals (Carretta et al. 2006). This species is rarely sighted during surveys along the west coast of the U.S. (Carretta et al. 2006).

Habitat Preferences—Baird's beaked whales appear to occur mainly in deep waters over the continental slope, oceanic seamounts and areas with submarine escarpments (Reeves and Mitchell 1993; Willis and Baird 1998b; Kasuya 2002; Tynan et al. 2005). 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). Off Washington State and British Columbia, Baird's beaked whales have been sighted in offshore waters with a bottom depth of 700 to 1,675 m (Wahl 1977; Willis and Baird 1998b). Whaling catches of this species off British Columbia were centered between approximately 182 m and 1,828 m (Reeves and Mitchell 1993). Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank.

Distribution—Baird's beaked whale is found only in the North Pacific and the adjacent seas (Bering Sea, Okhotsk Sea, Sea of Japan, and the Gulf of California), mainly north of 34°N in the west and 28°N in the east (Reeves et al. 2003). The southernmost record is a mass stranding in the southern Gulf of California (Balcomb III 1989). The best-known populations occur in the coastal waters around Japan since whaling takes place here. Commercial whaling took place in British Columbia waters from 1905 to 1967, with occasional catches of Baird's beaked whales (Pike and MacAskie 1969; Nichol et al. 2002). Small catches were also made at central California whaling stations between 1956 and 1971 (e.g., Rice 1963). Along the U.S. west coast, Baird's beaked whales are seen primarily along the continental slope from late spring to early fall (Green et al. 1992; Carretta et al. 2006). British Columbia whalers commented that Baird's beaked whales were most often sighted during May through September, with most catches occurring during August (Pike and MacAskie 1969; Reeves and Mitchell 1993). Baird's beaked whales are seen less frequently and are presumed to be further offshore during the colder water months of November through April (Carretta et al. 2006).

➢ <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

- <u>Upwelling season</u>—The Baird's beaked is considered to be a slope-associated species. The area of primary occurrence for the Baird's beaked whale in the Pacific Northwest OPAREA is in waters deeper than the 500 m isobath (**Figure B-25**). The area of secondary occurrence is between the 200 m to 500 m isobaths. There is a rare occurrence in waters shallower than 200 m. The majority of the Puget Sound Study Area is an area of rare occurrence for this species, with the exception of the deeper waters of the Strait of Juan de Fuca where there is an area of secondary occurrence.

- <u>Relaxed season</u>—Occurrence of Baird's beaked whale is expected to be the same as during the upwelling season (**Figure B-25**).

Behavior and Life History—Baird's beaked whales occur in relatively large groups of 6 to 30 individuals, although groups of up to 50 or more are occasionally observed (Balcomb III 1989). Baird's beaked whales occur in multi-male groups; the large groups observed in this species can consist of adults of both sexes (MacLeod and D'Amico 2006). Sightings off British Columbia have been of groups of 3 to 21 individuals (Pike and MacAskie 1969; Willis and Baird 1998b). 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 III 1989).

Sexual maturity occurs at about 8 to 10 years, with physical maturity at over 20 years (Balcomb III 1989). Mating generally occurs in October and November, and with a gestation period of about 17 months, there is a calving peak in March and April (Balcomb III 1989).

Until recently, it was thought that all beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey was encountered or was locally abundant, by suction-feeding (Heyning 1989; Heyning and Mead 1996; MacLeod et al. 2003). However, based on recent tagging data from Cuvier's and Blainville's beaked whales, Baird et al. (2005b) suggested that feeding might actually occur at mid-water rather than only at or near the bottom. Baird's beaked whales feed mainly on benthic fishes and cephalopods but occasionally on pelagic fish such as mackerel, sardine, and saury (Kasuya 2002; Walker et al. 2002; Ohizumi et al. 2003). Stomach contents from specimens taken in whaling operations off Vancouver Island and off central California included squid, octopus, various species of fishes, and skate egg cases (Pike 1953; Rice 1963; Pike and MacAskie 1969).

Prolonged dives by Baird's beaked whales for periods of up to 67 min have been reported (Kasuya 2002), although dives of 25 to 35 m for about 45 min are more typical (Kasuya 1986; Balcomb III 1989; Von Saunder and Barlow 1999). 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. 2003).

Acoustics and Hearing—Sounds recorded from beaked whales are divided into two categories: whistles and pulsed sounds (clicks), with whistles likely serving a communicative function, and pulsed sounds being important in foraging and/or navigation (Johnson et al. 2004; Madsen et al. 2005; MacLeod and D'Amico 2006). Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz, however, as noted by MacLeod and D'Amico (2006), higher frequencies may not be recorded due to equipment limitations. 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 at 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 direct information available on the exact hearing abilities of beaked whales (MacLeod 1999). In fact, there is no direct information available on the exact hearing abilities of most beaked whales (MacLeod 1999), except for some recent information for the Gervais' beaked whale (*Mesoplodon europaeus*). A stranded juvenile was found to be most sensitive to high frequency signals between 40 and 80 kHz but produced smaller evoked potentials to 5 kHz (Cook et al. 2006). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no direct evidence to support this idea (MacLeod 1999).

- **Rough-toothed Dolphin (*Steno bredanensis*)**

Description—This is a relatively robust dolphin with a cone-shaped head, and the only one with no demarcation between the melon and beak (Jefferson et al. 1993). The "forehead" 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 are white and many individuals have white scars. The rough-toothed dolphin reaches 2.8 m in length (Jefferson et al. 1993).

Status—There are no abundance estimates available for this species in the NOAA stock assessment report for this area of the Pacific.

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), the Bahamas (Banick and Borger 2005), and in coastal waters off Brazil, including even in a lagoon system (Flores and Ximenez 1997; Lodi and Hetzel 1999). At the Society Islands, rough-toothed dolphins were sighted in waters with a bottom depth less than 100 m to over 3,000 m, although apparently favoring the 500 to 1,500 m range (Gannier 2000).

Distribution—Rough-toothed dolphins are found in tropical to warm-temperate waters globally, rarely ranging north of 40°N or south of 35°S (Miyazaki and Perrin 1994). Rough-toothed dolphins occur in low densities throughout the ETP where surface water temperatures are generally above 25°C (Perrin and Walker 1975). Sighting and stranding records in the eastern North Pacific Ocean are rare (e.g., Ferrero et al. 1994).

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—There is a rare occurrence of rough-toothed dolphins throughout the Pacific Northwest OPAREA and the Puget Sound Study Area (**Figure B-26**). This species is not expected to occur in the OPAREA or the Puget Sound Study Area. There are a few rough-toothed dolphin strandings recorded in Oregon and Washington State (Ferrero et al. 1994); however, since this species prefers warm-temperate and tropical waters, these records are considered to be extralimital.

- Relaxed season—Occurrence patterns are the same as the upwelling season (**Figure B-26**).

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). Rough-toothed dolphins tend to associate with floating objects in the ETP and Gulf of Mexico (Pitman and Stinchcomb 2002; Fulling et al. 2003). Cephalopods and fish, including large fish, such as dorado, are prey (Miyazaki and Perrin 1994; Reeves et al. 1999; Pitman and Stinchcomb 2002). Reef fish are also preyed upon; Perkins and Miller (1983) noted that parts of reef fish had been found in the stomachs of stranded rough-toothed dolphins in Hawai'i. Gannier and West (2005) observed rough-toothed dolphins feeding during the daytime on epipelagic fishes, including flying fishes. Female rough-toothed dolphins reach sexual maturity between 4 and 6 years of age; males attain sexual maturity between 5 and 10 years (Mead et al. 2001). Rough-toothed dolphins may stay submerged for up to 15 min and are known to dive as deep as 70 m but can probably dive much deeper (Miyazaki and Perrin 1994).

Acoustics and Hearing—The rough-toothed dolphin produces a variety of sounds, including broadband echolocation clicks and whistles. Echolocation clicks (duration <250 microseconds [µsec]) typically have a frequency range of 0.1 to 200 kHz, with a dominant frequency of 25 kHz (Miyazaki

and Perrin 1994; Yu et al. 2003; Chou, L-S., National Taiwan University, pers. comm., 11 January 2005). Whistles (duration <1 sec) have a wide frequency range of 0.3 to greater than 24 kHz but dominate in the 2 to 14 kHz range (Miyazaki and Perrin 1994; Yu et al. 2003).

There has been no data collected on rough-toothed dolphin hearing ability. However, odontocetes are generally adapted to hear high-frequencies (Ketten 1997).

- **Bottlenose Dolphin (*Tursiops truncatus*)**

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

The taxonomy of *Tursiops* continues to be in flux; two species are currently recognized, the bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*; Rice 1998; IWC 2005), with additional species likely to be recognized with future morphometric and genetic analyses (Natoli et al. 2004). The bottlenose dolphin occurs as two morphotypes (or forms): a nearshore (coastal) and an offshore form (Hersh and Duffield 1990; Hoelzel et al. 1998a). There is a clear distinction between the nearshore and offshore form of the bottlenose dolphin in the western North Atlantic and western North Pacific, suggesting that the two forms may be eventually considered two different species (Curry and Smith 1997; Hoelzel et al. 1998a; Kingston and Rosel 2004).

Status—Bottlenose dolphins within the U.S. EEZ are divided into the following three stocks: the California coastal stock, California/Oregon/Washington State offshore stock, and the Hawaiian stock (Carretta et al. 2006). Bottlenose dolphins found in the Pacific Northwest OPAREA and Puget Sound Study Area could be from the California coastal stock or the California/Oregon/Washington State offshore stock. There is a minimum population estimate of 186 individuals for the California coastal stock and 3,053 individuals for the California/Oregon/Washington State offshore stock (Carretta et al. 2006).

Habitat Preferences—The 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 (Miyashita 1993; Reeves et al. 2002).

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

Distribution—The overall range of *Tursiops* is worldwide in tropical to temperate waters. *Tursiops* generally do not range poleward of 45°, except around the United Kingdom and northern Europe (Jefferson et al. 1993). The bottlenose dolphin has been recorded in tropical to temperate regions throughout the world.

In the eastern North Pacific Ocean, the distribution of coastal bottlenose dolphins off California/Mexico extends from at least Ensenada, Baja California, Mexico to Monterey Bay, California with occasional sightings as far north as San Francisco and a stranding as far north as Washington State in March 1988 (Orr 1963; Ferrero and Tsunoda 1989; Bonnell and Dailey 1993; Maldini-Feinholz 1996). Individuals have been documented in offshore waters as far north as about 41°N; they may range into Oregon and Washington State waters during warm-water periods (Carretta et al. 2006).

Climate changes have contributed to range extensions. For example, a 600 km northward range extension to Monterey Bay (for some bottlenose dolphins known from the San Diego, California, area) was linked to the 1982/1983 El Niño event (Wells et al. 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 Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—There is an area of rare occurrence for the bottlenose dolphin throughout the Pacific Northwest OPAREA and Puget Sound Study Area (**Figure B-27**). Bottlenose dolphins have been documented in offshore waters as far north as 41°N and may move into waters off Oregon and Washington State during warm-water periods (Norman et al. 2004; Carretta et al. 2006). The northernmost record in the eastern North Pacific is a stranding that occurred in March 1988, near Colony Creek, 100 km north of Seattle (Osborne and Ransom 1988; Ferrero and Tsunoda 1989). Bottlenose dolphins are not expected to occur in the OPAREA or Study Area; any sightings of this species would be considered extralimital.

- Relaxed season—Bottlenose dolphin occurrence during the relaxed season is assumed to be similar to that of the upwelling season (**Figure B-27**).

Behavior and Life History—*Tursiops* are very gregarious; they are typically found in groups of 2 to 15 individuals although groups of up to 100 or more have been reported in some areas (Shane et al. 1986). Based on photo-identification techniques using dorsal fin shapes and markings (Würsig and Würsig 1977; Würsig and Jefferson 1990), it is well known that *Tursiops* has a fluid social organization (Connor et al. 2000). Habitat structure, in terms of complexity and water depth, is generally a major force that shapes *Tursiops* groupings (Shane et al. 1986). Shallow-water areas typically have smaller group sizes than open water 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).

Along the Atlantic coast of the U.S., where the majority of detailed work on bottlenose dolphins has been conducted, male and female bottlenose dolphins reach physical maturity at 13 years, with females reaching sexual maturity as early as 7 years (Mead and Potter 1990). Bottlenose dolphins are flexible in their timing of reproduction. Seasons of birth for bottlenose dolphin populations are likely responses to seasonal patterns of availability of local resources (Urian et al. 1996). Newborn calves are seen year-round off southern California; data are not available to determine calving peaks (Weller, D., NMFS-SWFSC, pers. comm., 15 April 2005). There is a gestation period of one year (Caldwell and Caldwell 1972). Calves of bottlenose dolphins typically remain with their mothers for 3 to 6 years (Wells et al. 1987).

Tursiops are opportunistic feeders, taking a wide variety of fishes, cephalopods, and shrimp (Wells and Scott 1999) and using a wide variety of feeding strategies (Shane 1990). In addition to use of active echolocation to find food, bottlenose dolphins likely detect and orient to fish prey by listening for the sounds they produce – so-called passive listening (Barros and Myrberg 1987; Gannon et al. 2005). Nearshore bottlenose dolphins prey predominately on coastal fish and cephalopods, while offshore individuals prey on pelagic cephalopods and a large variety of epi- and mesopelagic fish species (Walker 1981; Van Waerebeek et al. 1990; Mead and Potter 1995). Pacific coast bottlenose dolphins feed primarily on surf perches (Family Embiotocidae) and croakers (Family Sciaendae; Norris and Prescott 1961; Walker 1981; Schwartz et al. 1992; Hanson and Defran 1993) and also consume squid (Loligo opalescens; Schwartz et al. 1992). Navy bottlenose dolphins have been trained to reach maximum diving depths of about 300 m (Ridgway et al. 1969a). Reeves et al. (2002) noted that the presence of deep-sea fish in the stomachs of some offshore individual bottlenose

dolphins suggests that they dive to depths of more than 500 m. Dive durations up to 15 min have been recorded for trained individuals (Ridgway et al. 1969a). Typical dives, however, are more shallow and of a much shorter duration.

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

Inner ear anatomy of this species has been described (Ketten 1992). The bottlenose dolphin can typically hear within a broad frequency range of 0.04 kHz to 160 kHz (Au 1993; Turl 1993). 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). Scientists have reported a range of highest sensitivity between 25 and 70 kHz, with peaks in sensitivity occurring at 25 and 50 kHz at threshold levels of 47 and 46 dB re 1 µPa-m, respectively (Nachtigall et al. 2000).

- **Striped Dolphin (*Stenella coeruleoalba*)**

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

Status—There is a minimum population estimate of 9,165 individuals for the California/Oregon/ Washington State stock of the striped dolphin (Carretta et al. 2006).

Habitat Preferences—Striped dolphins are usually found beyond the continental shelf, typically over the continental slope out to oceanic waters, and are often associated with convergence zones and waters influenced by upwelling (Au and Perryman 1985). In the eastern Pacific, striped dolphins inhabit areas with large seasonal changes in surface temperature and thermocline depth, as well as seasonal upwelling (Au and Perryman 1985; Reilly 1990). This species appears to avoid waters with sea temperatures of less than 20°C (Van Waerebeek et al. 1998).

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

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Striped dolphins are expected to be rare throughout the Pacific Northwest OPAREA and Puget Sound Study Area. This species prefers cool-temperate and tropical oceanic waters. Striped dolphins typically do not occur north of California; however, there are a few sighting records off Oregon and Washington State (Wahl 1977; Von Saunder and Barlow 1999; Barlow 2003). Stranding records of this species are documented along the coasts of Oregon, Washington State, and British Columbia (Kellogg and Scheffer 1947; Kenyon and Scheffer 1949; Cowan and Guiguet 1952; Scheffer 1960). Records of this species north of California may be related to stretches of warm water moving northward (Baird et al. 1993; Norman et al. 2004).

  - Upwelling season—The area of primary occurrence for the striped dolphin in the Pacific Northwest OPAREA is in coast waters warmer than 15.5°C and deeper than the 100 m isobath (**Figure B-28**). There is a secondary occurrence between the 15°C and 15.5°C

isotherms. The area of rare occurrence is in waters cooler than 15°C on the outer coast and throughout the Puget Sound Study Area.

- Relaxed season—The area of primary occurrence is based on information from the upwelling season. The area of secondary occurrence buffers the area of primary occurrence (**Figure B-28**). There is an area of rare occurrence inshore of the band of secondary occurrence, as well as in the Puget Sound Study Area.

Behavior and Life History—Striped dolphins are typically 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; Von Saunder and Barlow 1999).

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

Striped dolphins often feed in pelagic or benthopelagic zones along the continental slope or just beyond in oceanic waters. A majority of their 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 II and Perrin 1999). Striped dolphins may feed at night in order to take advantage of the deep-scattering layer's diurnal vertical movements. Small, mid-water fishes (in particular, myctophids or lanternfish) and squids are the dominant prey (Perrin et al. 1994).

Acoustics and Hearing—Striped dolphin whistles range from 6 to greater than 24 kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Thomson and Richardson 1995).

A single striped dolphin's hearing range, determined by using standard psycho-acoustic techniques, was from 0.5 to 160 kHz with best sensitivity at 64 kHz (Kastelein et al. 2003).

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

Description—Short-beaked common dolphins are moderately-robust dolphins, with a moderate-length beak, and a tall slightly falcate dorsal fin. The beak is shorter than in long-beaked common dolphins, *Delphinius capensis*, and the melon rises from the beak at a steeper angle (Heyning and Perrin 1994). Short-beaked common dolphins are distinctively marked, with a V-shaped saddle caused by a dip in the cape below the dorsal fin, yielding an hourglass pattern on the side of the body (Jefferson et al. 1993). The back is dark brownish-gray, the belly is white, and the anterior flank patch is tan to cream in color. The lips are dark, and there is a dark stripe from the eye to the apex of the melon and another one from the chin to the flipper (the latter is diagnostic to the genus). There are often variable light patches on the flippers and dorsal fin. Length ranges up to about 2.3 m (Heyning and Perrin 1994).

Status—The single current management unit recognized by NMFS in this area is the California/Oregon/Washington State stock, which has a minimum population estimate of 365,617 individuals (Carretta et al. 2006). Genetic analyses for this species in the eastern North Pacific Ocean are revealing that there are multiple populations with boundaries corresponding to region's primary oceanographic water masses (Chivers et al. 2005a).

Habitat Preferences—Common dolphins occupy a wide range of habitats, including waters over the continental shelf, along the continental shelf break, and over prominent underwater topography (e.g., seamounts; Hui 1979; Evans 1994; Bearzi 2003). Common dolphins in some populations appear to preferentially travel along bottom topographic features, such as escarpments and seamounts (Evans 1994). Short-beaked common dolphins are routinely sighted in the ETP where they are generally

found in upwelling-modified waters (Au and Perryman 1985; Reilly 1990; Ballance and Pitman 1998). This species prefers areas with large seasonal changes in surface temperature and thermocline depth (Au and Perryman 1985). Abundance of the short-beaked common dolphin off California varies with seasonal and interannual changes in oceanographic conditions; movements may be north-south and/or inshore-offshore (Barlow 1995; Forney and Barlow 1998; Carretta et al. 2006).

Distribution—The short-beaked common dolphin occurs from southern Norway to West Africa in the eastern Atlantic (including the Mediterranean and Black seas); from Newfoundland to Florida in the western Atlantic; from southern Canada to Chile across the eastern Pacific; in the central North Pacific (but not in Hawai'i); and from central Japan to Taiwan and around New Caledonia, New Zealand, and southern Australia in the western Pacific. This species is possibly absent from much of the South Atlantic and Indian oceans (Perrin 2002).

This species' distribution overlaps with that of the long-beaked common dolphin in southern California. The short-beaked common dolphin is distributed from the coast to at least 556 km from shore (Carretta et al. 2006). Short-beaked common dolphin abundance off California has increased dramatically since the late 1970s, along with a concomitant decrease in abundance in the ETP, suggesting a large-scale shift in the distribution of this species in the eastern North Pacific (Forney et al. 1995; Forney and Barlow 1998). The northward extent of short-beaked common dolphin distribution appears to vary interannually and with changing oceanographic conditions (Forney and Barlow 1998).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

  - Upwelling season—The primary occurrence of the short-beaked common dolphin along the outer coast is in waters deeper than the 200 m isobath, south of 42°N during this time of year (**Figure B-29**). The area of secondary occurrence is between the 100 m and 200 m isobaths south of 42°N and seaward of the 100 m isobath north of 42°N. There is a rare occurrence for this species in waters shallower than the 100 m isobath and in the Puget Sound Study Area where this species is not expected to occur.

  - Relaxed season—The primary occurrence of the short-beaked common dolphin in the Pacific Northwest OPAREA is south of the 13°C isotherm (**Figure B-29**). The area of secondary occurrence is between the 12°C and 13°C isotherms. There is a rare occurrence for this species in waters cooler than 12°C. There is a rare occurrence within the Puget Sound Study Area where the common dolphin is not expected to occur.

Behavior and Life History—Group size ranges from several dozen to over 10,000 (Jefferson et al. 1993). In southern California waters, an average group size of less than 200 short-beaked common dolphins is reported (Hill and Barlow 1992; Bearzi 2003). Common dolphins are fast-moving swimmers, active bowriders, and they often jump in the air. The peak calving season is spring and early summer (Forney 1994).

Stomach contents of *Delphinus* from southern California waters revealed 19 species of fish and two species of cephalopods; *Delphinus* feeds primarily on organisms in the vertically migrating DSL (Evans 1994). Diel fluctuations in vocal activity of this species (more vocal activity during late evening and early morning) appear to be linked to feeding on the DSL as it rises during the same time (Goold 2000). A tagged individual tracked off San Diego, California conducted dives deeper than 200 m, but most dives were between 9 and 50 m (Evans 1971, 1994).

Acoustics and Hearing—Recorded *Delphinus* vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998). Maximum source levels were approximately 180 dB 1 µPa-m (Fish and Turl 1976). Oswald et al. (2003) found that short-beaked common dolphins in the ETP have whistles with a mean frequency range of 6.3 kHz, mean maximum frequency of 13.6 kHz, and mean duration of 0.8 sec.

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. This species' hearing range extended from 10 to 150 kHz and was most sensitive from 60 to 70 kHz.

- **Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)**

Description—The Pacific white-sided dolphin is dark gray or black on the back and sides, as well as on the short beak, the leading edge of the tall strongly recurved dorsal fin, and the pointed flippers. Gray, linear dorsal flank blazes, often called "suspender stripes," project forward from the grayish flank patches along the back and disappear above the eyes (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). Two forms are recognized for the eastern North Pacific. The southern form is the larger and is thought to range from southern California to Baja California, while the northern form ranges from southern California to Alaska (Carretta et al. 2006). Both forms are known to occur off southern California (Lux et al. 1997; Carretta et al. 2006). These two forms are not readily distinguishable or recognizable in the field (Jefferson, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005).

Status—There is a minimum combined population estimate (Northern and Southern stocks) of 39,822 individuals for the California/Oregon/Washington State of the Pacific white-sided dolphin (Carretta et al. 2006).

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).

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 southern Alaska (Leatherwood et al. 1984). Surveys suggest a seasonal north-south movement of Pacific white-sided dolphins in the eastern North Pacific, with animals found primarily off California during the colder water months and shifting northward into Oregon and Washington State as water temperatures increase during late spring and summer (Green et al. 1992; Forney 1994; Carretta et al. 2006). Peak abundance off Oregon and Washington State is typically in May (Green et al. 1993).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Pacific white-sided dolphins regularly occur throughout the OPAREA and Study Area year-round. They are widely distributed along the shelf break, continental slope, and in offshore waters (Leatherwood et al. 1984; Calambokidis et al. 2004b). Due to the seasonal north-south movement patterns, Pacific white-sided dolphins are more abundant off Oregon and Washington State in spring and summer and off California in fall and winter (Leatherwood et al. 1984; Green et al. 1992; Forney 1994). Seasonal changes in density suggest east-west movements between the slope and offshore waters off Oregon and Washington State (Green et al. 1992). Pacific white-sided dolphins also occur in inshore waters such as the Strait of Juan de Fuca and the Strait of Georgia (Stacey and Baird 1991b; Norman et al. 2004).

  - Upwelling season—The area of primary occurrence for the Pacific white-sided dolphin in the Pacific Northwest OPAREA is between the 100 m isobath and a line based on the distribution of sightings and also takes into consideration the high number of catches in the offshore driftnet fishery (**Figure B-30**). The area of secondary occurrence is a region extending seaward of the area of primary occurrence. The area of rare occurrence is inshore of the 100 m isobath. Within the Puget Sound Study Area, there is an area of secondary occurrence in the Strait of Juan de Fuca and the Strait of Georgia based on sighting records (**Figure B-31**). There is another rare occurrence in southern Puget Sound since there are no known sightings here (Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005).

- Relaxed season—The area of primary occurrence is between the 100 m and 2,000 m isobaths (**Figure B-30**). The area of secondary occurrence is a 50 NM (93 km) buffer seaward the area of primary occurrence. There is a rare occurrence in waters deeper than the area of secondary occurrence, as well as in waters shallower than the 100 m isobath. Within the Puget Sound Study Area, there is an area of secondary occurrence in the Strait of Juan de Fuca and the Strait of Georgia based on sighting records (**Figure B-31**). There is a rare occurrence in southern Puget Sound waters.

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 are frequently found in mixed-species aggregations, often with Risso's dolphins and northern right whale dolphins (Brownell et al. 1999). Calving peaks occur during June through August (Heise 1997b). Pacific white-sided dolphins in the eastern North Pacific feed primarily on epipelagic fishes and cephalopods (e.g., Schwartz et al. 1992; Black 1994; Heise 1997a; Brownell et al. 1999; Morton 2000). Pacific white-sided dolphins are known to feed on salmonids off Washington State (Stroud et al. 1981). This does not appear to be a deep-diving species. Based on feeding habits, Fitch and Brownell (1968) inferred that Pacific white-sided dolphins dive to at least 120 m. The majority of foraging dives last less than 15 to 25 sec (Black 1994; Heise 1997a).

Acoustics and Hearing—Vocalizations produced by Pacific white-sided dolphins include whistles and echolocation clicks. Whistles are in the frequency range of 2 to 20 Hz (Thomson and Richardson 1995). Echolocation clicks range in frequency from 50 to 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 0.075 kHz through 150 kHz. The greatest sensitivities were from 2 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 (*Lissodelphis australis*), is the only member 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 a bit larger than females (Leatherwood and Walker 1979). Weights of up to 116 kg have been recorded (Jefferson et al. 1994).

Status—Dizon et al. (1994) examined a small sample of specimens to determine whether there were different populations along the west coast of North America and in the pelagic waters of the central North Pacific. Although they found no evidence of population structuring, the statistical power of their analyses to detect differences was not high, and separate stocks are assumed to exist (Carretta et al. 2006). There is a minimum population estimate of 16,417 individuals and a best estimate of 20,362 for the California/Oregon/Washington State stock of the northern right-whale dolphin (Carretta et al. 2006).

Habitat Preferences—This species occurs in oceanic waters and along the outer continental shelf and slope, normally in waters colder than 20°C (Leatherwood and Walker 1979). Northern right whale dolphins generally move nearshore only in areas where the continental shelf is narrow or where productivity on the shelf is especially high (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 such as Tanner and Cortes banks in southern California.

Distribution—The northern right whale dolphin occurs in cool temperate to 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). Surveys suggest that, at least in the eastern North Pacific, they make seasonal inshore-offshore and north-south movements that are presumably related to prey availability. Occurrence patterns in the eastern Pacific generally coincide with peaks in abundance of market squid, *Loligo opalacens*, a major prey item (Leatherwood and Walker 1979). Northern right whale dolphins are found primarily off California during the colder water months, with distribution shifting northward into Oregon and Washington State as water temperatures increase during late spring and summer (Leatherwood and Walker 1979; Forney 1994; Barlow 1995; Forney et al. 1995; Forney and Barlow 1998).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Northern right whale dolphins occur in the OPAREA and Study Area year-round but abundance and distribution vary seasonally. Northern right whale dolphins are primarily found off Oregon and Washington State throughout the year except during winter; peak abundance occurs along the continental slope in fall (Green et al. 1992). This species is most abundant off central and northern California in nearshore waters in winter (Dohl et al. 1983).

  - Upwelling season—The area of primary occurrence for the northern right whale dolphin in the Pacific Northwest OPAREA is in waters cooler than the 15°C isotherm and deeper than the 100 m isobath (**Figure B-32**). The area of secondary occurrence is between the 15°C and 16°C isotherms. There is a rare occurrence in waters warmer than 16°C and shallower than 100 m, as well as within the Puget Sound Study Area (**Figure B-33**).

  - Relaxed season—The area of primary occurrence is in waters deeper than the 100 m isobath along the outer coast (**Figure B-32**). There is a rare occurrence in waters shallower than the 100 m isobath on the outer coast, as well as throughout the Puget Sound Study Area (**Figure B-33**).

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 although 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). There is no information on diving depths for northern right whale dolphins.

Acoustics and Hearing—Clicks with high repetition rates and frequencies extending beyond 40 kHz (frequency limit of sonobuoy) have been recorded from northern right whale dolphins at sea (Fish and Turl 1976; Leatherwood and Walker 1979). Maximum source levels were approximately 170 dB 1 µPa-m (Fish and Turl 1976).

Detailed physical structures of their sounds have not been reported in the published literature. There are no published empirical 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). The head is blunt and squarish, without a distinct beak, and there is a vertical crease on the front of the melon. The dorsal fin is tall and falcate and the flippers are sickle-shaped. Young Risso's dolphins range from light gray to dark brownish gray and are relatively unmarked

(Jefferson et al. 1993). Adults range from dark gray to nearly white and are covered with white scratches and splotches.

Status—The Risso's dolphin is relatively common in most nearshore waters of the Pacific coast of the continental U.S. There is a minimum population estimate of 12,748 individuals for the California/Oregon/Washington stock of the Risso's dolphin.

Habitat Preferences—A number of studies have noted that Risso's dolphins are most commonly found along the continental slope in the Pacific, Atlantic, Gulf of Mexico, and Caribbean (CETAP 1982; Green et al. 1992; Baumgartner 1997; Davis et al. 1998; Mignucci-Giannoni 1998; Kruse et al. 1999). Baumgartner (1997) hypothesized that the strong correlation between Risso's dolphin distribution and the steeper portions of the upper continental slope in the Gulf of Mexico is most likely the result of cephalopod distribution in the same area.

Distribution—The Risso's dolphin is distributed worldwide in tropical to warm-temperate waters, roughly between 60°N and 60°S, where surface water temperature is usually greater than 10°C (Kruse et al. 1999). In the eastern North Pacific, the Risso's dolphin reaches its northern limits in Canadian waters (e.g., Reimchen 1980; Baird and Stacey 1991). Water temperature appears to be a factor that affects the distribution of Risso's dolphins in the Pacific (Leatherwood et al. 1980; Kruse et al. 1999). Changes in local distribution and abundance along the southern California coast are probably in response to protracted or unseasonal warm-water events, such as El Niño events (Shane 1994, 1995).

➢ Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area

- Upwelling season—There is an area of primary occurrence for the Risso's dolphin in the Pacific Northwest OPAREA between the 100 m and approximately 3,000 m isobaths (**Figure B-34**), based on the distribution of sighting records. There is a band of secondary occurrence offshore of the area of primary occurrence. There is a rare occurrence shallower than the 100 m isobath on the outer coast, as well as within the Puget Sound Study Area (**Figure B-35**).

- Relaxed season—There is an area of primary occurrence for the Risso's dolphin in the Pacific Northwest OPAREA between the 100 m and 2,000 m isobaths (**Figure B-34**). There is a 50 NM buffer of secondary occurrence offshore of the area of primary occurrence. There is a rare occurrence seaward of the area of secondary occurrence (**Figure B-34**), as well inshore of the 100 m isobath, as well as within the Puget Sound Study Area (**Figure B-35**). The only reported inland water stranding records for this species are during March 1975 in Discovery Bay in the eastern Strait of Juan de Fuca (Everitt et al. 1979) and near Port Angeles in October 1987 (Osborne et al. 1988).

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, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005). 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, such as the Pacific white-sided dolphin and the northern right whale dolphin (Kruse et al. 1999). They may remain submerged on dives for up to 30 min (Kruse et al. 1999) and dive as deep as 600 m (DiGiovanni et al. 2005). Cephalopods are the primary prey (Clarke 1996).

Acoustics and Hearing—Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and combined whistle and burst-pulse sounds that range in frequency from 0.4 to 22 kHz and in duration from less than a second to multiple seconds (Corkeron and Van Parijs 2001). The combined whistle and burst pulse sound (2 to 22 kHz, mean duration of 8 seconds) appears to be unique to Risso's dolphin (Corkeron and Van Parijs 2001). Risso's dolphins also produce echolocation clicks (40 to 70 µs duration) with a dominant frequency range of 50 to 65 kHz

and estimated source levels up to 222 dB re 1 µPa-m peak-to-peak (Thomson and Richardson 1995; Philips et al. 2003; Madsen et al. 2004).

Baseline research on the hearing ability of this species was conducted by Nachtigall et al. (1995) in a natural setting (included natural background noise) using behavioral methods on one older individual. This individual could hear frequencies ranging from 1.6 to 100 kHz and was most sensitive between 8 and 64 kHz. Recently, the auditory brainstem response technique has been used to measure hearing in a stranded infant (Nachtigall et al. 2005). This individual could hear frequencies ranging from 4 to 150 kHz, with best sensitivity at 90 kHz. This study demonstrated that this species can hear higher frequencies than previously reported.

- **False Killer Whale (*Pseudorca crassidens*)**

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

Status—There are no abundance estimates available for this species in the NOAA stock assessment report for this area of the Pacific. Although they do occasionally occur this far north, false killer whales are not common anywhere north of the U.S./Mexico border.

Habitat Preferences—This species is found primarily in oceanic and offshore areas, though they do approach close to shore at oceanic islands (Baird 2002). False killer whales have been known to approach very close to shore in such areas as the inshore waters of Washington State 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 50°S and 50°N latitude with a few records north of 50°N in the Pacific and the Atlantic (Baird et al. 1989; Odell and McClune 1999). Norman et al. (2004) remarked that most of the stranding events for this species in Washington State and Oregon occurred during or within a year of an El Niño event(s). Seasonal movements in the western North Pacific may be related to prey distribution (Odell and McClune 1999).

➢ <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

- <u>Upwelling season</u>—There is a rare occurrence for the false killer whale throughout the entire Pacific Northwest OPAREA and Puget Sound Study Area (**Figure B-36**). False killer whales usually occur in warmer waters than those of the OPAREA. Individuals and small groups are on occasion documented to spend extended periods of time within the area (e.g., Osborne et al. 1988; Barry et al. 1989; Stacey and Baird 1991a; Shore 1999; Douglas and Calambokidis 2002; Sandilands 2003). Most occurrence records are for the upwelling season.

- <u>Relaxed season</u>—False killer whale occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area is assumed to be similar to occurrence during the upwelling season (**Figure B-36**).

Behavior and Life History—This species may occur in large groups (group sizes as large as 300 have been reported; Brown et al. 1966). The known maximum dive depth is about 500 m (Odell and McClune 1999). No seasonality in reproduction is known for the false killer whale (Jefferson et al.

1993). False killer whales primarily eat deep-sea cephalopods and fish (Odell and McClune 1999), but they have been known to attack other cetaceans, including dolphins (Perryman and Foster 1980; Stacey and Baird 1991a), sperm whales (Palacios and Mate 1996), and baleen whales (Jefferson, T.A., NMFS-SWFSC, pers. comm., 14-18 March 2005). Stomach contents of an individual that stranded in Puget Sound contained a few salmon vertebrae (Scheffer and Slipp 1948).

Acoustics and Hearing—Dominant frequencies of false killer whale whistles are from 4 to 9.5 kHz and those of their echolocation clicks are from either 20 to 60 kHz or 100 to 130 kHz depending on ambient noise and target distance (Thomson and Richardson 1995). Click source levels typically range from 200 to 228 dB re 1 µPa-m (Ketten 1998). Recently, false killer whales recorded in the Indian Ocean produced echolocation clicks with dominant frequencies of about 40 kHz and estimated source levels of 201-225 dB re 1 µPa-m (Madsen et al. 2004).

False killer whales can hear frequencies ranging from approximately 2 to 115 kHz with best hearing sensitivity ranging from 16 to 64 kHz (Thomas et al. 1988). Additional behavioral audiograms of false killer whales support a range of best hearing sensitivity between 16 and 24 kHz, with peak sensitivity at 20 kHz (Yuen et al. 2005). The same study also measured audiograms using the ABR technique, which came to similar results, with a range of best hearing sensitivity between 16 and 22.5 kHz, peaking at 22.5 kHz (Yuen et al. 2005). Behavioral audiograms in this study consistently resulted in lower thresholds than those obtained by ABR.

- **Killer Whale (*Orcinus orca*)**

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

There are at least three ecotypes in the eastern North Pacific: “residents,” “transients,” and “offshores.” Resident animals differ from both transient and offshore individuals by having a dorsal fin that is more curved and rounded at the tip, especially among mature females (Ford et al. 1994). Residents also exhibit five patterns of saddle patch pigmentation, two of which are shared with transients (Baird and Stacey 1988). Offshores are thought be slightly smaller in body size than residents and transients and have dorsal fins and saddle patches resembling those of residents (Ford et al. 1994; Wiles 2004).

Status—Most cetacean taxonomists agree that multiple killer whale species or subspecies occur worldwide (Krahn et al. 2004; Waples and Clapham 2004). Krahn et al. (2004) concluded that all North Pacific resident killer whales should be treated as a single unnamed subspecies distinct from offshore and transient whales.

As noted earlier, there are at least three ecotypes in the eastern North Pacific. The terms “residents” and “transients” are colloquial terms; neither term is particularly descriptive of site-fidelity and actual movement patterns of the animals (e.g., NFMS 2005i). Some researchers instead refer to these two ecotypes as “fish-eaters” (i.e., residents) and “mammal-hunters” (i.e., transients).

Five killer whale stocks are currently identified by the NMFS within the Pacific U.S. EEZ: (1) the Eastern North Pacific Northern Resident stock – occurring from British Columbia through Alaska; (2) the Eastern North Pacific Southern Resident stock (discussed earlier in this chapter) – occurring within the inland waters of Washington State and southern British Columbia; (3) the Eastern North Pacific Transient stock – ranging all along the west coast of North America; (4) the Eastern North Pacific Offshore stock – occurring from southeast Alaska through California; and (5) the Hawaiian stock (Carretta et al. 2006).

Resident killer whales are distributed from Alaska to California, with four distinct recognized communities: southern, northern, southern Alaska, and northern Alaska (Krahn et al. 2004). There are two populations of resident killer whales in the Washington State/British Columbia area: NRKW and SRKW. Genetic analyses using nuclear (microsatellite) and mitochondrial DNA indicate that the two populations are most likely reproductively isolated from each other (Hoelzel et al. 1998b; Barrett-Lennard 2000). It is primarily the SRKW that occurs in the Pacific Northwest OPAREA and Puget Sound Study Area, although individuals of the NRKW occasionally venture into the area. The Eastern North Pacific Northern Resident stock numbers 723 individuals, also based on a direct count of individually identifiable animals (Carretta et al. 2006). The NRKW contains 16 pods (see NMFS 2005i) and appears to be on the increase.

There are genetically distinct assemblages of transient killer whales in the northeastern Pacific: 1) west coast transients, which occur from southern California to southeastern Alaska; 2) Gulf of Alaska transients, which inhabit the Gulf of Alaska, Aleutians, and Bering Sea (although significant genetic differences may exist within the population; and 3) the AT1 pod, which occurs in Prince William Sound and the Kenai Fjords in the northern Gulf of Alaska. Only the west coast transients are expected to occur in the Pacific Northwest OPAREA and Puget Sound Study Area; they are 320 individuals which include about 225 in Washington State and British Columbia, and southeastern Alaska, and 105 off California. The number in Washington State waters at any one time is probably fewer than 20 individuals (Wiles 2004).

Offshore killer whales have not been observed to intermix with residents and transients (Wiles 2004). The minimum population estimate for the Eastern North Pacific Offshore stock of the killer whale is 1,038 individuals (Carretta et al. 2006). A minimum of 361 individual offshore killer whales is estimated to be in U.S. waters off California, Washington State, and Oregon (Carretta et al. 2006). The total number of known offshore killer whales is 211 individuals, but it is not known what proportion of time this transboundary stock spends in U.S. waters (Carretta et al. 2006).

Habitat Preferences—Killer whales have the most ubiquitous distribution of any species of marine mammal, 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). In the eastern North Pacific, killer whales are found in protected inshore waters, as well as offshore waters off the outer coast (Wiles 2004). Killer whales in the eastern North Pacific occasionally enter the lower reaches of rivers in Washington State and Oregon while feeding (Wiles 2004). In fact, in October 1931, a killer whale made its way up the Columbia River and was killed in the Oregon Slough, a branch of Portland Harbor, 110 mi inland from the Pacific Ocean (Shepherd 1932). Killer whale sightings have been made up to 500 km off the Washington State coast (Krahn et al. 2004).

Resident and transient killer whales exhibit somewhat different patterns of habitat use while in protected inland waters. Residents generally spend more time in deeper water and only occasionally enter water less than 5 m deep (Heimlich-Boran 1988; Baird 2000). Several studies have reported that southern residents feed heavily in areas characterized by high-relief underwater topography, such as subsurface canyons, seamounts, ridges, and steep slopes (Heimlich-Boran 1988; Felleman et al. 1991). Such features may concentrate prey, thereby resulting in greater prey availability, and be used by the whales as underwater barriers to assist in herding fish (Heimlich-Boran 1988).

Transient whales also occupy a wide range of water depths, including deep areas exceeding 300 m; they have a preference for coastal waters. However, transients show greater variability in habitat use than residents, with some groups spending most of their time foraging in shallow waters close to shore while others hunt almost entirely in open water (Heimlich-Boran 1988; Felleman et al. 1991; Baird and Dill 1995; Matkin and Saulitis 1997). In contrast to residents, transients regularly enter small bays and narrow passages (Morton 1990; Scheel et al. 2001). Groups using nearshore habitats often concentrate their activity in shallow waters near pinniped haulout sites.

NRKW engage in beach rubbing during July and August in Robson Bight on northern Vancouver Island within Johnstone Strait (north of the OPAREA; Ford et al. 1994). The beaches here are covered with small, flat, round and smooth stones, and individuals are seen rubbing their bodies over the stones.

Offshore killer whales usually occur 15 km or more offshore but also visit coastal waters and occasionally enter protected inshore waters (Wiles 2004).

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 2002b). Though found in tropical waters and the open ocean, killer whales as a species are most numerous in coastal waters and at higher latitudes (Mitchell 1975; Miyazaki and Wada 1978; Dahlheim et al. 1982).

Along the Pacific coast of North America, killer whales are found along the entire Alaskan coast, in British Columbia and Washington State inland waterways, and along the outer coasts of Washington State, Oregon, and California down into Mexican waters (Black et al. 1997; Carretta et al. 2006). Some individual killer whales have been documented to move between the waters of southeast Alaska and central California (Goley and Straley 1994). SRKW regularly visit coastal sites off Washington State and Vancouver Island (Ford et al. 1994) and are known to travel as far south as central California (Black et al. 2003; Black[4,5]) and as far north as the Queen Charlotte Islands (Wiles 2004).

The NRKW population resides primarily from central Vancouver Island (including the northern Strait of Georgia) to Frederick Sound in southeastern Alaska (Ford et al. 1994; Dahlheim et al. 1997); (Barrett-Lennard and Ellis 2001; Wiles 2004). From June to October, many northern resident pods congregate in the vicinity of Johnstone Strait and Queen Charlotte Strait off northeastern Vancouver Island, but movements and distribution during other times of the year are less well-known (Ford et al. 1994). The area of overlap for the NRKW and SRKW is the central Strait of Georgia near Nanaimo, offshore of Barkley Sound on the west coast of Vancouver Island, and in the Strait of Juan de Fuca. It should be noted, however, that NRKW individuals have been found as far south as Oregon, and possibly California (Morin et al. 2006).

Transient killer whales in the eastern North Pacific spend most of their time along the outer coast, but visit Hood Canal and Puget Sound in search of harbor seals, sea lions, and other prey. Transient occurrence in inland waters appears to peak during August and September (Morton 1990; Baird and Dill 1995; Ford and Ellis 1999) which is the peak time for harbor seal pupping, weaning, and post-weaning (Baird and Dill 1995).

Most encounters with offshore killer whales in the Pacific Northwest have taken place near the Queen Charlotte Islands (Haida Gwaii) and 15 or more km off the west coast of Vancouver Island (NMFS 2005i). Groups of offshores are encountered as far south as Los Angeles, mostly during winter (Ford et al. 1994).

➢ <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>

- <u>Upwelling season</u>—There is a primary occurrence for the killer whale throughout the entire OPAREA and the Puget Sound Study Area during the upwelling season (**Figure B-37**). Residents and transients are most often seen during May through October when they are found in inland waters around the San Juan Islands, including Haro Strait, Boundary Passage, and the eastern portion of the Strait of Juan de Fuca (Heimlich-Boran 1988; Ford et al. 1994; Olson 1998; Wiles 2004).

  Killer whales tend to show up along the Oregon coast during late April and May and may target gray whale females and calves migrating north. Transients are common in inland waters only from August to October (Baird and Dill 1995; Olson 1998), which is the peak time

for harbor seal pupping. Transients are common then on the southern end of Vancouver Island near Race Rocks and Victoria. Noteworthy are two recent events of transient killer whales staying for extended times in Hood Canal to feed on harbor seals. One event involved 11 transient killer whales occupied Hood Canal for an unprecedented 60 days from 2 January to 3 March 2003 (London et al. 2005). The transients consumed a median estimate of 711 harbor seals which is more than half the estimated harbor seal population (1,400) in Hood Canal. One of the killer whales (T-14) had been captured during March 1976 together with four other transients at Budd Inlet near the head of Puget Sound, as part of a live-capture operation to supply whales to aquaria; due to public outcry at the time of the capture, all the whales were eventually released (Ford and Ellis 1999). (After that incident no more commercial live-captures took place in the Pacific Northwest.) The second event in Hood Canal took place in 2005, with six transient killer whales taking an estimated 835 seals over the course of over 150 days (London et al. 2005). Although the predicted consumption during these events represents over 80% of the estimated harbor seal population, aerial surveys and land-based counts have not indicated a noticeable decline in abundance (London et al. 2005).

NRKW are common throughout the summer and congregate at particular coastal locations at this time of year in association with high densities of migrating salmon (Heimlich-Boran 1986; Nichol and Shackleton 1996; Olson 1998; NMFS 2005i). The summer core areas are Johnstone Strait and Haro Strait. Their strong preference for chinook salmon may influence the year-round distribution patterns of resident killer whales in coastal British Columbia and adjacent waters (Ford and Ellis 2005).

- Relaxed season—There is a primary occurrence for the killer whale throughout the entire OPAREA and the Puget Sound Study Area (**Figure B-37**). In Washington State inland waters, L pod typically departs around October and K pod in October or November, while J pod stays here, ranging as far south in Puget Sound as Olympia. Noteworthy is that in late October 1997, 19 southern resident killer whales spent 30 days in Dyes Inlet near Bremerton, Washington State, likely having followed a chum salmon run to Chico Creek. The occurrence of killer whales in offshore waters of the OPAREA during this time of year is reported (Wahl 1977; Green et al. 1992; Shelden et al. 2000; Norman et al. 2004), but much less is known about the movements and distribution of killer whales in the winter months than during the remaining times of the year.

Behavior and Life History—Killer whales have the most stable social system known among all cetaceans. In all areas where longitudinal studies have been carried out, there appear to be long-term associations between individuals and limited dispersal from maternal groups called pods (Bigg et al. 1990; Baird 2000).

Residents are organized into a series of social units from small to large on the basis of maternal genealogy (e.g., Ford et al. 1994). The maternal relatedness of the whales diminishes as one goes from the smallest kin unit, the mother and her offspring, through increasingly larger units: the matriline, the pod, and the clan. Residents occur in small highly stable social units known as matrilines in which all individuals are maternally related. Pods are larger social groups comprised of several matrilines and typically hold about 10 to 60 whales. The clan is comprised of pods that have similar vocal dialects or acoustic behavior. It may be that clans are linked through a common maternal ancestor but one that is more ancient than that which links pods within clans. The top level of social structure is the community which is made up of pods that regularly associate with one another. As noted earlier, there are two resident communities in coastal waters of British Columbia and Washington State: the northern and the southern (discussed earlier in this chapter) communities.

Transients also travel in small matrilineal groups which typically contain less than 10 animals (e.g., Morton 1990; Ford and Ellis 1999). Although some matriline members maintain long-term bonds, the social organization of transients is generally more flexible than in residents (Ford and Ellis 1999). Transients are also different from residents in that dispersal of both males and females from the natal

pod can occur (Baird and Whitehead 2000). Differences in social organization compared to resident killer whales likely relate to differences in foraging ecology (Baird and Whitehead 2000).

Few details are known about the biology of offshore killer whales, but they commonly occur in large groups of 20 to 75 individuals (Wiles 2004). Resident, transient, and offshore killer whales rarely interact and apparently do not interbreed despite having largely sympatric year-round geographic ranges (e.g., Morton 1990; Baird and Dill 1995; Black et al. 1997).

Among resident killer whales in the northeastern Pacific, births occur largely from October to March, although births can occur year-round (Olesiuk et al. 1990; Stacey and Baird 1997). Females typically give birth for the first time at 11 to 15 years of age (Ford and Ellis 1999). Maximum life span is estimated to be 80 to 90 years for females and 50 to 60 years for males (Olesiuk et al. 1990).

Killer whales have a diverse diet, feeding on bony fishes, elasmobranchs, cephalopods, seabirds, sea turtles, and other marine mammals (Jefferson et al. 1991; Fertl et al. 1996). Diet in the eastern North Pacific is specific to the type of killer whale. Based on both behavioral observations and stable isotope analyses, transients are primarily mammal-eaters, residents are mostly fish-eaters, and offshores appear to eat mostly fish as well (e.g, Bigg 1982; Morton 1990; Heise et al. 2003; Herman et al. 2005).

Salmon are the principle prey for resident killer whales during spring, summer, and fall (Heimlich-Boran 1986; Felleman et al. 1991; Ford et al. 1998; Baird and Hanson 2004; Ford and Ellis 2005; Hanson et al. 2005). Current data suggest that chinook salmon (the area's largest salmonid) are the most commonly targeted species. Other salmonids appear to be eaten less frequently, as are rockfish, halibut, lingcod, and herring. Chinook is the predominant prey species taken by northern resident communities during May through August, but chum salmon is more prevalent in September through October. NRKW occurrence in Johnstone Strait has been tied more strongly to the large seasonal runs of sockeye and pink salmon, as well as chum salmon to a lesser degree (Nichol and Shackleton 1996).

Transients have diets largely consisting of marine mammals and, to a lesser extent, seabirds but apparently no fish (e.g., Morton 1990; Baird and Dill 1996; Ford et al. 1998; Ford and Ellis 1999; Ford et al. 2005). Transients spend more time foraging than residents do (Morton 1990). Transients hunt typically either by nearshore foraging or open-water foraging (Baird and Dill 1995; Ford and Ellis 1999). When nearshore foraging, whales hug the shoreline and swim relatively close together, typically looking for harbor seals at haulout sites. Open-water foraging seems to be a tactic mostly for hunting Dall's and harbor porpoises. Attacks on larger whales are rarer (Ford and Ellis 1999; Ford et al. 2005).

The maximum depth recorded for free-ranging killer whales diving off British Columbia is 264 m (Baird et al. 2005a). On average, however, for seven tagged individuals, less than 1% of all dives examined were to depths greater than 30 m (Baird et al. 2003b). 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—Killer whales produce a wide-variety of clicks and whistles, but most of this species social sounds are pulsed, with frequencies ranging from 0.5 to 25 kHz (dominant frequency range: 1 to 6 kHz) (Thomson and Richardson 1995). Echolocation clicks recorded for this species indicate source levels ranging from 195 to 224 dB re: 1 µPa-m peak-to-peak, dominant frequencies ranging from 20 to 60 kHz, and durations of 80 to 120 µs (Au et al. 2004). Source levels associated with social sounds have been calculated to range from 131 to 168 dB re 1 µPa-m and have been demonstrated to vary with vocalization type (e.g., whistles: average source level of 140.2 dB re 1 µPa-m, variable calls: average source level of 146.6 dB re 1 µPa-m, and stereotyped calls: average source level 152.6 dB re 1 µPa-m) (Veirs 2004). Additionally, killer whales modify their vocalizations depending on social context or ecological function (i.e., short-range vocalizations [<10 km range]) are

typically associated with social and resting behaviors and long-range vocalizations [10 to 16 km range] associated with travel and foraging) (Miller 2006).

Resident killer whales are very vocal, making calls during all types of behavioral states. Acoustic studies of resident killer whales in the Pacific Northwest have found that there are dialects in their highly stereotyped, repetitive discrete calls, which are group-specific and shared by all group members (Ford 1991, 2002b). 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 1991, 2002b). Dialects have been documented in northern Norway (Ford 2002a) and southern Alaskan killer whales populations (Yurk et al. 2002) and are likely occur in other regions as well. Residents do not need to alter their sounds (i.e., frequency or amplitude) when hunting fishes, since most of their prey (i.e., salmonids) are not capable of hearing in this frequency range (i.e., >20 kHz) (Hawkins and Johnstone 1978; Au et al. 2004). Transient killer whales, conversely, appear to use passive listening as a primary means of locating prey, call less often, and frequently vocalize or use high-amplitude vocalizations only when socializing (i.e., not hunting), trying to communicate over long distances, or after a successful attack, as a result of their prey's ability (i.e., primarily other marine mammal species) to hear or "eavesdrop" on their sounds (Barrett-Lennard et al. 1996; Deecke et al. 2005; Saulitis et al. 2005).

Both behavioral and auditory brainstem response (ABR) techniques indicate killer whales can hear a frequency range of 1 to 100 kHz and are most sensitive at 20 kHz, which is one the lowest maximum-sensitivity frequency known among toothed whales (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 Pacific Northwest OPAREA and Puget Sound Study Area. Pilot whales are among the largest members of the family Delphinidae. In general, the short-finned pilot whale is smaller than the long-finned pilot whale, reaching lengths of 5.5 m (females) and 6.1 m (males; Jefferson et al. 1993).

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

Status—Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters where two stocks have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). There is a minimum population estimate for the California/Oregon/Washington stock of the short-finned pilot whale of 149 individuals (Carretta et al. 2006).

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 worldwide are typically distributed along the continental shelf break, movements over the continental shelf are commonly observed in the northeastern U.S. (Olson and Reilly 2002) 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; 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, 1995); but since then, they have returned to the area.

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 50°N or south of 40°S (Jefferson et al. 1993). Although it did in the past, 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).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Along the west coast of North America, sightings of short-finned pilot whales north of Point Conception are uncommon (Everitt et al. 1979; Osborne et al. 1988; Forney 1994). Baird and Stacey and Baird (1993) reviewed occurrence records in British Columbia waters and recommended that it be considered rare there, occurring in most years, but with only a few records per year. Norman et al. (Norman et al. 2004) remarked that most of the stranding events for this species occurred during or within a year of an El Niño event(s).

  - Upwelling season—Occurrence records for the OPAREA are primarily during the warmer months of the upwelling season (e.g., Fiscus and Niggol 1965; Pike and MacAskie 1969; Everitt et al. 1979; Baird and Stacey 1993). There is a rare occurrence for the short-finned pilot whale throughout the entire Pacific Northwest OPAREA and Puget Sound Study Area (**Figure B-38**).

  - Relaxed season—Pilot whale occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area is assumed to be similar to occurrence during the upwelling season (**Figure B-38**).

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).

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 around 4 to 6 years (Bernard and Reilly 1999). Calving peaks in the northern hemisphere vary by stock (Jefferson et al. 1993).

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

Acoustics and Hearing—Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and 30 to 60 kHz, respectively, at an estimated source level of 180 dB re 1 µPa-m (Fish and Turl 1976; Ketten 1998).

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 eastern North Pacific; they reach a maximum length of 2 m (Jefferson et al. 1993). The body is stocky with dark gray to black coloring 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 no distinct beak. The flippers are small and pointed, and the dorsal fin is short and triangular and is located slightly behind the middle of the back.

Status—There are nine stocks of harbor porpoise recognized along the U.S. Pacific coast: (1) Bering Sea; (2) Gulf of Alaska, (3) Southeast Alaska, (4) Inland Washington State, (5) Oregon/Washington State coast, (6) Northern California/Southern Oregon, (7) San Francisco-Russian River, (8) Monterey Bay, and (9) Morro Bay (Carretta et al. 2006). The Northern California/Southern Oregon, Oregon/Washington State coast and Inland Washington State stocks are found in the Pacific Northwest OPAREA and Puget Sound Study Area. There is a minimum population estimate of 12,940 individuals in the Northern California/Southern Oregon stock; 28,967 in the Oregon/Washington State coast stock; and 2,545 in the Inland Washington State stock (Carretta et al. 2006). The boundaries of these three stocks are as follows: Northern California/Southern Oregon stock (Point Arena, CA, to Cape Blanco, OR), Oregon/Washington State coast stock (Cape Blanco, OR, to Cape Flattery, WA), and Inland Washington State stock (waters east of Cape Flattery, including Puget Sound; Carretta et al. 2006).

Habitat Preferences—Harbor porpoise are generally found in cool temperate to subarctic waters over the continental shelf (Read 1999). This species is seldom found in waters warmer than 17°C (Read 1999). Harbor porpoises occur south only to about Point Conception. The reasons for this cut-off in distribution are not known (Barlow and Hanan 1995). However, there is a well-known biogeographic boundary at Point Conception, based largely on currents and water temperature (Hubbs 1960).

Distribution—Harbor porpoises occur in both the North Atlantic and North Pacific (Read 1999). In the Pacific, harbor porpoises are found in coastal and inland waters from Point Conception, California to Alaska and across to Kamchatka and Japan. This species has more restricted movements along the Pacific coast than along the Atlantic coast of the U.S. (Carretta et al. 2006).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Harbor porpoises regularly occur in the OPAREA and Study Area year-round. Peak abundance off Oregon and Washington State occurs in the fall and winter (Green et al. 1992). Abundance of harbor porpoises off northern California also peaks in the fall (Dohl et al. 1983). Harbor porpoises occur year-round and breed in the inland waters of the transboundary area between Washington State and British Columbia (Osborne et al. 1988). Harbor porpoise strandings within Puget Sound and surrounding waters are an expected seasonal phenomenon. They occur most frequently during May, with 70% of all known annual strandings recorded between March and June (Osborne 20039; NMFS 2005j).

  - Upwelling season—The area of primary occurrence for the harbor porpoise in the Pacific Northwest OPAREA is in waters shallower than 100 m (**Figure B-39**). There is a secondary occurrence between the 100 m and 300 m isobaths. There is a rare occurrence in waters deeper than the 300 m isobath.

    The harbor porpoise used to be common throughout Puget Sound (Scheffer and Slipp 1948; Flaherty and Stark 1982; Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005). In recent years, most sightings within Puget Sound have been in the central portion, including a sighting of 50 individuals near Bush Point (Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005). There are high harbor porpoise densities north of Orcas Island (Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005). Historically, the southern portion of Puget Sound was an area of primary occurrence for this species (e.g., 1940s, Scheffer and Slipp 1948); however, in recent years, this has not been the case (Calambokidis et al. 1992; Raum-

Suryan and Harvey 1998). There is a primary occurrence for the harbor porpoise north of Whidbey Island (**Figure B-40**). There is another secondary occurrence south of Whidbey Island.

- Relaxed season—Occurrence patterns for the harbor porpoise are assumed to be similar to the upwelling season, even though the survey effort is much less than during the upwelling season (**Figure B-39**, **Figure B-40**). The harbor porpoise in this area is thought to have limited movement patterns, based largely on tagging data (Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005).

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). Calves are born in late spring (Read 1990b; Read and Hohn 1995). Many females are pregnant and lactating simultaneously (Read 1990a; 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.

Interestingly, while there is some evidence of it occurring in other areas as well (e.g., Morejohn et al. 1973; Hall 1981), Dall's and harbor porpoises appear to hybridize relatively frequently in the Puget Sound area. Genetic studies conducted by Willis et al. (2004) have confirmed that the unusual-looking porpoises that are often seen in the area are indeed hybrids between Dall's porpoise mothers and harbor porpoise fathers.

Harbor porpoises feed on a wide variety of small, schooling clupeoid (herring-like) and gadid (cod-like) fishes up to 40 cm in length, and usually less than 30 cm in length (Read 1999). Harbor porpoises along the coast of Washington State primarily feed on Pacific herring, market squid, and smelts (Gearin et al. 1994). 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). Average dive depths range from 14 to 41 m with a maximum known dive of 226 m, and average dive durations ranging from 44 to 103 sec (Westgate et al. 1995). Westgate and Read (Westgate et al. 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 (*Phocoenoides dalli*)**

Description—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). Dall's porpoise has a stocky body with a wide-based triangular dorsal that is slightly recurved at the tip; in mature males the fin can become extremely canted (Jefferson 1990). The caudal peduncle is strongly keeled, especially in adult males (Jefferson 1990). The teeth are extremely small, the smallest of any cetacean species (Jefferson 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 1990). 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 *truei*-type Dall's porpoise was found stranded in San Mateo County, California (Szczepaniak et al. 1992).

Status—There is a minimum population estimate of 75,915 individuals for the California/ Oregon/Washington State stock of the Dall's porpoise (Carretta et al. 2006). The stock structure of eastern North Pacific Dall's porpoises is not well-known, but based on patterns of stock differentiation in the western North Pacific, it is expected that separate stocks will emerge when data become available (Carretta et al. 2006).

Habitat Preferences—Dall's porpoise is a cool temperate to subarctic species (Houck and Jefferson 1999). The primary habitat of Dall's porpoise is cool (<17°C), deep (>180 m), OCS, slope, and oceanic waters (Jefferson 1988; Ferrero et al. 2002; Carretta et al. 2006).

Distribution—Dall's porpoise is endemic to the North Pacific. It is found from northern Baja California, Mexico, north to the northern Bering Sea and south to southern Japan (Jefferson et al. 1993). 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 State 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. Dall's porpoises probably also range south into Mexican waters during exceptional coldwater periods (Leatherwood et al. 1988; Bonnell and Dailey 1993). Inshore/offshore movements off southern California have also been reported, with individuals remaining inshore in fall and moving offshore in the late spring (Norris and Prescott 1961; Houck and Jefferson 1999; Lagomarsino and Price 2001). Seasonal movements have also been noted off Oregon and Washington State with higher densities of Dall's porpoises sighted offshore in winter and spring and inshore in summer and fall (Green et al. 1992).

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>—Dall's porpoises regularly occur throughout the OPAREA and Study Area year-round. Dall's porpoise is the most common cetacean species in northern Puget Sound and the Strait of Juan de Fuca (Osborne et al. 1988). They are also found in Haro Strait between San Juan Island and Vancouver Island; tagging studies suggest that Dall's porpoises seasonally move between the Haro Strait area and the Strait of Juan de Fuca or farther west (Hanson et al. 1998).

  - <u>Upwelling season</u>—Along the coast of the Pacific Northwest OPAREA, the area of primary occurrence for the Dall's porpoise is in waters cooler than 15.5°C and deeper than 100 m (**Figure B-41**). There is a secondary occurrence in waters between the 15.5° and 16°C

isotherms and deeper than 100 m, which is based on sighting data further south in southern California (Barlow, J., NMFS-SWFSC, pers. comm., 15-16 March 2005). There is a rare occurrence in waters shallower than 100 m along the outer coast. Within the Puget Sound Study Area, there is a primary occurrence in the Strait of Juan de Fuca and approximately north of Whidbey Island and into the Strait of Georgia (**Figure B-42**). There is a secondary occurrence south of approximately Whidbey Island based on scattered sighting reports in the southern portion of Puget Sound (Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005). There is also a rare occurrence in the western portion of southern Puget Sound.

- Relaxed season—There is an area of primary occurrence in waters deeper than 100 m (**Figure B-41**). There is an area of rare occurrence in waters inshore of the 100 m isobath. Occurrence within the Puget Sound Study Area during this time of the year is similar to that of the upwelling season, with an increase in the number of individuals in the Strait of Georgia (Keple 2002; **Figure B-42**).

Behavior and Life History—Groups of Dall's porpoises are generally small (most often less than 10 individuals) and fluid, and composed of very small subgroups, which may aggregate especially for feeding (Jefferson 1990, 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 porpoises 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 porpoises have even been observed to "snout ride" on bow waves pushed forward by the heads of large whales (Jefferson 2002).

Very little information is available on Dall's porpoise reproduction in the eastern North Pacific (Jefferson 1990; Forney 1994). There is apparently a very strong summer calving peak in the months of June through August, and a smaller peak in March (Jefferson 1989). Gestation lasts about 10 to 12 months (Jefferson 2002); the lactation period is unknown, but it is thought to be very short, perhaps 2 to 4 months (Jefferson 1990). 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).

Interestingly, while there is some evidence of it occurring in other areas as well (e.g., Morejohn et al. 1973; Hall 1981), Dall's and harbor porpoises appear to hybridize relatively frequently in the Puget Sound area. Genetic studies conducted by Willis et al. (2004) have confirmed that the unusual-looking porpoises that are often seen in the area are indeed hybrids between Dall's porpoise mothers and harbor porpoise fathers.

Dall's porpoises feed primarily on small fish and squid (Houck and Jefferson 1999). Dall's porpoises in some areas appear to feed preferentially at night on vertically-migrating fish and squid associated with the DSL (Houck and Jefferson 1999). In Washington State waters, they are known to feed on squid, capelin, eulachon, and righteye flounder (Stroud et al. 1981). Blackbelly eelpout, *Lycodopsis pacifica*, is also a main prey species within the inland waters of Washington State (Walker et al. 1998). Hanson and Baird (1998) provided the first data on diving behavior for this species, an individual tagged for 41 min dove to a mean depth of 33.4 m (S.D.=±23.9 m) for a mean duration of 1.29 min (S.D.=±0.84 min).

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 µs), high-frequency, narrow band clicks, with peak energies between 120 and 160 kHz (Jefferson 1988).

There are no published data on hearing abilities 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).

- **Harbor Seal (*Phoca vitulina richardsi*)**

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 (Bigg 1981).

Status—The harbor seal is the most common pinniped species in the Pacific Northwest OPAREA and Puget Sound Study Area (Brown 1997; Jeffries et al. 2000). Three separate harbor seal stocks are recognized along the west coast of the continental U.S.: 1) inland waters of Washington State (including Hood Canal, Puget Sound, and the Strait of Juan de Fuca out to Cape Flattery); 2) outer coast of Oregon and Washington State; and 3) California (Carretta et al. 2006). Minimum population estimates are as follows: Washington State Inland Waters-12,844; Oregon/Washington State-22,380; and California-31,600 (Carretta et al. 2006).

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 several kilometers 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, peat banks in salt marshes, as well as logbooms, docks, and recreational floats (Wilson 1978; Prescott 1982; Schneider and Payne 1983; Gilbert and Guldager 1998; Jeffries et al. 2000).

Distribution—The harbor seal is one of the most widespread of the pinniped species. Its distribution stretches from the eastern Baltic Sea, west across the Atlantic and Pacific Oceans to southern Japan (Stanley et al. 1996). In the Pacific Northwest, harbor seals are distributed along haulout sites on mainland beaches of Washington State, Oregon, and northern California and on islands in the Puget Sound Study Area (Calambokidis and Jeffries 1991; Bonnell et al. 1992).

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>—Harbor seals regularly occur in the OPAREA and Study Area year-round. Haulout sites are concentrated in about 50 locations along the coasts of Oregon and Washington State, particularly in coastal estuaries and along the Olympic Peninsula (Bonnell et al. 1992; Jeffries et al. 2003). Main haulout sites in Washington State inland waters include the Strait of Juan de Fuca, San Juan Islands, Eastern Bays, Puget Sound, and Hood Canal (DoN 2001b; Jeffries et al. 2003; **Figure B-43**). Woodard Bay and Gertrude Island are the two most important rookery sites in the Puget Sound Study Area (Calambokidis and Jeffries 1991). In Washington State and Oregon, harbor seals tend to use particular estuaries and bays for breeding and others primarily for feeding (Boveng 1988). Harbor seals generally haul out on recreational floats, log rafts and booms, oyster rafts, fish net pens, marina floats, and breakwaters in the Puget Sound Study Area (Calambokidis and Jeffries 1991). Harbor seals also haul out on submarines at SUBASE Bangor (DoN 2001b).

  Aerial surveys off Oregon and Washington State recorded most harbor seals within 20 km of shore and at depths less than 200 m (Bonnell et al. 1992; Calambokidis et al. 2004b). Sightings further offshore and in waters between the 200 m and 2,000 m isobaths are recorded (Wahl 1977; Bonnell et al. 1992). 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). Peak abundance occurs during the pupping season and the annual molt which geographically vary in timing (Jeffries et al. 2000).

- Upwelling season—Primary occurrence is between the shore and the 500 m isobath along the outer coast and throughout the entire Puget Sound Study Area (**Figures B-44** and **B-45**). An area of secondary occurrence is between the 500 m and 2,000 m isobaths. Rare occurrence extends seaward of the 2,000 m isobath. Of note are two events in which transient killer whales fed on harbor seals in Hood Canal (London et al. 2005). These extended foraging events occurred between January and March in 2003 and over a 150-day period in 2005. The transients consumed a median estimate of 711 and 835 seals, respectively, during these two foraging events (London et al. 2005). Although the predicted consumption during these events represents over 80% of the estimated harbor seal population, aerial surveys and land-based counts have not detected a noticeable decline in abundance (London et al. 2005).

- Relaxed season—Occurrence is the same as that of the upwelling season (**Figures B-44** and **B-45**).

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). Group size ranges from a few animals to several thousand in the Pacific Northwest Region (Jeffries et al. 2000). This species is gregarious on land (though 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 some site fidelity by individuals to specific haulout sites within seasons. Human disturbance can affect haulout choice (Harris et al. 2003).

The timing of harbor seal pupping along the western North American coast varies geographically (Jeffries et al. 2000). In coastal and inland regions of Washington State, pups are born from April through January; pups are generally born earlier in the coastal estuaries and later in the Puget Sound/Hood Canal region (Calambokidis and Jeffries 1991; Jeffries et al. 2000). Delayed implantation occurs. In general, the pupping season lasts up to 10 weeks with a two-week peak (Burns 2002). Suckling harbor seal pups spend as much as 40% of their time in the water (Bowen et al. 1999). The nursing period is approximately four to six weeks (Scheffer and Slipp 1944; Newby 1973; Jeffries et al. 2000). Mating takes place in the water shortly after the pups are weaned.

Harbor seals are opportunistic feeders that 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. Pacific hake, Pacific staghorn sculpin, osmerids, Pacific lamprey, and shiner surfperch are the most common prey species for harbor seals in the Pacific Northwest Region (Roffe and Mate 1984; Orr et al. 2004). Although harbor seals in the Pacific Northwest are common in inshore and estuarine waters, they primarily feed at sea (Orr et al. 2004). 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 seal males produce a variety of low-frequency (<4 kHz) in-air vocalizations including snorts, grunts, and growls, while pups make individually unique calls for mother recognition (contain multiple harmonics with main energy below 0.35 kHz) (Bigg 1981; Thomson and Richardson 1995). Adult males also produce several underwater sounds during the breeding season that typically range from 0.025 to 4 kHz (duration range: 0.1 s to multiple seconds) (Hanggi and Schusterman 1994). Hanggi and Schusteman (1994) found that there is individual variation in the dominant frequency range of sounds between different males, and Van Parijs et al. (2003) reported oceanic, regional, population, and site-specific variation (i.e., could be vocal dialects) between males.

Harbor seals hear nearly as well in air as underwater (Kastak and Schusterman 1998). Harbor seals hear frequencies from 1 to 180 kHz (most sensitive at frequencies below 50 kHz; above 60 kHz sensitivity rapidly decreases) in water and from 0.25 kHz to 30 kHz in air (most sensitive from 6 to 16 kHz using behavior and auditory brainstem response testing) (Richardson 1995; Terhune and Turnbull 1995; Wolski et al. 2003).

- **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 360 to 710 kg (females) and 3.8 to 4.1 m and 2,300 kg (males; Stewart and Huber 1993; Deutsch et al. 1994). 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 (reddish or pinkish) from fighting with other males (Jefferson et al. 1993). Females and young males lack these exaggerated characters; their appearance is more similar to that of the related monk seals. The coloration of the northern elephant seal is simple countershading, with a dark brown back and slightly lighter belly.

Status—The northern elephant seal population has recovered dramatically after being reduced to several dozen to perhaps no more than a few animals in the 1890s (Bartholomew and Hubbs 1960; Stewart et al. 1994). Although movement and genetic exchange continue between rookeries, most elephant seals return to their natal rookeries to breed (Huber et al. 1991). The California and Mexican breeding groups may be demographically isolated and are currently considered two separate stocks (Carretta et al. 2006). Individuals from the California stock occur in the Pacific Northwest OPAREA and Puget Sound Study Area. The population size has to be estimated since all age classes are not ashore at any one time of the year (Carretta et al. 2006). There is a conservative minimum population estimate of 60,547 elephant seals in the California stock (Carretta et al. 2006). Based on trends in pup counts, abundance in California is increasing by around 6% annually, but the Mexican stock is decreasing slowly (Stewart et al. 1994; Carretta et al. 2006).

Habitat Preferences—Breeding and molting habitats for northern elephant seals are 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, B.S., Hubbs-Sea World Research Institute, pers. comm., 14-26 January and 20 April 2005). 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 far removed from the breeding rookeries (Stewart and DeLong 1995; Stewart 1997; Le Boeuf et al. 2000). Adult

seals migrate to feeding areas in the Subarctic Current between 40 and 50 degrees North Latitude and the Alaska Stream which flows northward through the Gulf of Alaska. Juvenile seals forage in the California Current and adults use the California Current System primarily as a migration corridor but also feed there while in transit (Stewart and Delong 1993).

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

Distribution—The northern elephant seal is endemic to the North Pacific Ocean, occurring almost exclusively in the eastern and central North Pacific. Vagrant individuals do sometimes range to the western North Pacific, however. The most far-ranging known individual appeared on Nijima Island, off the Pacific coast of Japan in 1989 (Kiyota et al. 1992). This demonstrates the great distances 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, Benito del Este, and Guadalupe Island. 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. 2006). There is some evidence that elephant seals may be expanding their pupping range northward, possibly in response to the continued population growth (Hodder et al. 1998). Bonnell et al. (1992) and Hodder et al. (1998) noted a possible breeding colony at Shell Island off Cape Arago in southern Oregon.

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°N and 45°N, whereas adult males range further north into the Gulf of Alaska and along the Aleutian Islands to between 47°N and 58°N (Stewart and Huber 1993; Stewart and DeLong 1995; Le Boeuf et al. 2000). Adults stay offshore during migration, while juveniles and subadults are often seen along the coasts of Oregon, Washington State, and British Columbia (Condit and Le Boeuf 1984; Stewart and Huber 1993). Females may cover over 18,000 km and males over 21,000 km during these post-breeding migrations (Stewart and DeLong 1995).

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>—Northern elephant seals occur in the OPAREA and Study Area year-round during the two annual migrations between southern California rookeries and haulout sites and offshore, foraging areas in the North Pacific (Stewart and DeLong 1994). They occasionally haul out along the coasts of northern California, Oregon, Washington State, and British Columbia (**Figure B-46**). Northern elephant seals regularly haul out on Shell Island off Cape Arago in southern Oregon; this island may be an incipient breeding colony (Hodder et al. 1998). Pups have been sighted there and at Protection and Minor Islands in the Puget Sound Study Area (Hodder et al. 1998; Jeffries et al. 2000).

  Juveniles migrate along the U.S. west coast during the summer and winter; they return to southern California rookeries and haulout sites in the fall. Adult males migrate during the spring and fall, returning south to molt in July and August and to mate in December through March. Adult females migrate in the spring, summer, and fall but return south to molt in April and May and to mate and give birth in January and February (Condit and Le Boeuf 1984).

- Upwelling season—Primary occurrence is seaward of the 200 m isobath along the outer coast based on feeding preferences (**Figure B-47**). An area of secondary occurrence is between the 100 m and 200 m isobaths. Rare occurrence is from the shore to the 100 m isobath.

  Northern elephant seals have a secondary occurrence in the Strait of Juan de Fuca and around the San Juan Islands that accounts for individuals moving into Puget Sound (**Figure B-48**). The southern part of Puget Sound and the Strait of Georgia are considered areas of rare occurrence.

- Relaxed season—Occurrence is similar to that of the upwelling season (**Figure B-47, Figure B-48**). Abundance during this period is expected to be low. Most elephant seals are found in breeding areas further south along the California and Mexican coasts from December through March, but some individuals stay in this area.

Behavior and Life History—Elephant seals are gregarious during the breeding season, but appear to be relatively solitary at sea. Adult elephant seals spend 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 mate, 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. Following one month ashore, the females return to sea for eight months (coincident with gestation), before returning to the rookery to give birth. Elephant seals do not necessarily return to the same beaches for breeding and molting. For example, Huber et al. (1991) found that female northern elephant seals often molt on one island and breed on another. Adult males spend approximately four months at sea following the breeding season, returning to shore in summer to molt. After one month ashore, they return to sea for four months before again 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, mate, and depart (Le Boeuf and Peterson 1969; Stewart and Huber 1993). Gestation is about 11 months, but there is a two to three month period of delayed implantation. During the breeding season, elephant seals congregate in large numbers on their breeding rookeries. Animals of all ages and both sexes are present on these beaches although yearlings generally do not return during the breeding season and are rare at rookeries. Large rookeries, such as those on Año Nuevo Island and Peninsula and the Channel Islands, may contain thousands of seals, which mostly arrange themselves in harems consisting of up to several dozen breeding females, a single dominant (alpha) male, and the newborn pups. Other animals, especially other bulls seeking to challenge the alpha male or sneak copulations, often surround the harems.

Males reach sexual maturity at about six or seven years but do not reach “social maturity” until nine 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. 2006).

Elephant seals are probably the deepest and longest diving pinnipeds; few other mammals can match their abilities. Adults dive continuously, day and night, during their feeding migrations (Le Boeuf et al.

1986; 1989; DeLong and Stewart 1991). 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 two to four min surface interval (Le Boeuf et al. 1986; 1989; DeLong and Stewart 1991). The longest known dive is 106 min (Le Boeuf and Crocker 2005). Dives average between 350 and 550 m in depth and can reach 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. Males forage along the continental margin at the distal end of their migration and may feed on benthic prey (Le Boeuf et al. 2000). Northern elephant seals primarily feed 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, such as squids, make diel vertical migrations and can be found in the DSL (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 Boeuf and Petrinovich 1974). The mean source level of the male-produced vocalizations during the breeding season is 110 dB re 20 µPa (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 vocalizations; they are produced as 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 among seals in which 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).

- **Northern Fur Seal (*Callorhinus ursinus*)**

Description—Northern fur seals are extremely sexually-dimorphic; males are a maximum of 4.5 times heavier 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 long ear flaps (Reeves et al. 1992).

Status—Two stocks of northern fur seals are recognized in U.S. waters: an Eastern Pacific stock and a San Miguel Island stock (Carretta et al. 2006). The Eastern Pacific stock includes the Pribilof Island

breeding group in the Bering Sea (NMFS 1993a). The minimum population estimate for this stock is 676,540 individuals (Angliss and Outlaw 2005). It is a strategic stock because it is considered depleted under the MMPA (Angliss and Outlaw 2005). The San Miguel Island stock is not considered to be depleted under the MMPA (Carretta et al. 2006). A very conservative estimate of the northern fur seal population at San Miguel Island, California, is 4,190 individuals (Carretta et al. 2006). Abundance has increased steadily, except for severe declines in 1983 and 1988, associated with ENSO events (DeLong and Antonelis 1991; Melin and DeLong 2000; Testa 2005).

Both the Eastern Pacific and the San Miguel Island stocks occur in the Pacific Northwest OPAREA and Puget Sound Study Area. Northern fur seals from the Eastern Pacific stock migrate along the coast and offshore from the Pribilof Islands to California (Bigg 1990). Based upon results of satellite tagging studies, adult females and juveniles from the San Miguel Island stock migrate in offshore waters along the coasts of California, Oregon, and Washington State (DeLong, R., NMML, pers. comm., 3 May 2006) and have been recorded offshore of Oregon and British Columbia (Bigg 1990). Therefore, sightings from this stock are possible in the Pacific Northwest OPAREA and Puget Sound Study Area.

Habitat Preferences—The northern fur seal is a highly 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). The subpolar continental shelf and shelf break from the Bering Sea to California provides suitable feeding habitat while northern fur seals are at sea (NMFS 1993a). Rookeries are typically composed of a rocky substrate; however, northern fur seals use sandy beaches for breeding on San Miguel Island (Bonnell et al. 1983; Baird and Hanson 1997).

Distribution—Northern fur seals occur from southern California north to the Bering Sea and west to the Okhotsk Sea and Honshu Island, Japan (Carretta et al. 2006). 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, Robben Island, and the Commander Islands in Russia; Bogoslof Island in the southeastern Bering Sea; and San Miguel and the Farallon islands in California (Pyle et al. 2001; Robson 2002).

Most northern fur seals, excluding those of the San Miguel Island stock, migrate along continental margins from low-latitude winter foraging areas to northern breeding islands (Gentry 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). Adult females and juveniles from the Eastern Pacific stock typically migrate from the Pribilof Islands to feeding areas offshore of British Columbia, Washington State, Oregon, and California, and occasionally to the Mexican border (Gentry 1981; Ream et al. 2005). Adult males generally migrate only as far south as the Gulf of Alaska in the eastern North Pacific Ocean (Kajimura 1984). Some northern fur seals remain near the Pribilof Islands year-round (Bigg 1990). The northward migration begins in March, and most of the Eastern Pacific stock has left the offshore area by June (Antonelis and Fiscus 1980). Adult females and juveniles from the San Miguel stock are found in offshore waters of northern California, Oregon and Washington from October through May or early June. They return to the rookery islands to pup and breed in June and July (DeLong, R., NMML, pers. comm., 3 May 2006).

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>—Northern fur seals are present in the OPAREA and Study Area year-round (Bonnell et al. 1992). They are most abundant there between January and May; sightings are more common off northern Washington State and Vancouver Island coasts in winter and off central and southern Oregon in spring (Bonnell et al. 1992; Laake, J., NMFS-NMML, pers. comm., 3-6 October 2005). The northern fur seal is a coldwater species and is usually sighted offshore and along the continental shelf and slope where they typically forage (Kajimura 1984). Migrating northern fur seals are commonly found in deep waters (>2,000 m) offshore of Oregon and Washington State (Bonnell et al. 1992). Northern fur seals rarely haul out on land during migrations (Bonnell et al. 1983). Some

individuals, mostly juveniles, make their way into the Strait of Juan de Fuca and the Puget Sound Study Area each year (Everitt et al. 1979). An unusual sighting in this area occurred in 1986 when a young male fur seal stranded in Monroe, Washington State. The seal had apparently traveled up the Snohomish and Skykomish Rivers into the Woods Creek (Osborne et al. 1988).

- Upwelling season—The northern fur seal prefers deep waters. The area of primary occurrence for the northern fur seal along the outer coast in the Pacific Northwest OPAREA is in waters seaward of the 100 m isobath (**Figure B-49**). The area of secondary occurrence is in waters inshore of the 100 m isobath, while the inland waters of the Puget Sound Study Area are an area of rare occurrence for this species.

- Relaxed season—The occurrence patterns are anticipated to be similar to those depicted for the upwelling season (**Figure B-49**).

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). On San Miguel Island, pupping season is from late May through July (DeLong 1982). Males establish territories in early to mid-May; females arrive in late May and give birth a few days later (Bonnell et al. 1983). Pups are born between June and August on the Pribilof Islands (York 1987). Northern fur seals exhibit strong site fidelity for mating and birthing; 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; they feed on a variety of fishes and squids throughout their range (Kajimura 1984). Primary prey species include northern anchovy, salmon, walleye pollock, Pacific whiting, market squid, Pacific saury, jack mackerel, rockfishes, sablefish, and the oceanic squids (Onychoteuthis spp.; Antonelis and Perez 1984; Kajimura 1984).

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). Females and pups produce airborne sounds (bawls) to reunite after separation (Thomson and Richardson 1995).

The hearing ability of this species has been measured in air and underwater by behavioral methods. 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). In air, this species can hear sounds ranging from 0.1 to 36 kHz, with best sensitivity from 2 to 16 kHz (Moore and Schusterman 1987; Babushina et al. 1991). There is an anomalous in-air hearing loss at around 4 or 5 kHz, which is attributed to a middle specialization (Moore and Schusterman 1987; Babushina 1999). The underwater hearing range of the northern fur seal ranges from 0.5 Hz to 40 kHz (most sensitive from 2 to 32 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).

- **California Sea Lion (*Zalophus californianus*)**

Description—California sea lions are highly sexually dimorphic. Males are larger, averaging 2.4 m and 390 kg, while females only reach 2.0 m and average 110 kg (Reeves et al. 1992). Pronounced foreheads or sagittal crests easily identify adult males (Heath 2002). The coat color varies from sandy brown to dark brown (Heath 2002).

Status—The U.S. stock of California sea lions is found in the Pacific Northwest OPAREA and Puget Sound Study Area. The minimum population size of the U.S. stock of the California sea lion is 138,881 individuals (Carretta et al. 2006). This number is determined from counts during the 2001 breeding season of all age and sex classes that were ashore at the four major rookeries in southern California and at haulout sites located between Point Conception and the Oregon/California border. An additional unknown number of California sea lions are at sea or hauled out at locations that were not censused (Carretta et al. 2006).

Habitat Preferences—California sea lions prefer to breed on sandy, remote beaches (Le Boeuf 2002). Breeding areas are restricted to productive upwelling zones so that prey is easily available to lactating females (Heath 2002). California sea lions frequent bays, harbors, and river mouths (Jefferson et al. 1993) and often haul out on man-made structures such as piers, jetties, offshore buoys, and oil platforms (Riedman 1990). California sea lions in the Puget Sound Study Area also haul out on log booms and U.S. Navy submarines and are often seen rafted off river mouths (Jeffries et al. 2000; DoN 2001b). They are occasionally sighted up to several hundred kilometers offshore (Jefferson et al. 1993).

Distribution—The range of the California sea lion extends from British Columbia to Mexico. During the summer, California sea lions breed on islands from the Gulf of California to the Channel Islands. The primary rookeries are located on the California Channel Islands of San Miguel, San Nicolas, Santa Barbara, and San Clemente (Le Boeuf and Bonnell 1980; Bonnell and Dailey 1993).

California sea lions congregate near rookery islands and specific open-water areas during the summer. Most stay within 50 km of the rookery islands during this time (Bonnell et al. 1983). They typically feed over the continental shelf and travel within 54 km from the islands but are known to travel as far north as Monterey Bay to feed during the breeding season (Antonelis et al. 1990; Melin and DeLong 2000). Their distribution shifts to the northwest in fall and to the southeast during winter and spring, probably in response to changes in prey availability (Bonnell and Ford 1987). In the non-breeding season, adult and subadult males migrate northward along the coast to central and northern California, Oregon, Washington State, and Vancouver Island and return south the following spring (Mate 1975; Bonnell et al. 1983). Females and juveniles disperse somewhat during the non-breeding season but tend to stay near the rookeries (Bonnell et al. 1983).

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>—California sea lions may be found in the OPAREA and Study Area throughout the year but are most abundant between September and June during the non-breeding season (Bonnell et al. 1983; NMFS 1997b). California sea lions in the Pacific Northwest OPAREA and Puget Sound Study Area are primarily only large, adult males. They occur in Washington State waters from around September through May and are concentrated in the Puget Sound Study Area (NMFS 1997b). They are present along the coast of Oregon from October to April (NMFS 1997b) and the northern coast of California mainly during May and June and September and October (Bonnell et al. 1983). California sea lions often haul out along the coasts and inland waters throughout the OPAREA and Study Area during migrations (**Figure B-50**). Main haulout sites include Cape Alava, Washington State; the Columbia River (South Jetty), Cascade Head, Cape Arago, Orford and Rogue Reefs, Oregon; St. George Reef and Castle Rock, Farallon and Año Nuevo islands California (Gearin et al. 2001; DeLong, R., NMML, pers. comm., 3 May 2006). California sea lions migrate along the coast, usually within 20 km from the shore (Bonnell et al. 1992). They are mostly sighted along the shelf break and continental slope (Bonnell et al. 1983; Calambokidis et al. 2004b).

- Upwelling season—The area of primary occurrence for the California sea lion is from the shore to the shelf break around haulout sites along the outer coast (**Figure B-51**). There is an area of secondary occurrence that buffers the area of primary occurrence out to a generalized 2,000 m isobath. There is a rare occurrence for the California sea lion seaward of the area of secondary occurrence. The Puget Sound Study Area is an area of primary occurrence for this species (**Figure B-52**).

- Relaxed season—The occurrence patterns for the California sea lion are anticipated to be similar to those depicted for the upwelling season (**Figure B-51**, **Figure B-52**).

Behavior and Life History—California sea lions are gregarious during the breeding season. Prior to mating, many females form groups of two to 20 individuals (Heath 2002). In the Puget Sound Study Area, they often haul out in groups of two to 52 individuals (Keple 2002). At sea, California sea lions are usually solitary but tend to form large aggregations near food-rich areas (Antonelis and Fiscus 1980). Male California sea lions are very territorial and must fight other males to maintain their territories. They establish territories in May and fast throughout the breeding season (Heath 2002). Females give birth in May and June and mate during July. They nurse their pups for eight days and then alternate between feeding trips at sea for three days and nursing periods of about two days (Antonelis et al. 1990; DoN 2002c). Pups are weaned between six months and a year or longer (Riedman 1990). Sexual maturity occurs at around four to five years of age, but males are typically not large enough to establish breeding territories for several more years (Heath 2002).

California sea lions feed on a wide variety of prey. Near rookeries in southern California, they primarily feed on Pacific whiting, northern anchovy, jack mackerel, market squid, and rockfish (Antonelis et al. 1990; Lowry et al. 1991). In the Pacific Northwest Region, prey species include Pacific whiting, squid, anchovy, steelhead, lamprey, and salmon (Everitt et al. 1981; Roffe and Mate 1984; Lowry et al. 1991). California sea lions typically feed over the continental shelf and travel within 54.2 km from rookeries but are known to travel as far north as Monterey Bay to feed during the breeding season (Antonelis et al. 1990; Melin and DeLong 2000). Most dives are within 80 m and less than three min long (Feldkamp et al. 1989). Females are known to dive to a maximum depth of 482 m for up to 16 min while foraging during the post-lactating period (Melin 2002).

At sea, California sea lions often “raft” at the surface alone or in small groups and frequently raise their flippers out of the water (Ronald and Gots 2003).

Acoustics and Hearing—In-air, California sea lions make incessant, raucous barking sounds; these have most of their energy at less than 2 kHz (Thomson and Richardson 1995). The male barks have most of their energy at less than 1 kHz (Schusterman et al. 1967). Males vary both the number and rhythm of their barks depending on the social context; the barks appear to control the movements and other behavior patterns of nearby conspecifics (Schusterman 1977). Females produce barks, squeals, belches, and growls in the frequency range of 0.25 to 5 kHz, while pups make bleating sounds at 0.25 to 6 kHz (Thomson and Richardson 1995). California sea lions produce two types of underwater sounds: clicks (or short-duration sound pulses) and barks (Schusterman et al. 1966, 1967; Schusterman and Balliet 1969). All underwater sounds have most of their energy below 4 kHz (Schusterman et al. 1967).

Audiograms are available for the California sea lion. The range of maximal sensitivity underwater is between 1 and 28 kHz (Schusterman et al. 1972). Functional underwater high frequency hearing limits are between 35 and 40 kHz, with peak sensitivities from 15 to 30 kHz (Schusterman et al. 1972). The California sea lion shows relatively poor hearing at frequencies below 1,000 Hz (Kastak and Schusterman 1998). Peak sensitivities in air are shifted to lower frequencies; the effective upper hearing limit is approximately 36 kHz (Schusterman 1974). The best range of sound detection is from 2 to 16 kHz (Schusterman 1974). Older (22 to 25 years of age) sea lions show in-air and underwater hearing losses that range from 10 dB at lower frequencies to 50 dB near the upper frequency limit (Schusterman et al. 2002). Kastak and Schusterman (2002) determined that hearing sensitivity

generally worsens with depth – hearing thresholds were lower in shallow water, except at the highest frequency tested (35 kHz), where this trend was reversed.

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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. 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 six species of sea turtles found in U.S. waters are currently listed as either threatened or endangered under the ESA.

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

Although they are specialized for life at sea, sea turtles begin their lives on land. Aside from this brief terrestrial period, which lasts approximately three months as eggs and an additional few minutes to a few hours as hatchlings scrambling to the surf, sea turtles are rarely encountered out of the water. 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, roots, or other obstacles), are distracted by surrounding conditions (by 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 that 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, macroalgae, 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.A. 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). For turtles, odors might be important for locating feeding sites, nesting beaches, and in social/ mating interactions (Lohman et al. 1999; Vogt et al. 2002). 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. 1969b; Lenhardt et al. 1983; Moein Bartol et al. 1999).

The range of maximum sensitivity for sea turtles is 100 to 800 Hz, with an upper limit of about 2,000 Hz (Lenhardt 1994). Hearing below 80 Hz is less sensitive but still potentially usable to the animal (Lenhardt 1994). Green turtles are most sensitive to sounds between 200 and 700 Hz, with peak sensitivity at 300 to 400 Hz. They possess an overall hearing range of approximately 100 to 1,000 Hz (Ridgway et al. 1969b). Moein 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 (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/species/turtles/conservation/planning.htm), 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 Pacific Northwest OPAREA and Puget Sound Study Area

Four of the seven living species of sea turtles are known or have the potential to occur in the Pacific Northwest OPAREA and Puget Sound Study Area: the leatherback, green, loggerhead, and olive ridley turtles (**Table 3-3**). All four of these species are protected under the ESA. The leatherback turtle is listed as endangered throughout its geographic range, while the loggerhead turtle is listed as threatened. As a species, the green and olive ridley turtles are also listed as threatened, although specific nesting populations in the eastern Pacific Ocean are currently listed as endangered. Green and olive ridley turtles occurring in the Pacific Northwest OPAREA and Puget Sound Study Area may come from either threatened or endangered nesting populations in the Pacific Ocean, although a risk-averse strategy would be to assume that all green and olive ridley turtles encountered in the OPAREA and Study Area come from the endangered ones. Critical habitat has not been designated for any of these species in the U.S. Pacific. A fifth species, the hawksbill turtle (*Eretmochelys imbricata*), is also found in the eastern North Pacific Ocean, although it is not expected to occur in the OPAREA or Study Area. There are no confirmed hawksbill sightings in recent history from the U.S. west coast (NMFS and USFWS 1998a), which indicates that the OPAREA and Study Area is likely situated far beyond the distributional limits of this species.

In the eastern North Pacific Ocean, sea turtles are not particularly common north of Mexico. Sea turtles are much less abundant off northern California, Oregon, and Washington State than they are in more tropical/subtropical areas of the U.S. such as off southern Florida, Puerto Rico, and the Hawaiian Islands. The distribution of sea turtles in ocean waters off the U.S. west coast is strongly affected by seasonal changes in water temperature. In general, sea turtle sightings off the U.S. west coast peak during summer months (July through September) and abnormally warm water years (e.g., El Niño years). During El Niño years, changes in ocean currents bring warmer waters north, which, in turn, has the potential to bring more sea turtles (and their preferred prey) to the region (NMFS 2003).

Throughout much of the year, the Pacific coast of North America experiences cool water temperatures (less than 20°C) well down to Baja California due to strong upwelling and the southward flow of the California current. Due to less than optimal water temperatures in the region, sea turtles are not known to nest on U.S. west coast beaches (Peckham, S.H., Blue Ocean Institute, pers. comm., 29 May 2004). Even if sexually mature sea turtles occupied the waters off California, Oregon, and Washington State and were able to copulate, ovulation and egg development probably would not occur because of cool water temperatures (LeBuff, C.R., Amber Publishing, pers. comm., 29 May 2004). Cool water temperatures off the U.S. west coast may also inhibit reproductive activity by reducing the quality and availability of food

Table 3-3. Sea turtle species with known or potential occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area. Taxonomy follows Pritchard (1997).

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

[a] A species' occurrence in the OPAREA and Study Area can be described as one of the following: Regular—occurs as a regular or normal part of the fauna in the OPAREA and Study Area, regardless of how abundant or common it is; Rare—occurs in the OPAREA and Study Area sporadically; or Extralimital—does not normally occur in the OPAREA and Study Area and occurrences there are considered beyond the species' normal range.

[b] 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. 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 all greens and olive ridleys found in the Pacific Northwest OPAREA are endangered.

[c] The NMFS and USFWS identify the regionally important population of green turtles nesting along the Pacific coast of Mexico, Central, and South America as a distinct population segment. Individuals from this nesting population are known as East Pacific green turtles or black turtles. However, since other non-distinct nesting populations of green turtles exist throughout the Pacific Ocean, it is possible that not all greens found in the Pacific Northwest OPAREA are East Pacific greens.

resources in the area (Fuentes et al. 2000). Regular nesting by leatherback and olive ridley turtles occurs along the Pacific coast of Baja California, which is the northernmost known nesting site in the eastern Pacific Ocean (Fritts et al. 1982; Sarti-M. et al. 1996; López-Castro et al. 2000).

Over the last few years, the NMFS has issued rulings in the *Federal Register*, closing waters off the U.S. west coast to fishing activities (namely drift gillnetting and pelagic longlining) due to adverse impacts caused to loggerhead and leatherback turtles. On 11 March 2004, the NMFS issued a final rule prohibiting fishing with shallow longline sets in Pacific Ocean waters east of 150°W for an indefinite period of time (NMFS 2004a).

The distribution of all available sea turtle occurrence records in the Pacific Northwest OPAREA and Puget Sound Study Area and vicinity by season (upwelling period: April through September; relaxed period: October through March) is presented in **Appendix C**, **Figures C-1** through **C-5**. Sea turtle occurrence records include sightings from NMFS aerial and shipboard surveys, sightings from other sources (non-NMFS surveys and opportunistic encounters), strandings, and incidental fisheries bycatch records. It should be noted that the number of sea turtle records in a given season or portion of the OPAREA and Study Area is often a function of the source or type of data, level of effort, and sighting conditions. Also depicted on all maps in **Appendix C** are tracklines from NMFS aerial and shipboard surveys for which occurrence data were collected.

Unidentified sea turtles (individuals that could not be identified to species) account for a large number of occurrence records, particularly sightings. The hard-shelled sea turtles (which include the green, loggerhead, and olive ridley) are often difficult to distinguish to species, particularly when they are young (i.e., small size classes), during aerial surveys, and/or when observers do not have a high level of experience (Kenney, R.D., University of Rhode Island, pers. comm., 24 February 2005). Species identification is less reliable when individuals from the general public (e.g., commercial and recreational fishermen, beachgoers) sight sea turtles.

A listing and description of data sources used to determine each species' occurrence in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity is found in **Appendix A-3**, while the process used to create the map figures is described in Section 1.4.2.2. On the map figures, various types of shading and terminology designate the areas of occurrence for each sea turtle species. Areas of

"primary" occurrence (shaded in dark blue) are defined as areas and habitats where a species is primarily found. Areas of "secondary" occurrence (shaded in medium blue) are areas and habitats where a species may be found, especially during anomalous environmental conditions (e.g., El Niño events). Areas of "rare" occurrence (shaded in light blue) are areas and habitats where a species is not expected to be found with any regularity. Areas identified as "no systematic survey effort" (hatched) are habitats that have not been adequately surveyed. Protected species biologists with the NMFS-SWFSC ultimately devised these qualitative terms that designate the areas of sea turtle occurrence in the OPAREA, Study Area, and vicinity.

Each sea turtle species known to potentially occur in the Pacific Northwest OPAREA and Puget Sound Study Area is listed below with its description, status, habitat preferences, distribution (including location and seasonal occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area), behavior, and life history. Species appearance within the text follows the taxonomic order as presented in **Table 3-3**.

Figure C-1 is a combined map of all sea turtles (including unidentified sea turtles) since all sea turtles are listed as threatened and endangered.

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—During the upwelling season, there is a secondary occurrence of threatened and endangered sea turtle species along the entire outer coast of the Pacific Northwest OPAREA, from the shore to seaward of the OPAREA boundaries (**Figure C-1**). Occurrence along the outer coast is driven by the leatherback turtle. Since sea turtles seldom frequent Puget Sound, there is a rare occurrence throughout the Puget Sound Study Area (**Figure C-1**).

  There is a rare occurrence of threatened and endangered sea turtle species along the entire outer coast of the Pacific Northwest OPAREA and within the Puget Sound Study Area during the cooler, relaxed season (**Figure C-1**).

- **Leatherback Turtle (*Dermochelys coriacea*)**

  Description—The leatherback turtle is the largest living sea turtle. These turtles are placed in the family Dermochelyidae, a separate family from all other sea turtles, in part because of their unique carapace structure. A leatherback turtle's carapace lacks the outer layer of horny scutes (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 1998d).

  Status—Leatherback turtles are classified as endangered under the ESA. Spotila et al. (1996; 2000) noted that leatherbacks in all oceans are on the road to extinction. 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 1998d). The Pacific Ocean may now contain as few as 2,300 adult females (Crowder 2000).

  Due to the high potential for interactions between leatherback turtles and drift gillnet fisheries off the U.S. west coast, the NMFS has designated a portion of the eastern North Pacific Ocean as a "Pacific Leatherback Conservation Zone" (**Figure 3-6**). From 15 August through 15 November of every year, fishing with drift gillnets with a mesh size ≥14 inches is prohibited in the conservation zone. The conservation zone is roughly located between Point Conception, California (34°27'N) and northern

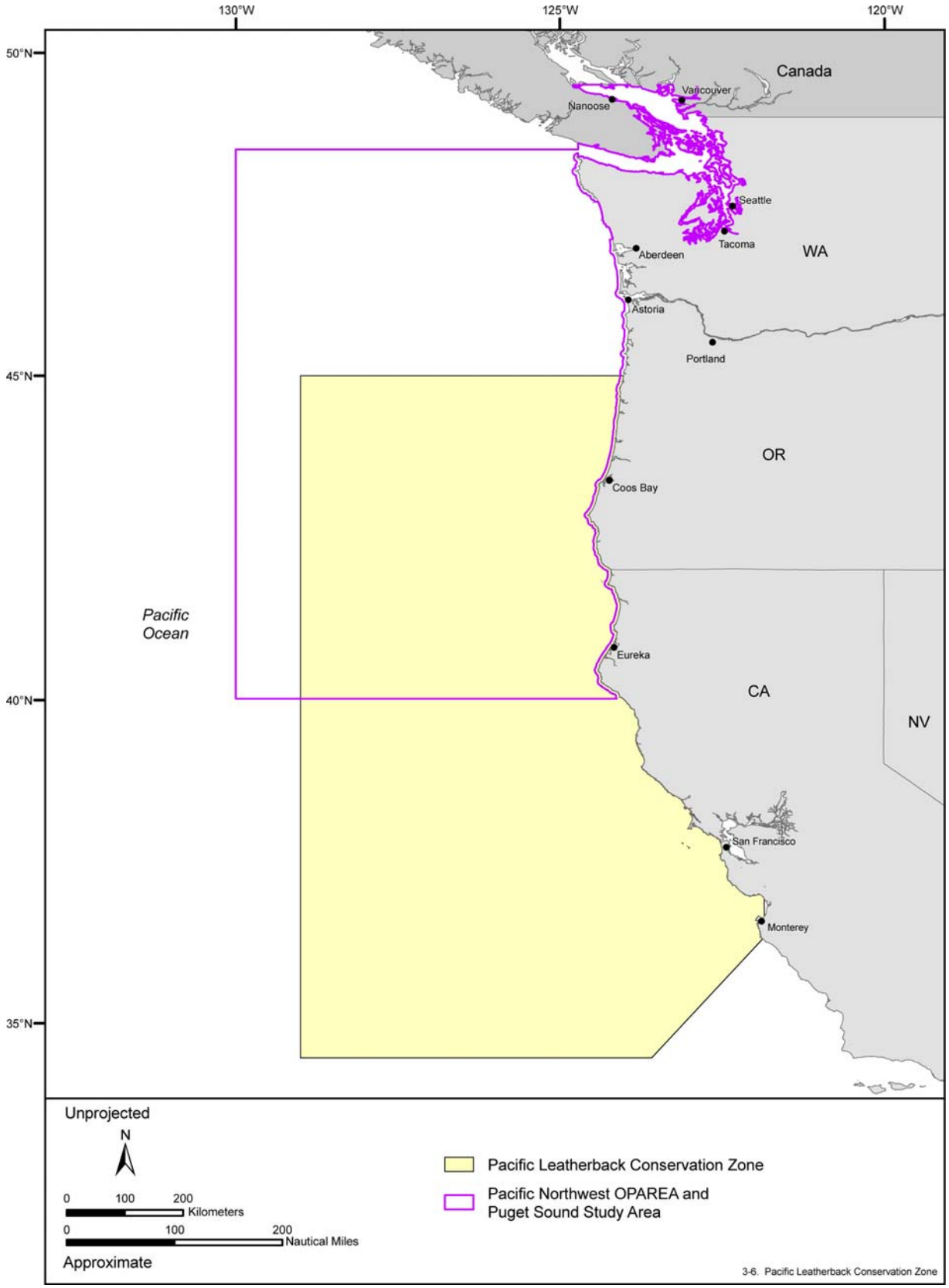


Figure 3-6. The location of the Pacific Leatherback Conservation Zone off the coasts of California and Oregon. This area is closed to drift gillnet fishing from 15 August through 15 November of every year to heighten the protection of leatherback turtles in the area. Source data: 50 CFR 660.713(c).

Oregon (45°N) and is described fully in 50 CFR 660.713(c). The Pacific Leatherback Conservation Zone provides this species with a strong level of protection from gillnet fishermen at a time of the year when they are known to reside off the U.S. west coast.

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 eastern North Pacific Ocean (NMFS and USFWS 1998d). 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 2002a).

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, S.A., WIDECAST, pers. comm., 28 June 2005).

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; James et al. 2005; Eckert, S.A., WIDECAST, pers. comm., 28 June 2005). 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 1998d). 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). 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 1998d; Eckert, S.A., WIDECAST, pers. comm., 28 June 2005).

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 (Eckert 1993; Wing and Hodge 2002). After analyzing over 300 records of sea turtles sighted along the Pacific coast of North America (from 29°45'N northward), Stinson (1984) concluded that the leatherback was the most common sea turtle in eastern Pacific waters north of Mexico. Aerial surveys off the coasts of

California, Oregon, and Washington State have shown that most leatherback turtles occur in continental slope waters, with fewer occurring over the continental shelf (Green et al. 1992, 1993; Carretta and Forney 1993; Bowlby et al. 1994). In October 2004, a single leatherback was sighted during a NMFS-SWFSC pilot study for sea turtles off Oregon and Washington State; this sighting was recorded over 160 km offshore (Dutton, P.H., NMFS-SWFSC, pers. comm., 5 October 2005). Leatherbacks have also been sighted opportunistically in shelf edge waters off Newport, Oregon and Humboldt Bay, California (Smith and Houck 1984).

The seasonal presence of leatherbacks off the U.S. west coast is believed to coincide with the summer arrival of the 16° to 17°C isotherms, which move north from Mexico during May and June (Stinson 1984). Sighting data suggest that leatherbacks begin to appear in ocean waters off central California and further north in the late summer and fall, when SSTs peak as a result of the relaxation of upwelling-favorable winds (Dohl et al. 1983; Benson et al. 2003). In the fall, leatherbacks regularly enter coastal waters off central California, most notably within Monterey Bay (Starbird et al. 1993). The NMFS has indicated that during warm months, leatherbacks may also occur in inshore waters of the Puget Sound Study Area.[1] Stinson (1984) and McAlpine et al. (2004) have reported inshore sightings of leatherbacks from waters as far north as Vancouver Island, British Columbia and Cordova, Alaska.

Historically, some of the world's largest nesting populations of leatherback turtles were found in the Pacific Ocean, although nesting on Pacific beaches under U.S. jurisdiction has always been rare (NMFS and USFWS 1998d). 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). The northernmost nesting sites in the eastern Pacific Ocean are located in the Mexican states of Baja California Sur and Jalisco (Fritts et al. 1982). 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 1998d). Genetic analyses of leatherbacks sampled in the Pacific Ocean indicate that gene flow between eastern and western Pacific nesting populations is restricted (Dutton et al. 1998, 1999, 2000a, 2000b).

- Information Specific to Pacific Northwest OPAREA and Puget Sound Study Area—Leatherback turtles are most commonly sighted in Pacific Northwest OPAREA waters during the upwelling period (**Figure C-2**). Occurrences are much less frequent during the relaxed period, although systematic survey effort during that period is lower. Leatherbacks are the most often-sighted sea turtle species in the Pacific Northwest Region, yet little is known about their seasonal occurrence patterns in eastern Pacific waters north of Monterey Bay. McAlpine et al. (2004) suggest that leatherback occurrences off British Columbia are most frequent from July to September and that the species is an uncommon seasonal resident of those waters.

  Due to the modest number of sightings that have been recorded in ocean waters off northern California, Oregon, and Washington State during the upwelling period, the entire offshore portion of the OPAREA is an area of secondary occurrence from April through September (**Figure C-2**). During the cooler, relaxed period (October through March), the offshore portion of the OPAREA is an area of rare occurrence due to the small number of recorded sightings and strandings (**Figure C-2**). Inshore waters of the Puget Sound Study Area are areas of rare occurrence year-round since the leatherback is primarily an oceanic species. Although Tsao et al. (2005) note that feeding leatherbacks are occasionally sighted in the Strait of Juan de Fuca, they are more apt to be found in deeper, open waters of the Pacific Ocean.

Behavior and Life History—Leatherback turtles primarily feed upon gelatinous zooplankton such as cnidarians (jellyfish and siphonophores) and tunicates (salps and pyrosomas) (Bjorndal 1997; NMFS and USFWS 1998d). 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 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.A. 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, S.A., WIDECAST, pers. comm., 28 June 2005). Studies of leatherback turtle diving patterns off St. Croix, U.S. Virgin Islands (USVI) suggested that individuals forage at night on the 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.A. Eckert et al. 1989). In late summer and fall, potential leatherback prey items in the Gulf of Alaska are often concentrated in the DSL (Hodge and Wing 2000). During migrations or long distance movements, leatherbacks maximize swimming efficiency by traveling within 5 m of the surface (Eckert 2002b; Eckert, S.A., WIDECAST, pers. comm., 28 June 2005).

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, S.A., WIDECAST, pers. comm., 28 June 2005). In the Mexican Pacific, the nesting season extends from November to February, with some females arriving as early as August (Fritts et al. 1982; NMFS and USFWS 1998d). In the western Pacific, 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 50 to over 150 eggs and take between 55 and 75 days to incubate. Females nesting on the Pacific coast of Mexico lay between one and 11 clutches in a single season at nine- to ten-day intervals (NMFS and USFWS 1998d). 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 habitats lasting up to four months (K.L. 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 1998d).

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). 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. 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. Typical dive durations in deepwater habitats averaged 6.9 to 14.5 min per dive, while those in shallow water habitats averaged 7.9 to 12.1 min. On average, day dives tended to be deeper, longer, and less frequent than those at night in both types of habitats (S.A. Eckert et al. 1989; Eckert et al. 1996).

- **Green Turtle (*Chelonia mydas*)**

Description—The green turtle is the largest hard-shelled sea turtle, with adults commonly exceeding 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). In San Diego Bay, and possibly off Baja California, resident populations of *Chelonia mydas* possess physical and genetic characteristics of both the Mexican Pacific and Hawaiian breeding populations (Dutton and McDonald 1990b; Nichols et al. 2000c). 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*.

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. The NMFS and USFWS recognize East Pacific green turtles as a distinct population segment and manage them under a separate recovery plan. East Pacific green turtles have exhibited an extreme decline in numbers over the last 35 years. This is undoubtedly due to the massive overharvesting of wintering turtles in Mexico's Gulf of California between 1950 and 1970 and the intense collection of eggs on Mexican Pacific beaches between 1960 and 1980 (Cliffton et al. 1995). The annual nesting population at the species' primary rookery in Michoacán, Mexico was estimated at around 15,000 females in the early 1970s, but has since dropped to fewer than 1,000 females despite ongoing protection of the nesting beach since 1979 (Seminoff et al. 2003).

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. 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, 1998b; Balazs and Chaloupka 2004). There are no estimates of the current population size of green turtles in the Pacific Ocean (NMFS and USFWS 1998a, 1998b).

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.[2] In recent years, small numbers of early juveniles have been captured by commercial driftnet vessels fishing in international waters to the north and west of the Hawaiian Islands (NMFS and USFWS 1998f). 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; 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 in depth) 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. In the Gulf of California, juveniles and adults display similar feeding tendencies, with most foraging activities occurring in nearshore waters with depths less than 10 m (Seminoff et al. 2002). Green turtles residing in the Hawaiian Islands also primarily forage in coastal waters less than 10 m deep, although some individuals are known to forage and rest at depths of 20 to 50 m (Balazs 1980; Brill et al. 1995).

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 U.S. Pacific waters, green turtles are regularly found off the coasts of southern California, the Hawaiian Islands, American Samoa, Guam, the Northern Mariana Islands, and several of the unincorporated U.S. territories such as Wake Island and Palmyra Atoll (NMFS and USFWS 1998a, 1998b).

Stinson (1984) concluded that green turtles are the most commonly observed hard-shelled sea turtles along the U.S. west coast. Nearly two-thirds of all green turtle sightings in her study area were from southern California and northern Baja California. It is not known whether green turtles encountered along the U.S. west coast are regular migrants from Mexican Pacific breeding grounds or whether they are vagrants that occasionally stray into more northern waters with El Niño currents (NMFS and USFWS 1998b). The northernmost resident population of green turtles in the eastern North Pacific Ocean occurs in the southern half of San Diego Bay (Dutton and McDonald 1990b; NMFS and USFWS 1998b). This small population of green turtles (numbering between 30 and 60 individuals) is believed to favor the warm water effluent that is discharged by the Duke Energy power plant (Dutton et al. 2002). Water in the effluent channel is typically 6°C warmer than that of the rest of the bay and at least 11°C warmer than that of the ocean off San Diego (Dutton and McDonald 1990a). South of the U.S., green turtles are widely distributed in the coastal waters of Mexico and Central America (Cliffton et al. 1995; Cornelius 1995).

During warm spells, green turtles have been sighted in eastern Pacific waters as far north as British Columbia and Alaska (Eckert 1993; McAlpine et al. 2002; Wing and Hodge 2002; McAlpine et al. 2004). There are 31 documented records of green turtles from these two areas (16 from British Columbia, 15 from Alaska). However, most of these encounters involved individuals that were either cold-stressed, likely to become cold-stressed, or already dead (Hodge and Wing 2000; McAlpine et al. 2002). The northernmost green turtle record in the Pacific Ocean is a live individual reported from Copper River Flats, Alaska (60°42'N, 145°00'W; Hodge and Wing 2000). In February 1966, a live green turtle was captured off Coos Bay, Oregon (Forbes and McKey-Fender 1968). It was ascertained that this individual either swam or was carried north by currents to the Coos Bay area. In December 1969, a green turtle stranded at the mouth of Redwood Creek in northern California (Smith and Houck 1984). In addition to these records, a number of strandings have been documented off the coasts of northern California, Oregon, and Washington State by the NMFS-NWR and NMFS-SWR. Combined, these records represent nearly all of the green turtle occurrences that have been recorded in the Pacific Northwest Region (Green, G.A., Tetra Tech EC, Inc., pers. comm., 2 December 2005).

Green turtles nest throughout the Pacific Ocean (between 40°N and 40°S), with active nesting colonies in the eastern, central, and western regions. The main nesting sites for the green turtle in the eastern Pacific are located in Michoacán (Mexico), the Islas Revillagigedos (an isolated group of Mexican-owned islands located about 361 km south of Baja California), and the Galapagos Islands (Ecuador; Dutton 2003). There is no nesting on the U.S. Pacific mainland, although nesting does occur in the Hawaiian Islands and a few other U.S. territories in the insular Pacific Ocean (Eckert 1993; NMFS and USFWS 1998a, 1998b). Dutton (2003) indicated that foraging populations of green turtles along the Pacific coast of Baja California and in San Diego Bay are primarily comprised of individuals from the Islas Revillagigedos nesting stock.

- Information Specific to Pacific Northwest OPAREA and Puget Sound Study Area—The entire Pacific Northwest OPAREA and Puget Sound Study Area is an area of rare green turtle occurrence year-round (**Figure C-3**). This is evidenced by the scarcity of available occurrence data for both the upwelling and relaxed seasons. Nearly all of the available green turtle occurrence records for the OPAREA, Study Area, and vicinity are strandings. McAlpine et al. (2004) describe green turtles as rare vagrants in waters off British Columbia and indicate that they are most likely to be found stranded between October and December. It is likely that green turtle occurrence patterns in the OPAREA and Study Area mirror those off British Columbia. Water temperatures off northern California, Oregon, and Washington State are near the minimum tolerable limits for green turtles throughout much of the year. Even during El Niño events, the waters of the Pacific Northwest Region are still at temperatures below the thermal preferences of this primarily tropical species. Green turtles are much more common in the tropical/subtropical waters off southern California, Mexico, and Central America, which are located a good distance south of the OPAREA (NMFS and USFWS 1998b).

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 eastern North Pacific Ocean, green turtles are known to feed on prey items ranging from eelgrass, red algae, and sea lettuce (plant matter) to sea slugs and possibly pelagic red crabs (animal matter; NMFS and USFWS 1998b; DoN 2000d; Mendilaharsu et al. 2003). Bjorndal (1997) postulated that green turtles in the eastern North Pacific might have more carnivorous diets than those in other regions.

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, 1998b). At Michoacán, mature females nest from one to seven times in a season (two to three times is typical) at approximately two-week intervals and reproduce every two to three years. Average clutch sizes in the eastern Pacific Ocean are known to vary geographically. Green turtle nests at Michoacán contained an average of 65 eggs while nests in the Galapagos Islands contained around 84 eggs (NMFS and USFWS 1998b). Along the Pacific coast of Mexico, nesting primarily occurs between August and January, whereas in the Islas Revillagigedos, nesting occurs over a larger portion of the year (between July and March). Nesting activity peaks in October and November at both locations (Juarez-Ceron et al. 2003).

Green turtles typically make dives shallower than 30 m (Hochscheid et al. 1999; Hays et al. 2000). In the eastern Pacific Ocean, green turtles have been observed at depths of 73 to 110 m (Berkson 1967). In 1997, a maximum dive depth of 164.5 m was recorded for a post-nesting female from Japan's Ogasawara Islands (Matsuzawa, Y., Sea Turtle Association of Japan, pers. comm., 18 August 2005). Although relatively few studies have been conducted on green turtle diving patterns in the eastern Pacific, a number of diving studies have been performed 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).

- **Loggerhead Turtle (*Caretta caretta*)**

Description—The loggerhead turtle 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 loggerhead is between 90 and 95 cm and the average weight is 100 to 150 kg (Dodd 1988; NMFS and USFWS 1998c). Adult loggerheads usually possess a reddish-brown carapace with scutes that are bordered with yellow (NMFS and USFWS 1998c).

Status—Loggerhead turtles are classified as threatened under the ESA. Recent data suggest that loggerhead nesting populations in Japan are in considerable decline (Sato et al. 1997; Kikukawa et al. 1999; Suganuma 2002; STAJ[3]). 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. 2002; STAJ[3]).

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

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; **Figure 3-7**). 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 hard bottom areas (Dodd 1988).

Satellite-tracking studies on loggerheads captured in the Hawaiian longline fishery indicate that individuals traveling west in oceanic waters of the North Pacific Ocean move north and south on a seasonal basis. These individuals move primarily through the region bounded by 28°N and 40°N 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 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.

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 (1998c) indicated that they are less common in the central Pacific than they are in the eastern and western Pacific. In the eastern Pacific Ocean, loggerheads are documented to occur as far north as Alaska (58°N, 152°W) and as far south as Chile (52°S) (Bane 1992; Donoso-P. et al. 2000). Some scientists believe that southern California is the northern limit of the loggerhead's range in the eastern Pacific, with occurrences further north (including infrequent cold-stunnings and strandings along the Oregon, Washington State, and Alaska coasts) identified as casual (Hodge and Wing 2000; Wing and Hodge 2002).

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 1998c; Nichols et al. 2000a; Nichols 2003). Juvenile loggerheads are also common year-round in the coastal waters of southern California, although most sightings occur between July and September (Guess 1982; Stinson 1984). These individuals may represent the northern fringe of the large juvenile population that occurs off the west coast of Baja California (Pitman 1990). Adult loggerheads, on the other hand, are hardly ever seen off the Pacific coasts of the U.S. and Mexico (NMFS and USFWS 1998c).

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; **Figure 3-7**). 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

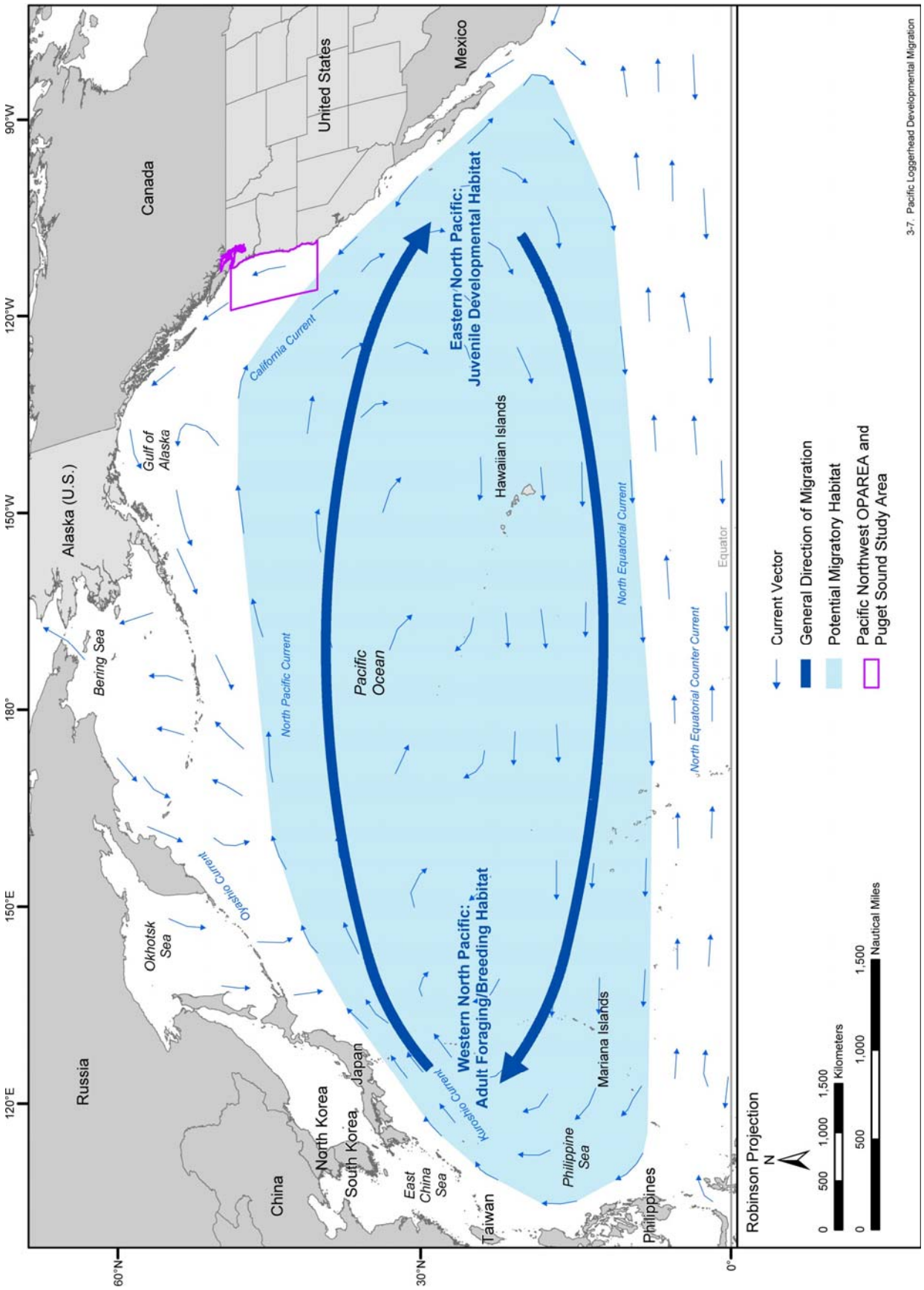


Figure 3-7. The generalized developmental migration of loggerhead turtles in the North Pacific Ocean. After hatching on nesting beaches in southern Japan, loggerheads travel across the North Pacific to developmental habitats in the eastern Pacific before returning as adults to foraging/breeding habitats in the western Pacific. Source information: Nichols (2005). Map adapted from: Pickard and Emery (1982).

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. (2000b) have concluded that loggerhead turtles are highly capable of transpacific migration and that the band of water between 25°N and 30°N, also known as the Subtropical Frontal Zone, may be an important migratory corridor for loggerheads returning to the western Pacific. 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 (Nichols et al. 2000b). 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 to Japan (Parker et al. 2005; Eckert, S.A., WIDECAST, pers. comm., 28 June 2005).

Loggerhead nesting grounds are located in warm, temperate, and subtropical regions (between 40°N and 40°S), 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). There is no loggerhead nesting on the west coast of the U.S. or Mexico (NMFS and USFWS 1998c).

- Information Specific to Pacific Northwest OPAREA and Puget Sound Study Area—Due to the lack of sighting records for both the upwelling and relaxed seasons, the entire Pacific Northwest OPAREA and Puget Sound Study Area is an area of rare loggerhead occurrence throughout the year (**Figure C-4**). The only available records for the OPAREA, Study Area, and vicinity are a few strandings along the coasts of Oregon and Washington State. Although loggerheads may traverse the southwesternmost waters of the OPAREA during developmental migrations to waters off southern California and Mexico (**Figure 3-7**), the likelihood of them taking an extreme northern route across the Pacific Ocean is remote. Instead, juvenile loggerheads will often associate with the TZCF and the northern edge of the Subtropical Frontal Zone, which are located between 28°N and 40°N (Polovina et al. 2000, 2004). During El Niño events, loggerheads that regularly occur off Baja California may expand their nearshore range north into U.S. waters. However, range expansion into waters off northern California, Oregon, and Washington State is not likely.

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 1998c). 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. However, fish and plants are also eaten on occasion (Dodd 1988).

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 (NMFS and USFWS 1998c). Females from the Japanese nesting stock nest at least three times per season, at about two-week intervals (Iwamoto et al. 1985; Eckert 1993). 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).

- **Olive Ridley Turtle (*Lepidochelys olivacea*)**

Description—The olive ridley turtle 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. 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 ETP, probably outnumbering all other sea turtle species combined in the area (NMFS and USFWS 1998e). Cliffton et al. (1995) estimated that a minimum of 10 million olive ridleys were present in ocean waters off the Pacific coast of Mexico prior to 1950. Even though there are no current estimates of worldwide abundance, the olive ridley is still considered the world's most abundant sea turtle in the Pacific and around the world. However, the number of olive ridley turtles occurring in U.S. territorial waters is believed to be small (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 latitude in waters between 23° and 28°C.

Distribution—The olive ridley turtle is a pantropical species, occurring worldwide in tropical and warm temperate waters. It is by far the most common and widespread sea turtle in the 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). Olive ridleys are rarely found north of southern California due to the cold waters of the California and Humboldt currents (Eckert 1993). Wing and Hodge (2002) reported three occurrences in Alaskan waters between 1960 and 2001. There are also a small number of known records for northern California, Oregon, and Washington State, most of which are strandings (Smith and Houck 1984; Richardson 1997a). 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. 2000b; Polovina et al. 2003, 2004).

Genetic analyses of olive ridleys captured in the Hawaiian longline fishery have shown that individuals from both eastern and western Pacific nesting populations forage in the central North Pacific Ocean (Dutton et al. 1999). However, olive ridleys born on eastern Pacific beaches appear to utilize different oceanic habitats in the region from those used by individuals born on western Pacific beaches. Olive ridleys of western Pacific origin have been observed in association with major ocean currents of the central North Pacific, specifically the southern edge of the Kuroshio Extension Current, the Northern Equatorial Current, and the Equatorial Counter Current. These habitats, which are also frequented by loggerhead turtles, are probably not used as frequently by olive ridleys of eastern Pacific origin. Instead, olive ridleys from eastern Pacific nesting populations more often 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 two-thirds of all olive ridleys found in the central North Pacific are derived from eastern Pacific nesting populations (HDLNR 2002).

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). Nesting does not occur along the U.S. west coast (NMFS and USFWS 1998e). In August 1973, a Scripps Aquarium employee observed two olive ridleys mating in the waters off La Jolla, California; however, this reproductive encounter was located far from any known nesting beach (Hubbs 1977).

- Information Specific to Pacific Northwest OPAREA and Puget Sound Study Area—Ocean temperatures likely restrict olive ridley turtles to waters well south of the Pacific Northwest OPAREA (Richardson 1997a; Polovina et al. 2004). As a result, the entire OPAREA and Study Area is an area of rare occurrence throughout the year (**Figure C-5**). The lack of available sighting records for both seasons also lends evidence to this determination. Only a few strandings have been documented along the northern California, Oregon, and Washington State coasts; all were recorded during the cooler, relaxed season. Those stranded turtles probably experienced cold-stunning due to low water temperatures in the area at the time. Focused investigations may reveal that a greater number of olive ridleys reside off the Pacific Northwest coast (McAlpine et al. 2004), although no olive ridleys were sighted during the October 2004 pilot study for sea turtles off Oregon and Washington State (Dutton, P.H., NMFS-SWFSC, pers. comm., 5 October 2005).

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. Off Baja California, olive ridleys may feed almost entirely on pelagic red crabs, which are extremely abundant in that area (Márquez-M. 1990; Pitman 1990). In the central Pacific Ocean, olive ridleys 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. In Costa Rica, *arribada* activity peaks in September and October, while in Baja California, most nesting takes place from July through November (López-Castro et al. 2000). Females usually nest every one to two years. A typical female produces two clutches per nesting season, with each clutch averaging 105 eggs. Lone individuals nest at 15- to 17-day intervals while mass nesters arrive to the nesting beach at 28-day intervals. Incubation time from deposition to emergence is approximately 55 days (Eckert 1993; NMFS and USFWS 1998e).

Relatively few studies have investigated the diving behavior of olive ridley turtles. In the ETP, 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 (Eckert et al. 1986; Polovina et al. 2003). It appears that the ETP'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).

3.2.3 Websites Accessed

[1] Leatherback sea turtle (*Dermochelys coriacea*). Accessed 27 October 2005. http://mehp.vetmed.ucdavis.edu/speciesconcern/seaturtle.html.

[2] The Hawaiian green turtle (*Chelonia mydas*). Accessed 27 October 2005. http://www.turtles.org/hawgrnd.htm.

[3] Sea Turtle Association of Japan (STAJ) website. Accessed 27 October 2005. http://www4.osk.3web.ne.jp/~umigame/E/ETop.html.

3.3 BIRDS

3.3.1 Introduction

The varied and unique landforms comprising the Pacific Northwest marine waters and shorelines provide habitat for a diversity of bird species associated with marine environments.

Unique to the state of Washington and adjacent British Columbia are the inland, deeper waters of Puget Sound, Hood Canal, the Strait of Juan de Fuca, and the Strait of Georgia. Carved by glaciation, they collectively comprise one of the world's largest estuaries, receiving significant freshwater runofforiginating from Cascade and Olympic mountain range interiors (LeBlond 1989), especially the Fraser River (Mackas and Fulton 1989). The surface flow of freshwater as it makes its way towards the sea induces more saline seawater to flow at depth into the estuary, setting up a dynamic circulation (Thomson 1994). This circulation brings rich nutrients into the estuary, these are transported to the surface near river mouths or nearshore tidal zones, supporting the inland water phytoplankton and zooplankton surface production (Mackas and Fulton 1989). In turn, the plankton drives the food web leading to marine birds at the upper trophic levels.

Inland water shorelines are generally rocky with pocket beaches at the mouths of streams and rivers, although extensive mudflats associated with river deltas support seasonally large populations of shorebirds and waterfowl. The circuitous coastline creates numerous bays and inlets, which provide sheltered waters for wintering waterfowl and seabirds. The wintering marine bird populations of these inland waters, composed largely of ducks, gulls, and shorebirds, are generally three times higher than the summer population, composed mostly of gulls and alcids (Nysewander et al. 2005). Much of the inland water shorelines interface with terrestrial forest habitats important to nesting and roosting bald eagles, a prominent predatory bird throughout the inland water region.

Past glaciation and the Olympic Mountains topography also influence the landforms characterizing the Washington outer coast. Several large rivers, plus the glacier-carved Strait of Juan de Fuca, cut through rocky coastlines or large embayments (Grays Harbor and Willapa Bay) before continuing to furrow seven submarine canyons in the continental shelf. These canyons disrupt and intercept the northward flowing California Current, creating pockets of water in a mixing zone near the shelf break or channel the deepwater flow to the surface at canyon headwalls, creating local upwelling zones (Hickey 1995) favored by feeding offshore seabirds and marine mammals. Allen et al. (2001) found that zooplankton (euphausiids) occurring at depth advected coastally (over the shelf) and near the surface by submarine canyon processes.

From Grays Harbor, south through Oregon and northern California, land topography has not been influenced by past glacial activity. Shorelines are generally beaches, characteristically supporting shorebirds, intersected by coastal headlands and rocky islands, which provide roosting habitat for gulls, pelicans, and cormorants. The continental shelf is generally uniform off Oregon and northern California, although five oceanic banks are found off the central Oregon coast. Three prominent features influence the oceanic ecology of Oregon. The first is the Columbia River plume. Depending on the season, the Columbia River effluent amounts to between 60 and 90% (depending on the season) of the freshwater discharge into the Pacific Ocean between the Strait of Juan de Fuca and San Francisco (Barnes et al. 1972). The second feature is Hecata Bank and Stonewall Bank complex, basically a bend in the continental shelf that appears to act as a circulation eddy, especially during the April to October upwelling season, advecting deeper waters over the shallow water over the continental shelf (Bakun 1973). The third is Cape Blanco on the southern Oregon coast. This feature, jutting into the sea, tends to concentrate winds (the Blanco Blow), which coupled with bottom topography, results in intensified upwelling in an area known as the Cape Blanco upwelling zone. Recent studies by Ainley et al. (2005) and Ressler et al. (2005) confirm that large concentrations of zooplankton and seabirds aggregate at the Cape Blanco and Hecata Bank upwelling areas.

Each of the oceanic and coastal topographical features—the cape, banks, submarine canyons, and river discharges—interact with seasonal winds and the California Current (plus the seasonal Davidson

Current) to produce upwelling and other water mixing zones, providing nutrient "hotspots" where seabirds concentrate.

3.3.2 Birds of the Pacific Northwest OPAREA and Puget Sound Study Area

- **Bald Eagle (*Haliaeetus leucocephalus*)**

Description—Bald eagles are among the largest birds in North America. Wing spans range from 2.0 to 2.3 m and body length from 0.8 to 0.9 m. Individuals can weigh from 2.7 to 6.8 kg. Females are larger than males.

Like the other seven species of sea eagles, bald eagles have unfeathered lower legs and large, powerful talons. The plumage of adult bald eagles is characterized by a snowy-white head and tail with deep-brown body and wing feathers. Adults have yellow eyes, beak, and cere (fleshy area at the base of the beak). Juveniles and subadults lack the white head and tail and display widely various patterns of dark brown, light brown, whitish-gray, and white on the body and wing feathers. Early in life, the eyes are dark brown, transforming with age. The beak and cere also start off very dark, almost black. Eagles in juvenile plumage appear larger than adults because of longer feathers, particularly in the wings and tail. These and other details of plumage and color allow the separation of five distinct plumages that correspond to age classes (Stalmaster 1987; Wheeler and Clark 2003).

Status—Bald eagles were listed as endangered in 43 of the 48 lower states under the ESA in 1967. In 1978, the bald eagle was listed as threatened in Minnesota, Wisconsin, Michigan, Washington State, and Oregon. The lower 48 was divided into five recovery regions with Washington State, Oregon, California, Nevada, Idaho, Montana, and Wyoming comprising the Pacific States Recovery Region (USFWS 1986). In 1995, the status of bald eagles was reclassified from endangered to threatened throughout the lower 48 states, which did not change the listing status for Washington State and Oregon. The bald eagle was proposed for delisting on 6 July 1999 (USFWS 1999); the decision on whether to delist the bald eagle is still pending.

There were an estimated 6,471 breeding pairs in 2000, the last year for which there is a complete data set for all the lower 48 states (USFWS 2006a). Although breeding and wintering bald eagle numbers have continued to increase in Washington State, Oregon, and California, and other states since the early 1980s, habitat removal and human disturbance are, and will continue to be, the main threats to bald eagle populations. Past impacts to bald eagle populations include poaching, timber harvesting, reduced salmon runs, and the use of the pesticide DDT; the greatest current threat to eagle populations is the loss of suitable nesting habitat.

- <u>Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area</u>—Bald eagles occur year-round throughout Washington State, Oregon, California, and British Columbia (**Figure D-1**). The foraging range shown in **Figure D-1** is based on previous studies. The typical bald eagle foraging area ranges from approximately 0.4 to 1.1 km during the breeding and wintering seasons, respectively. Nesting bald eagles are opportunistic foragers, but feed most consistently on fish and waterfowl which are usually associated with large, open expanses of water (Stalmaster 1987). Bald eagles most often forage close to shoreline perch trees (distance of 500 m);areas of shallow water may be preferred, because the limited depth brings fish closer to the surface (Buehler 2000). Eagles roost in stands of timber that are adjacent to or relatively near foraging areas; all 26 studied by Watson and Pierce (1998a) were within 1.1 km of foraging areas. A conservative approach was used for this project; this includes areas out to 1.6 km from shore.

  The last statewide surveys in Washington State were conducted in 1998; 664 of 841 known nesting territories were recorded as occupied. From 1981 to 1998, the nesting population in Washington State increased 427%, or about 10% annually (Stinson et al. 2001). There are some indications that the population has reached its carrying capacity in parts of western Washington State (Stinson et al. 2001); the majority of nesting territories occurs within Puget Sound,

particularly the San Juan Islands (**Figure D-1**). However, numerous nesting territories are also found along the outer coast. Winter populations in Washington State are higher (3,500 to 4,000 birds) due to an influx of migrants from Alaska and the Canadian provinces, with particular concentrations along the Skagit, Snohomish, and Nooksack rivers.

In Oregon, the majority of nesting bald eagles occur along the Columbia River south of Portland, along the coast, within the Coast Range, the High Cascades, Klamath Basin, and the upper Willamette River Basin (**Figure D-1**; Isaacs and Anthony 2003). Nesting surveys conducted in 2003 recorded 405 breeding pairs in Oregon, with an additional 40 on the Washington State side of the Columbia River.[1] Population goals in eight of 10 recovery zones for Oregon have been met or exceeded. Wintering bald eagles are found throughout the state, but concentrations occur in areas with dependable food supplies, such as Klamath and Harney basins and along the Snake and Columbia rivers.

In California, bald eagles may be found on most of the lakes, reservoirs, rivers, and some rangelands and coastal wetlands in winter. Breeding habitats are mainly in mountain and foothill forests and woodlands near reservoirs, lakes, and rivers. California currently has an estimated 151 nesting pairs of bald eagles.[2] Most breeding territories are in northern California, althoughnesting occurs in scattered locations in the mountains and foothills of central and southern Sierra Nevada; several locations from the central coast range to inland southern California; and on Santa Catalina Island. As of 1999, only four nesting territories, all inland, were documented in Humboldt County, and none in Del Norte County (**Figure D-1**; CDFG[2]).

Within Washington State, the DoN developed a Bald Eagle Management Plan (BEMP) for its operations at the 4,046 ha Naval Air Station Whidbey Island (NASWI) near Oak Harbor (DoN 1996b). The BEMP has continued to provide long-term guidance to ensure that NASWI operations and land uses are compatible with protecting and enhancing bald eagle populations and their habitat.

Habitat Preferences—Breeding bald eagles nest in large trees near open water that are not typically subject to intense human activity. In some cases, eagles will use smaller, second-growth trees (Stinson et al. 2001). Nesting bald eagles feed most consistently on fish and waterfowl, which are usually associated with large, open expanses of water (Stalmaster 1987). In Washington State, nearly all (99%) bald eagle nests are within 1.6 km of a lake, river, or marine shoreline (Stinson et al. 2001). The distance to open water varies somewhat with shore type. Nests tend to be closer to marine shores and rivers than to lake shores (mean=139 m [marine] versus 202 m [river] versus 304 m [lakes]; Stinson et al. 2001). In Oregon, all nests have been found within 6.9 km of permanent bodies of water, and most nests (85%) are within 1.6 km of water (Anthony and Isaacs 1989). Bald eagles most often forage close to shoreline (distance <500 m) perch trees, and areas of shallow water may be preferred because the limited depth brings fish closer to the surface (Buehler 2000).

Assuming the presence of an adequate food supply, the single most critical habitat factor associated with eagle nest locations and success is the presence of prominent trees (Anthony and Isaacs 1989; Watson and Pierce 1998a). Bald eagles are not old-growth obligates, but need large trees capable of supporting their weight and their massive nests. They typically select the largest trees in a stand for nesting (Anthony et al. 1982). Because average life expectancy of nests is 5 to 20 years (Stalmaster 1987), bald eagles need trees of similar stature located nearby, to serve as replacement nest trees if a nesting territory is to persist at the site.

Behavior and Life History—Bald eagles typically begin breeding at 6 years of age, but sometimes may attempt to breed at 3 or 4 years of age, if food is abundant or little competition for territories exists (Gerrard et al. 1992; Buehler 2000), or may defer breeding until they are 7 or 8 years old, if prey resources are limited or populations are near carrying capacity (Bowman et al. 1995; Buehler 2000). Bald eagles establish and defend their territories from other adult eagles that attempt to intrude. The adult pair attempts to maintain exclusive occupancy of the territory through passive perching atop dominant trees, threat vocalizations, circling displays, and territorial chases. Subadult

eagles are usually tolerated to a greater degree than intruding adults. Eagles occasionally fight using their talons to grasp the opponent while in flight. A nest territory may contain only one nest, but can have several alternate nests (Grubb 1976). Eagles usually return to the same territory year after year provided that a reliable food source remains present.

- Mating behavior—In the Pacific Northwest, territorial eagles engage in courtship behavior during January and February, although some pairs begin to repair nests as early as December (Watson and Pierce 1998a). The courtship of bald eagles can involve vocal displays, various chase displays, and copulation (Stalmaster 1987).

- Nesting and brood rearing—The clutch is most often two eggs (79% of the time), occasionally one (17%) or three (4%; Stalmaster 1987) laid in late March to early April. Most eagles begin to incubate their eggs by the third week in March; incubation lasts for about 35 days. Young typically hatch by late April (Watson and Pierce 1998a). Most young eagles fledge at 11 to 13 weeks of age, usually during early to mid-July (Watson and Pierce 1998a).

- Movements and dispersal—Washington State's breeding adults are on their territories until early fall when they migrate north to coastal British Columbia and southeast Alaska for several weeks to take advantage of food supplies associated with early salmon runs (Servheen and English 1979; Watson and Pierce 1998a). They return to territories in Washington State by January to commence nesting again. Fledglings also disperse northward, but they may remain there for several months before returning to Washington State (Watson and Pierce 1998a). Juvenile eagles from California also migrate north and pass through western Washington State while en route to Canada (Hunt et al. 1992).

  Eagles generally leave northern breeding grounds during fall and seek out milder climates where prey is concentrated during the winter months. Fall migration may be a response to dwindling food supplies on breeding areas, or the lack of feeding opportunities when lakes and rivers freeze over in interior areas. The relatively mild winter climate and abundant fall salmon runs in Washington State and Oregon attract eagles from as far away as the northern Canadian provinces, Alaska, and Montana (Swenson et al. 1986; McClelland et al. 1994; 1996; Harmata et al. 1999; Watson and Pierce 2001). Migrants from Alaska and Canada move south in the fall along both coastal and interior routes. Some of these birds cross the Continental Divide to the Skagit and other coastal rivers of Washington State and British Columbia, while others by-pass Washington State to winter in California (Watson and Pierce 2001). In contrast, many eagles, particularly breeders, in southeast and coastal Alaska do not migrate very far from their breeding areas.

  Watson and Pierce (2001) reported that the average initiation date for fall migration for eagles monitored by satellite telemetry was 17 November (with a range of 13 July to 19 January) in Washington State and lasted approximately 38 days. Initial satellite studies conducted from 1994-1997 at NASWI in Washington State documented fall migration dates and movements for eagles (breeding and non-breeding). Studies showed that territorial birds in the vicinity of the NASWI left territories in early August to early September. One adult female migrated from NASWI approximately 700 km north into British Columbia, covering 2,134 km in 68 days before returning to western Washington State in mid-October (Watson and Pierce 1997).

- Foraging behavior—Bald eagles are capable predators and regularly kill prey using a variety of hunting behaviors. They are known to raid gull and seabird roosts or nesting colonies, and great blue heron (*Ardea herodias*) rookeries to prey on adults, nestlings, or eggs (Kaiser 1989; Norman et al. 1989; Thompson 1989). One foraging tactic used by bald eagles is kleptoparasitism, in which eagles have been documented stealing fish from ospreys (*Pandion haliaetus carolinensis*), gulls, loons, and mergansers (*Lophodytes* spp.), and other prey items from raptors and sea otters (Stalmaster 1987; Watt et al. 1995). Eagle predatory behavior can be disruptive to the nesting success of other birds such as herons, red-tailed hawks (*Buteo jamaicensis*), gulls, and common murres (*Uria aalge*).

Fish are usually the most common prey taken by breeding bald eagles throughout North America, but a variety of birds are also taken (Stalmaster 1987). Direct observations of nesting eagles in the Puget Sound Study Area found that eagles captured fish 78% of the time, 19% birds, and 3% mammals (Watson and Pierce 1998a). Fish that occurred several times in western Washington State studies include flounder, plainfin midshipman (*Porichthys notatus*), dogfish shark (*Squalus acanthias*), sculpin, rockfish, lingcod, walleye pollock, Pacific hake, Pacific cod, cabezon (*Scorpaenichthys marmoratus*), red Irish lord (*Hemilepidotus hemilepidotus*), salmon, and channel catfish (*Ictalurus punctatus*) (Knight et al. 1990; Watson and Pierce 1998a, 1998b). Birds, including gulls (especially glaucous-winged, *Larus glaucescens*), ducks (at least 15 species, especially scoters, mallards, and mergansers), western grebes (*Aechmophorus occidentalis*), common murres, great blue herons, and pelagic cormorants (*Phalacrocorax pelagicus*) were among the most common prey remains (Knight et al. 1990; Watson and Pierce 1998a). Diving ducks are taken by circling above and diving upon the duck, causing it to dive repeatedly until it is so out-of-breath that it is easily taken.

Mammals, including rabbits, raccoons, muskrats, opossums, deer carrion, and the carrion or the after-birth of cattle, sheep, and seals are also eaten by bald eagles (Knight et al. 1990; Seeley and Bell 1994). Bald eagles are known scavengers, feeding on well-decayed flesh or garbage.

- **California Brown Pelican (*Pelecanus occidentalis californicus*)**

Description—Although the brown pelican is the smallest of the world's pelicans, it is still a ponderous bird with a wingspan up to 2.1 m and weighing up to 3.6 kg (USFWS 1985). Brown pelican adults have white heads tinging to yellow during the breeding season. Their long, permanently S-shaped necks are dark-brown during the breeding season and nearly white during the non-breeding period. Their backs are gray-brown giving way to dark brown, nearly black bellies. Juveniles are brown progressing to adult plumage colors as they mature to full adult plumage by their fourth or fifth year. Characteristic of pelicans are their long, pouched bill capable of holding 11 liters of fish and water, and that their feet webbing extends to the fourth hind toe (Shields 2002).

Status—The California population of brown pelican was federally listed as endangered in 1970. Major declines occurred in the 1960s from the effects of chlorinated hydrocarbons (DDT, DDE). Eggshell thinning from these pesticide derivatives resulted in dramatic nesting failures to such an extent, that the 1969 and 1970 nesting seasons were virtually shut down (Anderson et al. 1975; Anderson and Gress 1983). The population was further impacted in the mid-1970s by crashes in stocks of their principle prey, northern anchovy (*Engraulis mordax*). Since that time, the brown pelican population has recovered dramatically with the West Anacapa Island (Channel Islands) colony supporting 4,000 to 6,000 nesting attempts annually.[3]

The California brown pelican subspecies contributes to about half the world's population of just over 100,000 breeding pairs, of which about 45,000 pairs breed at Mexican colonies (Shields 2002).

Habitat Preferences—Brown pelicans in California ground nest on rocky, steep slopes, canyons, and ridgetops of predator-free coastal islands. Individuals also roost and loaf on sandy beaches, offshore rocks, pilings, jetties, and breakwaters (Briggs et al. 1983). Large numbers roost during the winter season on sandy islands, protective of predators and winds, in Oregon and Washington State (e.g., Grays Harbor, Willapa Bay, and the mouth of the Columbia River; Schreiber and Schreiber 1982; Jaques and Strong 2003; Wahl et al. 2005).

Brown pelicans generally forage in the nearshore littoral zone and bay and river channels up to 20 km from nesting islands. They will also forage offshore up to 75 km of the nesting colonies to exploit concentrated prey (Briggs et al. 1983). Foraging offshore beyond the nearshore littoral zone is apparently rare off Washington State (Wahl and Tweit 2000).

Distribution—The California brown pelican is a colonial nester in Mexico and southern California that wanders north as far as British Columbia during the non-breeding period. Brown pelicans nest from

southern California south to Mexico. In California, there are approximately 6,000 annual nesting attempts, about 90% on West Anacapa Island and the rest on Santa Barbara Island or other scattered locations in the Southern California Bight (Shields 2002). Nesting has occurred in central California during past warm-water years (Briggs et al. 1983). Non- and post-breeding birds from Mexico and southern California migrate north during the summer and early fall into central and northern California and the Pacific Northwest. Most individuals return south to breeding colonies by January (Briggs et al. 1981; Briggs et al. 1983), although a few birds overwinter in southern Oregon (Contreras 1998).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Brown pelicans were apparently common inhabitants of Oregon and Washington State, between Willapa Bay and Columbia River, in the 1800s, but declined in the early 1900s (Wahl et al. 2005). In both states, sightings were rare and noteworthy until hundreds came north during the El Niño event of 1983 (Wahl et al. 2005). Thousands of pelicans now seasonally (May through November) inhabit Oregon, Washington State, and northern California (**Figure D-2**), with peak concentrations between July and October (Briggs et al. 1983; 1992; Jaques et al. 2003). Small numbers overwintered in southern Oregon at Coos Bay and Charleston (Contreras 1998). Today, concentrations can be found at Grays Harbor, Willapa Bay, and East Sand Island at the mouth of the Columbia River where Jaques et al. (2003) estimated 9,000 individuals in 2002. Based on the shear numbers of California brown pelicans found north of Mexico in the fall, and the relatively few pairs that nest in California, Briggs et al. (1983) concluded that most birds wintering on the U.S. west coast originate from Mexican colonies. Shields (2002) stated that the "Postbreeding migration out of Gulf of California brings large numbers of *P. o. californicus* to the Pacific coast of California, Oregon, and Washington State in autumn."

  There are occasional incursions of brown pelicans into inland marine waters of Washington State, with most in the Strait of Juan de Fuca to Point No Point (Wahl et al. 2005). Of note, during 1997 there was an incursion of about 300 pelicans into the Strait of Juan de Fuca and about 90 individuals into Hood Canal and central Puget Sound during a warm-water event (Wahl et al. 2005). Inland sightings since then have been rare. Further, brown pelicans were not observed during extensive marine bird studies in the Georgia Strait during the 1980s (Vermeer and Butler 1989), and Nysewander et al. (2005) did not report pelicans during extensive marine bird surveys of Washington State inland waters from 1992 to 1999. Thus, California brown pelican use of the Strait of Juan de Fuca and Puget Sound is apparently rare and episodic.

  In northern California, Briggs et al. (1983) found large numbers of California brown pelicans roosting between Trinidad and the Klamath River between July and October. Important roosting sites included Castle Rock, False Klamath Rock, Klamath River mouth, White Rock, Redding Rock, Big Lagoon, and Flatiron Rock.

  During transect surveys conducted offshore the mouth of Grays Harbor between 1972 and 1998, Wahl and Tweit (2000) recorded 32,533 brown pelicans, of which 97% were observed in channel or littoral waters (<20 m deep), and nearly all the several thousand pelicans observed off Oregon and Washington State by Briggs et al. (1992) were found in nearshore waters. Occurrence farther offshore during the late summer and fall appears to be rare off the Pacific Northwest. Briggs et al. (1983) noticed a pattern of pelican distribution with birds in southern California foraging well out to sea, while birds in central and northern California were found foraging much closer to shore, possibly due to nearshore distributions of northern anchovy. The three locations where large numbers of brown pelicans concentrate in Oregon and Washington State—Grays Harbor, Willapa Bay, and the mouth of the Columbia River—support highly abundant populations of northern anchovy, as well as Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), longfin smelt (*Spirinus thaleichthys*), and eulachon (*Thalichthys pacificus*; Emmett et al. 1991), which may be influencing the nearshore distribution pattern.

Behavior and Life History—Breeding in southern California begins in January and is timed to coincide with the peak in anchovy abundance near the colonies (Anderson et al. 1982; Anderson and

Gress 1983). Females construct nests from sticks supplied by the males. Egg-laying begins the first of March (normal clutch size is three eggs and incubation lasts a month) and young begin to appear by the first of April (Shields 2002). Most young leave their nests and form crèches three to five weeks after hatching, but do not attain flight until about 11 weeks of age (Pinson and Drummond 1993). Most young have fledged by the end of July (Shields 2002). First year birds may wander extensively (Schreiber 1976), but usually return each subsequent year to the natal colony, but do not generally breed until they attain adult breeding plumage (3 to 5 years of age; Blus and Keahey 1978; Schreiber et al. 1989).

Annual productivity is greatly dependent on food supply (Schreiber 1979; Anderson et al. 1982) but averages about one fledgling per nest (Schreiber 1979). Only about 30% survive the first year (Schreiber and Mock 1988). The average breeding life of an adult is four to seven years, with only 2% living longer than 10 years total (Schreiber and Mock 1988). However, brown pelicans are biologically capable of living to 43 years (Schreiber and Mock 1988).

Communal roost sites are essential habitat for brown pelicans (Anderson and Gress 1983), because unlike other seabirds, pelicans have wettable plumage (Rijke 1970), which can become heavy and hypothermic in cold water if they do not come ashore regularly to dry and recondition their plumage. Roost site selection is based on minimal disturbances and microclimate features that aid in thermoregulation, which is why brown pelicans in the Pacific Northwest congregate on islands (inaccessible to predators) located within weather-protected embayments (e.g., Gray Harbor, Willapa Bay, and Columbia River mouth).

Brown pelicans are diving birds that feed almost exclusively on fish and dive from up to 18 m in the air (Carl 1987). In the past, northern anchovies were found to comprise 92% of the diet of California brown pelicans nesting in southern California (Anderson and Gress 1983). In recent years, however, Pacific sardine (*Sardinops sagax*) populations have been increasing and may now be common items in the California brown pelican diet. In the Pacific Northwest, Pacific herring and Pacific sand lance are frequent prey items (Burger et al. 1998).

- **Marbled Murrelet (*Brachyramphus marmoratus*)**

Description—The marbled murrelet is a small alcid (24 to 25 cm long; wing length of 12 to 15 cm; adult mass of 188 to 269 g) with sooty brown to brownish-black upper parts, rusty margins on the back-feathers (area between rump and nape), and reddish scapulars (Carter and Stein 1995). Under parts (chest, sides, flanks) and sides of head to above eye and neck are light, mottled brown (white feathers with broad brown margins). Rectrices and upperwing-coverts are dark brown with occasional white margins and brownish dots on the outer rectrices. Wintering adults are blackish brown above, with bluish gray margins on back-feathers and largely white scapulars (especially inner ones). Non-breeding adults also have white under parts, although some brown gray flecking may persist on sides and flanks (Schreiber et al. 1989; Carter and Stein 1995). Juvenal plumage is similar to that of adult plumage, except the under parts are white and speckled with blackish brown spots, and they are more brownish above and their bluish gray margins are less visible (Schreiber et al. 1989; Shields 2002).

Status—Listed as threatened in 1992 (USFWS 1992), marbled murrelet populations have suffered significant population declines in the Pacific Northwest due primarily to the removal of essential habitat by logging and coastal development (Wahl et al. 2005). To stem these declines, critical habitat was designated (**Figure 3-8**; USFWS 1996b); this includes 1,573,353 ha of mature and old-growth forest nesting habitat in Washington State, Oregon, and California. All critical habitat is located onshore and outside of the Pacific Northwest OPAREA and Puget Sound Study Area. The designation of critical habitat contributes to the species conservation by identifying areas that contain essential nesting habitat features, or areas that may require protection or special management. Fisheries, especially gill-net fisheries, and oil spills have also contributed to population declines. An estimated 3,500 marbled murrelets are killed annually in Alaska by gill-net fisheries (Carter et al. 1995; Piatt and Naslund 1995); Carter and Sealy (1982) estimated that between 175 and 250 birds

(at least 6.2% of the local population) were killed in a single season of gill-net fishing in Barkley Sound, British Columbia. Pierce et al. (1996), however, found little mortality associated with tribal gill-net fishing in the Puget Sound Study Area.

Over 1,000 oiled marbled murrelet carcasses were collected after the *Exxon Valdez* oil spill in Alaska (Carter and Kuletz 1995). Several hundred, or more, were killed off California, Oregon, Washington State, and British Columbia from six separate oil spills in the 1980s and 1990s (Carter and Kuletz 1995).

Most marbled murrelets live in Alaska where the population is estimated at between 200,000 and 800,000 (Isleib and Kessel 1989; Piatt and Ford 1993; Piatt and Naslund 1995; Nelson 1997). Population estimates for British Columbia are 55,000 to 78,000 (Rodway et al. 1992; Burger 2002), Washington State 5,000 to 6,500 (Speich and Wahl 1995; Varoujean II and Williams 1995), Oregon 6,600 to 20,000 (Strong et al. 1995; Varoujean II and Williams 1995), and California 6,450 (Ralph and Miller 1995). The great variation in the Oregon population estimates relates more to differences in how correction factors were applied to observed densities in two separate studies (Strong et al. 1995; Varoujean II and Williams 1995) than to great differences in observed densities. Overall, Beissinger's (1995) demographic trend analyses suggested that the North American marbled murrelet population has been declining as much as 4 to 7% per year.

Habitat Preferences—In general, marbled murrelets south of southeast Alaska nest in trees, while those west of Kodiak Island nest on the ground, with an overlap in nesting modes between Kodiak and Prince of Wales islands. The great majority (97%) of marbled murrelets in Alaska nest in trees (Piatt and Ford 1993). In Alaska, both tree and ground nests are usually found within 6.4 km from the coast (Simons 1980; Hirsch et al. 1981; Day et al. 1983; Johnston and Carter 1985; Naslund et al. 1995), while in the Pacific Northwest, most nests are found within 30 km of marine waters (Hamer and Nelson 1995a), although Hamer (1995) detected nesting murrelets in western Washington State as far as 84 km from the nearest saltwater.

Tree nests are found primarily in old-growth conifer forests, or mature forests with old-growth components or trees with large branch platforms or mistletoe clumps (Naslund et al. 1995; Nelson 1997). Marbled murrelets do not build a nest, but rather are dependent on features, such as moss or needle piles, to hold their single egg on tree limbs, or mistletoe clumps (Nelson 1997). Multi-storied canopy layers and less than average canopy closures are also an important feature in nesting forest stands (Grenier and Nelson 1995; Hamer and Nelson 1995a; Miller and Ralph 1995). In both Washington State and Oregon, nesting stands are dominated by trees greater than 81 cm in diameter. In Oregon and Washington State, most (71%) nests have been found in Douglas-fir (*Pseudotsuga menziesii*) trees, followed by western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), and western red cedar (*Thuja plicata*), while in California, 10 nests have been found equally distributed in coastal redwoods (*Sequoia sempervirens*) and Douglas-fir (Hamer and Nelson 1995a). Habitat along major drainages is a key habitat component (Nelson 1997), as murrelets tend to use these as flight corridors to and from inland nest sites.

Distribution—The North American race of marbled murrelet (*Brachyramphus marmoratus*) is distributed along the coastal margins of the Gulf of Alaska from Attu Island near the end of the Aleutian Archipelago to British Columbia, then south along the Pacific coast to south Humboldt County, California. A disjunct breeding population is found in Half Moon Bay and its vicinity, in central California (Nelson 1997). The distribution south of central Alaska appears to be associated with the nearby presence of suitable forest nesting habitat (Ralph and Miller 1995). Marbled murrelets are observed during the breeding season as far inland as 88 km in Washington State and 50 km (confirmed nest) inland in Oregon (Nelson 1997). A grounded juvenile was found in British Columbia 101 km inland of marine waters (Rodway et al. 1992), and there are possible vagrant records to 129 km inland in Oregon (Nelson 1997).

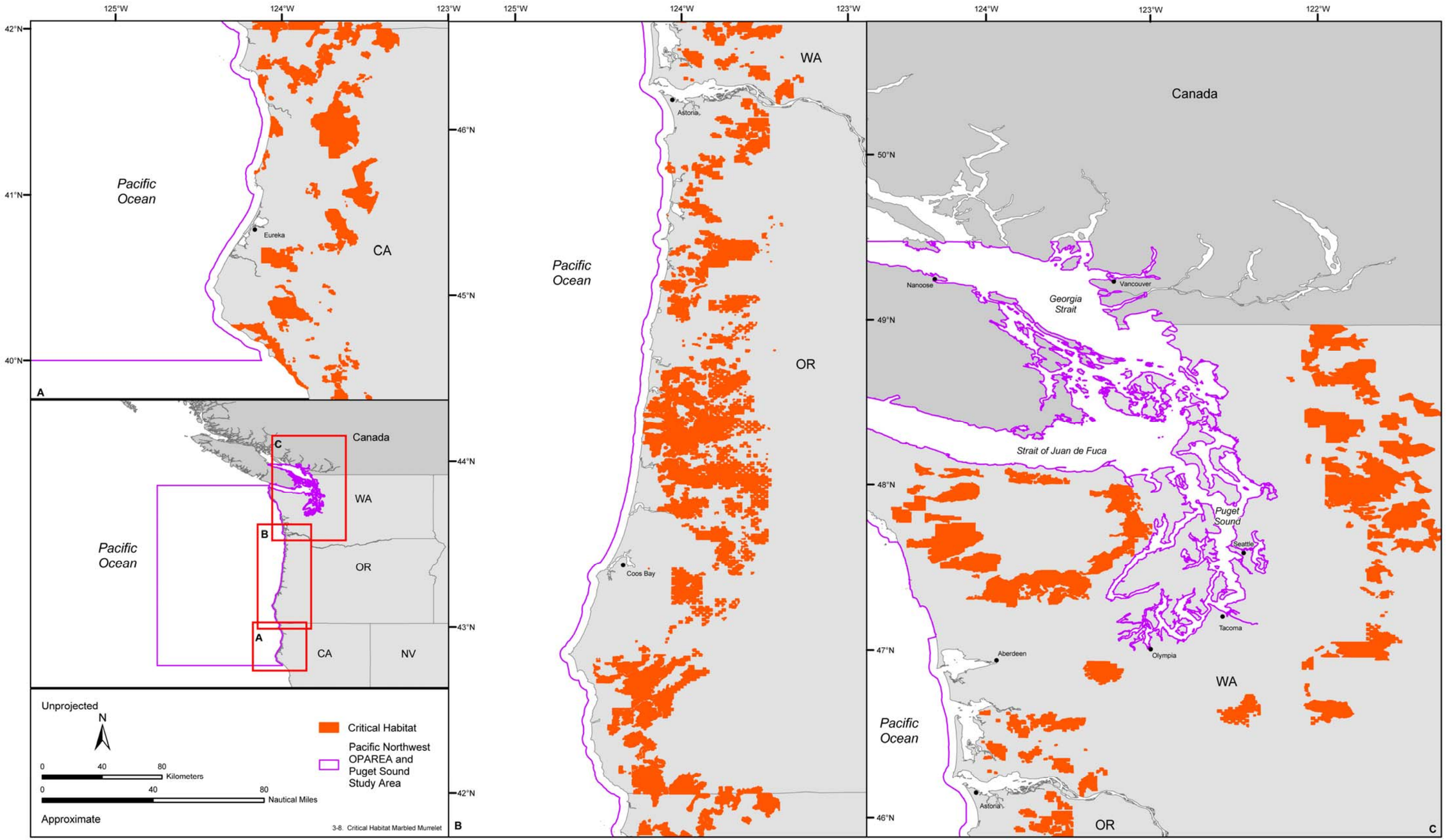


Figure 3-8. Designated critical habitat for the marbled murrelet. Source data: USFWS (1996).

Winter distributions of marbled murrelets are poorly documented. In Alaska, many birds apparently move offshore as far as 300 km (Piatt and Naslund 1995), while others, especially in British Columbia, move to sheltered waters (Burger 2002). California birds will disperse in the winter as far south as southern California and northern Mexico (Erickson et al. 1995). In the Pacific Northwest, where winter survey data is limited, marbled murrelets appear to overwinter within their breeding range, although Nysewander et al. (2005) found that the Puget Sound population of murrelets increases during the winter, likely from winter immigrants.

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—Marbled murrelets occur year-round in all inland marine waters of the Strait of Juan de Fuca, Puget Sound, and Georgia Strait, and the entire nearshore outer coast from Cape Flattery, Washington State, south to south Humboldt County, California (**Figure D-3**; Strong et al. 1995; Varoujean II and Williams 1995). During summer aerial surveys conducted between 1992 and 1999, marbled murrelets were distributed throughout the inland marine waters of Washington State (with notable gaps between Everett and Tacoma) during the summer, with concentrations in the San Juan Islands, north Hood Canal, and along the south coast of the Strait of Juan de Fuca. By winter, there was a definite shift towards the more protective waters embayments of the San Juan Islands, Hood Canal, Discovery Bay, Saratoga Passage, and Port Townsend, although some murrelets could be found throughout the summer range.

  Although all marbled murrelet critical habitat is located onshore, birds will forage for prey offshore, in the Pacific Northwest OPAREA and Puget Sound Study Area. Strong et al. (1995) and Ralph and Miller (1995) looked at summer offshore distributions of marbled murrelets off Oregon and northern California, respectively, and both found murrelet sightings to drop off to near zero at about 6 km offshore. Speich and Wahl (1995) examined murrelet distribution off the Washington State coast by water depth and found 97% of the sightings inshore of the 50 m isobath and 93% inshore of the 20 m isobath (littoral zone; off Grays Harbor, where their study was focused, the 20 m isobath is approximately 6.5 km offshore). Other studies (Varoujean II and Williams 1995; Thompson 1999) also measured murrelet distance from shore, but their transect lines were truncated (usually less than 2 km) before they reached the outer limits of marbled murrelet occurrence.

  Nysewander et al.'s (2005) surveys clearly show that marbled murrelets tend to concentrate in nearshore areas of the inland marine waters of Washington State. However, both their summer and winter surveys, as well as surveys conducted by Speich and Wahl (1995) and Pierce et al. (1996) show that these birds can be found throughout all water depths of Puget Sound and the Strait of Juan de Fuca, leading O'Neil et al. (2001) to classify marbled murrelets as highly associated with inland deep water habitats.

Behavior and Life History—Since marbled murrelets are difficult to observe, data on their behavior and life history is incomplete (Nelson 1997), although some information has been collected on diet, mortality, and nesting phenology (plus distribution and habitat use, as mentioned above).

Predation is a major contributor to nest failure (as high as 72% in some populations; Nelson and Hamer 1995; Nelson 1997). Chicks and eggs are often left unattended by adults, especially at nests that are considerable distances inland, where there is vulnerability to predation by Steller's jays (*Cyanocitta stelleri*), common ravens (*Corvus corax*), and sharp-shinned hawks (*Accipiter striatus*; Singer et al. 1991; Marks and Naslund 1994; Nelson and Hamer 1995). The latter two species are also known to also kill nest-attending adults; adults are vulnerable to peregrine falcon predation during transit flights.

Nesting phenology is protracted and variable. Pairs may be seen year-round, both in ocean and forest habitats, and courtship behaviors have been witnessed from winter to summer (Levy 1993; Nelson 1997). Timing of breeding is affected by food availability and weather; nest initiation may begin as early as early March or late as mid-July. The length of the nesting season changes with latitude. In California, the nesting season last about 170 days, while in Oregon it is about 149 days

and only 106 days in Alaska (Hamer and Nelson 1995b; Nelson and Peck 1995). It is unknown if late breeders actually renest after initial failure, or possibly double-brood (Naslund et al. 1995; Nelson 1997), although a bimodal nesting chronology suggests the latter does occur in California (Hamer and Nelson 1995b).

Compared to other alcids, marbled murrelets have a short (27 to 30 day) incubation period, and produce a single egg (De Santo and Nelson 1995). Chicks leave the nest at between 27 and 40 days of age, with the variability probably due to differences in food-provisioning rates (Nelson 1997). The earliest recorded fledging date is 20 May (California), while the latest is 21 September (Oregon) (Hamer and Nelson 1995b). Fledglings begin arriving at sea during May peaking by mid-summer (Hamer and Nelson 1995b).

Burkett (1995) compiled foraging data from 26 North American studies and determined that, in general, marbled murrelets forage on invertebrates, especially euphausiids, during the winter and spring months, and then switch to small schooling fish during the summer and fall. Pacific sand lance is the most important fish prey item, especially in the northern half of the bird's range. Other important fish prey includes Pacific herring, smelt, northern anchovy, and Pacific sardine, the latter two especially in California (Burkett 1995).

- **Short-tailed Albatross (*Phoebastria albatrus*)**

Description—The short-tailed albatross is the largest of the three North Pacific albatrosses with a body length of 84 to 94 cm and a wingspan of 2.1 to 2.3 m (Harrison 1984). Adult short-tailed albatrosses are readily distinguishable from other Pacific albatrosses by their entirely white back and large bubble-gum pink bill that is strongly hooked at the end. Juveniles are entirely dark during their first year, but can be distinguished from young black-footed (*Phoebastria nigripes*) and Laysan (*Phoebastria immutabilis*) albatrosses by their large pale bill and pale legs (USFWS 2001b). Juveniles go through successive plumage changes until developing the characteristic golden crown and nape of adulthood at about the age of 12 years (Rice 1984; Sibley 2000).

Status—The short-tailed albatross was listed as endangered throughout its range under the ESA in 2000 (USFWS 2000b). During the late 1800s, the world population of short-tailed albatrosses was decimated for their plumage. Approximately five million birds were killed between 1885 and 1903 at the Torishima Island (Japan) colony alone. By 1932, short-tailed albatrosses had been extirpated from at least a dozen known nesting locations in Japan and Taiwan, prompting the Japanese government to attempt to protect the remaining birds at Torishima. The edict declaring the island a bird refuge came too late and, coupled with volcanic eruptions in 1939 and 1941, resulted in the disappearance of the last remaining colony. After an extensive investigation of the historical breeding sites, Austin (1949) declared the species extinct. Yet, breeding was again reported at Torishima in 1950, presumably by birds that were wandering juveniles during the final years of slaughter (Tickell 2000). By 1954 this colony had grown to 25 birds with at least six breeding pairs (USFWS 2000b), and by 1998, Hasegawa estimated that there were 388 breeding birds present. A second colony (12 adults) was rediscovered at a former breeding site at Minami-kojima in the Senkaku Islands in 1971 (Hasegawa 1984); however, the first chick was not observed until 1988. By 1999, this colony had grown to 150 birds and 30 breeding pairs. The 2005 estimate was 1,712 individuals and 513 pairs at Torishima, and 340 birds and 85 breeding pairs for Minami-kojima (USFWS 2005d), showing both colonies to continue to grow at rapid rates. The Torishima colony has been growing at an annual rate of between 6.5 and 8.0% the past 20 years, while the average annual growth rate of the Minami-kojima colony was recently estimated at 11% (USFWS 2005d).

Since the 1930s, short-tailed albatross have been occasionally reported during the breeding season at Midway Atoll, where two million black-footed and Laysan albatross nest. Some of these individuals would return year after year, but the first confirmed nesting with egg did not occur until 1993 (Harrison et al. 1984), although disputed successful nesting was report in 1961 and 1962 (Tickell 2000). The 1993 nesting was by an eleven-year-old female from Torishima that laid eggs again at Midway in 1995 and 1997. In all cases the eggs were inviable.

Short-tailed albatross were also once reported to nest in the Aleutian Islands of Alaska based on faunal records, sightings, and local lore. Yesner (1976) investigated this contention and concluded that while short-tailed albatross were numerous summer visitors and hunted by local Aleuts, no evidence of nestling age albatross could be found in the archaeological record.

Plastics, which may be mistaken for food items or may have food such as flying fish eggs or invertebrates attached, are commonly ingested and contribute to chick mortality (BLI 2001; R. Suryan, Oregon State University, pers. comm., 8 August 2006). Other sources of mortality include volcanic eruption (at Torishima), typhoons, demersal longline fishery (Alaska and Russia), jig/troll fishery (Japan), invasive species at colonies (cats, rats, and plants), and researcher disturbance (USFWS 2005d).

Habitat Preferences—Current and historical nesting habitat can be described as flat to steep slopes, sparsely or fully vegetated, on isolated and windswept offshore islands. On Torishima, short-tailed albatross nest on steep slopes of loose volcanic ash (Tickell 2000; USFWS 2005d).

Recent observational and telemetry data (USFWS 2005d) clearly show that, while at sea, short-tailed albatross concentrate along the shelf edge north and south of the Aleutian Islands and along the Bering Sea shelf. Piatt et al. (2006) believe that short-tailed albatross are so closely tied to Alaska shelf edge upwelling zones that their distribution can be readily predicted. Past premises of short-tailed albatross as a “coastal” bird is apparent only in the Aleutian Islands where the shelf break is very close to island shorelines. Upwelling zones are not only nutrient-rich, but they bring deeper water squid and fish to the surface, where they become available to albatross.

Distribution—Short-tailed albatrosses are pelagic wanderers, traveling thousands of miles at sea during the non-breeding season. Their at-sea distribution includes the entire North Pacific north of about 20°N, including the Bering Sea and Okhotsk Sea. However, recent telemetric data, and opportunistic observational data, indicate that these birds concentrate along the continental shelf edges of the North Pacific, especially along the Aleutians in the Bering Sea (Piatt et al. 2006). Two immature males tagged at-sea in the Aleutian Islands and tracked for approximately 100 days from August to November 2003 are shown in **Figure 3-9**. Both individuals traveled approximately 25,000 km between Japan and the Pacific Northwest (Suryan et al. 2006).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—There are few records of short-tailed albatross for the Pacific Northwest (**Figure D-4**) compared to the shelf waters of Alaska. Suryan et al. (2006) tracked an immature male throughout the Pacific Northwest OPAREA in November 2003 (**Figure 3-9**). Of the 14 short-tailed albatrosses in the study, this is the only individual that traveled to the Pacific coast of the U.S. Prior to 1993, there were no confirmed records of short-tailed albatross for Washington State for 96 years. Since 1993, there are four records: three over Grays Canyon (50 to 60 km west of Grays Harbor) (Wahl et al. 2005) and a fourth record off Edmonds in Puget Sound. Verifiable Oregon records include two sightings 51 km west of Yachats (Lincoln County)—one on 11 December 1961 and the other on 24 March 2001; one in June 1978, 32 km west of the Columbia River mouth; and one during November 1996, 82 km west of Arch Cape (Clatsop County). The four other records include a sighting in October 2000, again 52 km west of Yachats; an October 1979 record at the mouth of the Columbia River; a September 1989 sighting, 32 km west of Depoe Bay; and a December 1999 record, 34 km off Curry County.[4] Roberson describes 12 recent (1977 to 2000) records from California, four from Monterey Bay where they were once considered common in the late 1800s.[4] None of these California records are from waters specific to the Pacific Northwest OPAREA. The collective records for Washington State, Oregon, and California indicate that this albatross could occur off the U.S. Pacific coast at any month of the year.

Behavior and Life History—Short-tailed albatrosses are long-lived birds (>40 years) that may begin breeding at age seven or eight, but do not attain full adult plumage until age 12 (Harrison 1990; USFWS 2001b). Nesting begins in October, with the hatching of the single egg in late December and

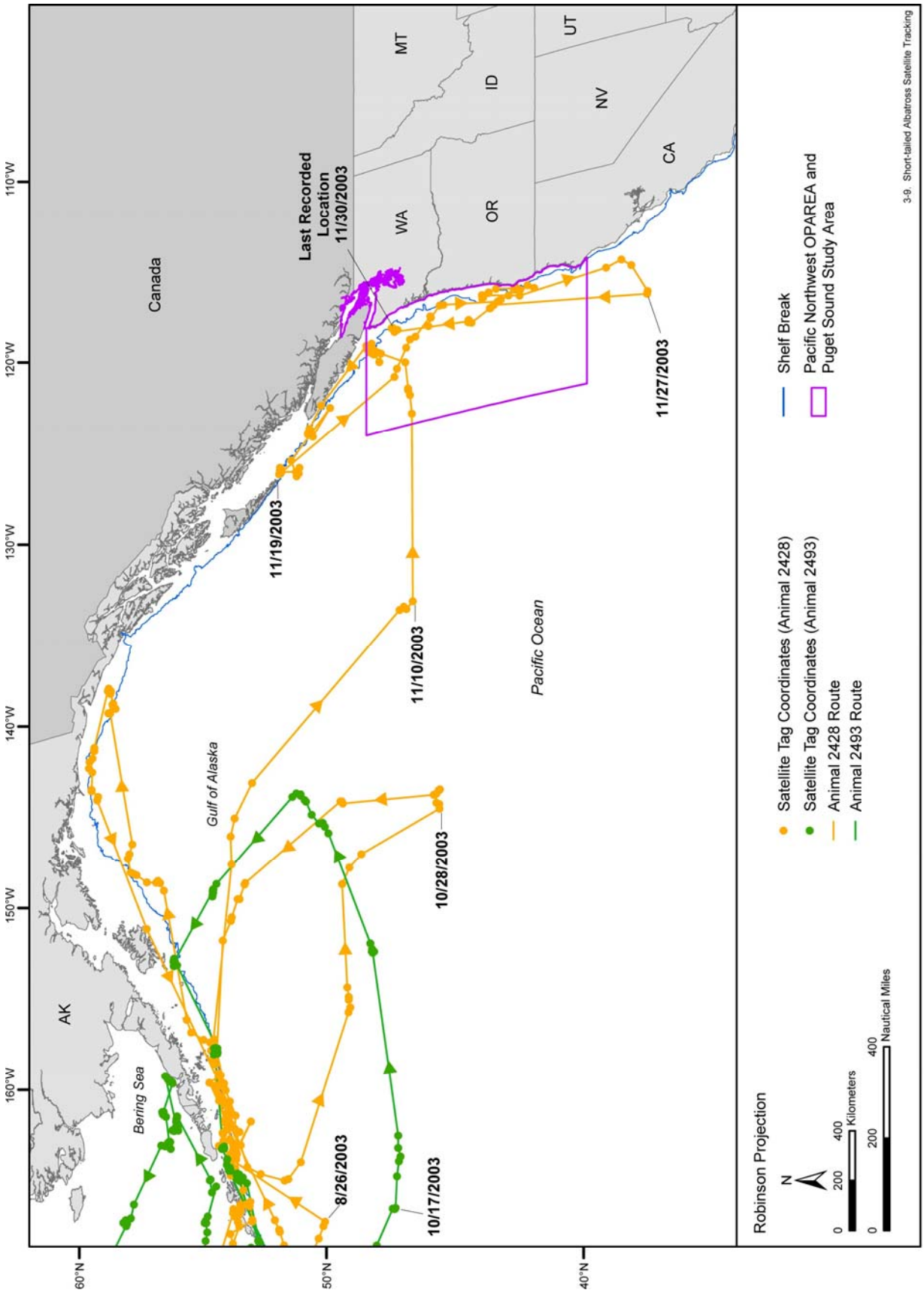


Figure 3-9. The movement of two immature short-tailed albatrosses tagged at-sea in Seaguam Pass, Aleutian Islands, Alaska. The individuals were tracked from August to November 2003. Satellite-tag coordinates with location class (LC) of 3 (accurate within 150 m) and other filtered data points (accuracy is <1.2 km [SE = 0.66] for LC 3-A and <7.1 km [SE = 15.3] for LC B) are presented. Source data: Suryan and Balogh (2006); Suryan et al (2006).

January. Fledging occurs in late April and early June, and the colony is totally deserted by mid-July (R. Suryan, Oregon State University, pers. comm., 8 August 2006). Non-breeders and failed breeders disperse from the colony months sooner. While many non-breeders return to the colonies each year, the presence of immature birds far from the colony (e.g., U.S. Pacific coast) during the breeding season suggests that some immature birds may spend years at sea before returning to the colony.

Like all albatrosses, short-tails use their long, low drag wings to skim the ocean waves using a method called dynamic soaring, which allows them to cover great distances with little effort. Most of their travel is concentrated along the continental shelf edge upwelling zones where they forage on squid, fish, shrimp and other crustaceans, and flying fish eggs (USFWS 2005d).

- **Western Snowy Plover (*Charadrius alexandrinus nivosus*)**

Description—The western snowy plover is a sparrow-sized shorebird (15 to 17 cm long and weighing 34 to 58 g) with a gray-brown back marked with a white hind neck collar and white belly (Page et al. 1995). Individuals have a black/brown forehead bar and eye patches with blackish bills and legs. During breeding season, adults develop dark markings on the head and breast; these are generally black on males and brown on females. Males will also develop rufous crowns early in the breeding season. During the non-breeding period, adults loose their breeding plumage and the sexes become indistinguishable. By October, juveniles also become indistinguishable from adults as their juvenile feather patterns (white edges on wing coverts and scapulars) wear.

Status—Once widely distributed and abundant along the Washington State, Oregon, and California coasts, this breeding population has been reduced to about 2,000 birds (USFWS 1995; USFWS 2001a). After continuing to witness significant declines in the 1980s, the USFWS (1993) listed the Pacific coast population as threatened in 1993. A petition was set forth to delist the species in 2004; however, following status review, the petition was deemed unwarranted and the western snowy plover remains listed (USFWS 2006a; USFWS 2006b). Because of poor early account records, the decline in Washington State is difficult to quantify, other than that only three of five historic nesting beaches were active in the late 1990s (USFWS 2001a). Western snowy plovers have historically nested at 29 coastal locations in Oregon, but at only nine sites by 1991 and eight sites by 2004. Since intensive population monitoring began in 1978, the Oregon coast adult population estimates ranged from a high of 139 in 1981 to a low 30 in 1992. The 2004 estimate, 120 breeding adults, showed a great improvement since the 1990s. During the initial 1977 population estimation surveys conducted in California, Page and Stenzel (1981) recorded 11 breeding adults in Del Norte County and 54 in Humboldt County. By 1995, the Del Norte population declined to zero and the Humboldt population to 19 birds. By 2002, the Humboldt population had increased to 63 (although Del Norte County still did not support western snowy plovers).

The primary agents causing declines have been habitat degradation by human disturbance (especially recreation), urban development, introduced beachgrass (*Ammophilia* spp.), and expanding predator populations (USFWS 2001a).

In an effort to ameliorate these impacts, the USFWS (2005e) designated critical habitat at three locations in Washington State, seven locations in Oregon, and seven locations in California (six in Humboldt County and one in Del Norte County; **Figure 3-10**).

Habitat Preferences—The Pacific coast population of the western snowy plover breeds and winters primarily on coastal beaches, including sand spits, dune-backed beaches, beaches at river and creek mouths, and lagoon/estuarine saltpans (USFWS 2001a). Individuals also occasionally use bluff-backed beaches, dredged material disposal sites, salt pond levees, dry salt ponds, and river bars. Nest sites are usually found on sandy or saline substrates with little or no vegetation and debris (e.g., driftwood; Widrig 1980; Page and Stenzel 1981). Although western snowy plovers move up and down the west coast during the non-breeding season, they primarily winter on the same beaches used for breeding (Page et al. 1995). The waterlines of these same beaches constitute their foraging habitat (Page et al. 1995).

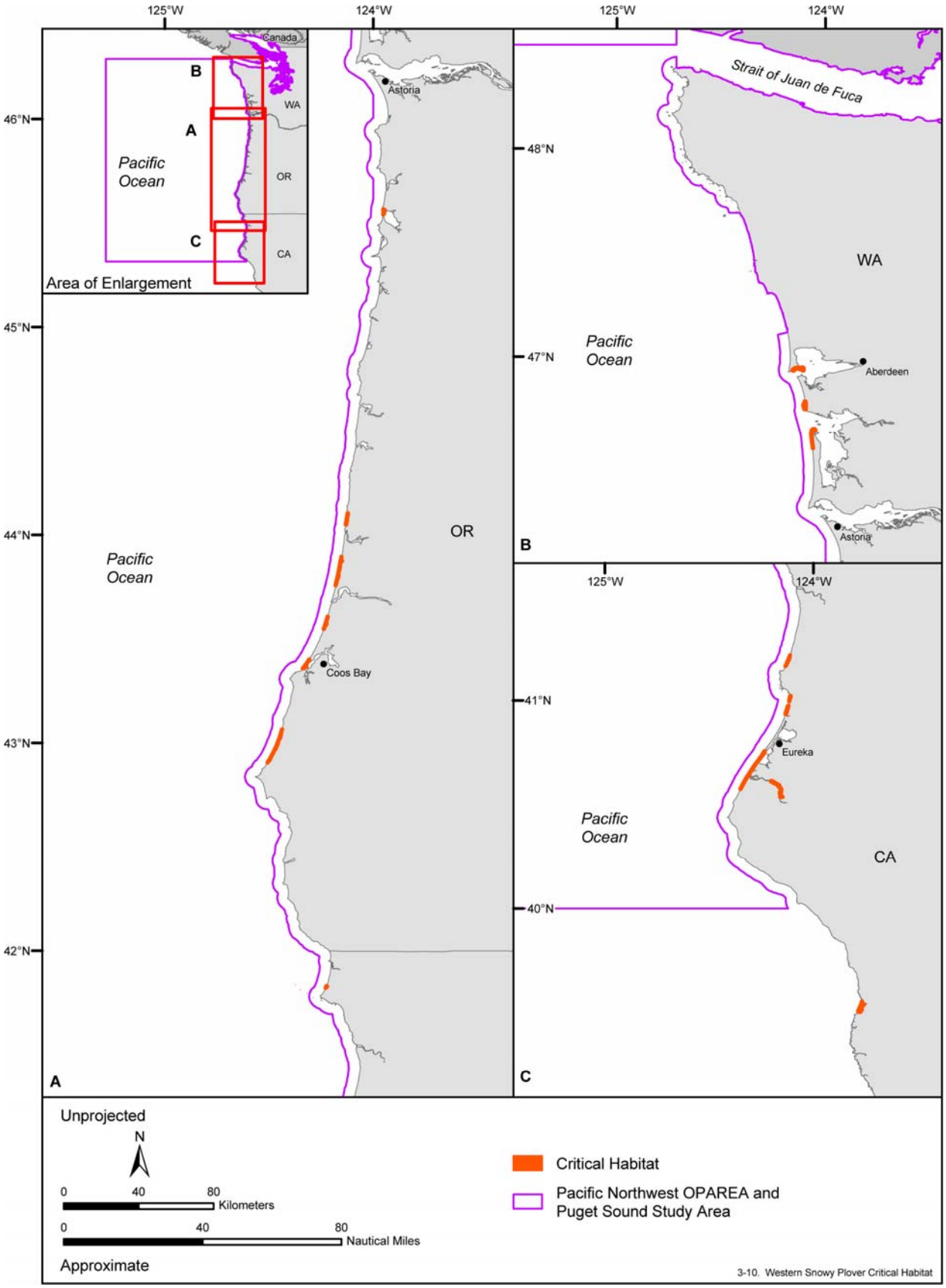


Figure 3-10. Designated critical habitat for the western snowy plover. Source data: USFWS (2005).

Distribution—The Pacific coast population of the western snowy plover extends from the mudflats and sandy beaches of Grays Harbor (Damon Point), Washington State, south to Baja Sur, Mexico. During the breeding season, western snowy plovers can be found at three nesting beaches in Washington State, eight locations in Oregon, and about 25 locations in California (three in Humboldt County; USFWS 2001a; Colwell et al. 2002; USFWS 2005e). These locations constitute the designated critical habitat outlined in **Figure 3-10**. Wintering birds can be found from southern Washington State to Central America (USFWS 2001a). Some coastal birds remain on or near their breeding beaches, while others migrate south or north; a late summer influx of birds into Washington State is thought to be migrants or wanderers (USFWS 2001a). In Washington State, most wintering birds are found at Midway Beach and Leadbetter Point, while in Oregon they are found wintering at all eight breeding locations (USFWS 2001a). They also have been found wintering at several locations in Humboldt County. The coastal beaches of California are also used by snowy plovers migrating from inland breeding locations (Page et al. 1995).

Migration patterns are varied. In California, about a quarter to a half of the birds are year-round residents, while the remaining migrate, often north as well south (Page et al. 1995). In the Oregon and Washington State, there are 10 locations typically supporting wintering birds, all of which support breeding populations (USFWS 2001a).

- Information Specific to the Pacific Northwest OPAREA and Puget Sound Study Area—The western snowy plover is a shorebird that confines its habitat use to the sandy beaches and mudflats of the Oregon, Washington State, and California coasts (**Figure D-5**). This species does not occupy any of the marine or rocky shore areas found in the Pacific Northwest OPAREA.

  In Washington State, western snowy plovers breed at Damon Point/Oyhut Wildlife Area, Midway Beach/Cape Shoalwater, and Leadbetter Point. In Oregon they nest at eight locations (Baker Beach/Sutton Beach, Siltcoos Estuary, Oregon Dunes Overlook, Tahkenitch Estuary, Tenmile Estuary, Coos Bay North Spit, New River Spit, and Bandon State Natural Area; Stern et al. 2003). In Humboldt County, California, nesting occurs at Eel River (gravel bars), Eel River Wildlife Area, and Clam Beach. There are no current nesting sites in Del Norte County, California. During the winter, snowy plovers may be found at Midway Beach and Leadbetter Point in Washington State, all breeding sites in Oregon, and a several sites in Humboldt County, California. Although snowy plovers exhibit strong site fidelity both during the wintering and breeding season, any beach habitat south of Damon Point providing suitable foraging habitat is potentially important, at least short-term, to dispersing adults and juveniles.

Behavior and Life History—In the Pacific Northwest, mating season usually begins in March or April, with the arrival of the portion of birds that migrated for the winter. In Oregon and Washington State, most nests are initiated from mid-April to mid-July, with fledging occurring from June through August (Widrig 1980; Wilson-Jacobs and Meslow 1984). The breeding season is protracted with females often double and triple clutching. Clutch sizes are usually three eggs (Warriner et al. 1986; Page et al. 1995), and both sexes incubate (Warriner et al. 1986). Females generally leave tending of broods to males, preferring to initiate new nests with new males (Page et al. 1995). The percentage of hatched young that fledge (reach flying edge) varies greatly. In Oregon, the annual fledging success from 1994 to 1998 for all sites combined ranged from 30% to 48%, with individual site annual rates as low as 14% and as high as 66% (USFWS 2001a).

In the Pacific Northwest, western snowy plovers generally feed in the wet sand or among surf-cast kelp, where they visually forage for flies, beetles, small clams and crabs, amphipods, seed shrimp (ostracods), and polychaetes (Page et al. 1995). During the winter, western snowy plovers often feed in loose flocks, and roost in depressions or behind sheltering debris, such as driftwood or kelp.

3.3.3 Websites Accessed

[1] Bald eagle: Population. Accessed 24 April 2006. http://www.fws.gov/midwest/eagle/population/index.html.

[2] Bald eagles in California. Accessed 24 April 2006. http://www.dfg.ca.gov/hcpb/species/t_e_spp/tebird/bald_eagle.shtml.

[3] Brown Pelicans in Channel Islands National Park. Accessed 24 April 2006. http://www.nps.gov/chis/pelican.htm.

[4] California short-tailed albatrosses. Accessed 24 April 2006. http://www.montereybay.com/creagrus/CA_STAL.html.

3.4 FISH

3.4.1 Introduction

One of the most important marine resources found in the Pacific Northwest OPAREA and Puget Sound Study Area is the Pacific salmonid. Salmon support important traditional, commercial, and recreational fisheries in Washington, Oregon, and California and have long been an integral part of the Native American culture and heritage in the Pacific Northwest.[1] Salmon are extremely important to both marine and terrestrial ecosystems (Gende et al. 2002). For example, the distribution and movement patterns of some marine mammal species, in particular, southern resident killer whales are driven by occurrences of salmon, an important prey source (see Section 3.1 for more information).

All Pacific salmon species are gonochoristic (species with sexes separate) and exhibit varying forms of anadromy; they spend their early lives in freshwater before migrating to the ocean to grow and mature. For further information on Pacific salmon species, and their life history and behavioral ecology, see Groot and Margolis (1991) and Emmett (1991).

The extent of hearing data for salmon is limited to the Atlantic salmon (*Salmo salar*) and masu salmon (*Oncorhynchus masou*). Atlantic salmon can detect sounds to frequencies somewhat above 600 Hz, however, at above about 150 Hz, the hearing sensitivity drops off sharply (Abbott 1973; Hawkins and Johnstone 1978; Knudsen et al. 1992; Kojima et al. 1992; Knudsen et al. 1994). Salmonids are unable to perceive high frequency sounds; these fish respond best to low frequencies (5 to 10 Hz) in the infrasound range. As noted by Mueller et al. (1999), life stage differences in hearing are to be expected due to developmental differences. As noted by Hastings and Popper (2005), care must be taken in extrapolating information from Atlantic salmon to Pacific Coast salmonids. Data on the ear anatomy of several salmonid species suggest that the auditory system is similar for all salmonids, however, without additional hearing data, this extrapolation must be done with considerable caution (Hastings and Popper 2005).

There are six salmonid species that have critical habitat designated within the OPAREA: chinook salmon, coho salmon, chum salmon, sockeye salmon, steelhead trout, and bull trout. Pacific salmon are federally protected by the designation of evolutionarily significant units (ESUs). ESUs are defined by NMFS as a population that is “substantially reproductively isolated from conspecific populations and represents an important component in the evolutionary legacy of the species” (WCSBRT 2003). It should be noted that due to the anadromous life history of salmon, any ESU (including those that are listed under the ESA) could possibly occur in the OPAREA and Study Area (**Table 3-4**). Designation of critical habitat affects only federal agency actions and federally funded or permitted activities. The National Defense Authorization Act has recently redefined critical habitat to exclude lands owned or controlled by the DoD that are subject to an INRMP, provided that the plan will afford protection to those areas for which designation is warranted (U.S. Congress 2004). For more information on DoD critical habitat exclusions refer to Chapter 1. Marine EFH is also designated for the chinook and coho salmon for marine waters within the EEZ along the Pacific Coast (PFMC 2000; **Figure 3-11**). Section 4-4 discusses EFH in greater detail, as well as the possible impacts of climate change on these species.

Each salmonid species known to occur in the Pacific Northwest is listed below with its description, status, habitat preferences, distribution (including location and seasonal occurrence in the Pacific Northwest OPAREA and Puget Sound Study Area), behavior, and life history.

- **Chinook Salmon (*Oncorhynchus tshawytscha*)**

  Description—Chinook salmon are gonochoristic, oviparous, and semelparous (Emmett et al. 1991). They are the largest member of Pacific salmon weighing as much as 45 kg and reaching 150 cm in length (PFMC 2000). Distinguishing characteristics include small black spots on both lobes of their caudal fin and black pigment along the base of the teeth (Healey 1991). Chinook also exhibit colors of flesh ranging from white through various shades of pink and red (Healey 1991). Chinook salmon exhibit one of the more diverse and complex life history strategies of all Pacific salmon and are

Table 3-4. Pacific salmonid ESUs in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity (USFWS 2005b; NMFS-NWR[2]).

Species	ESU	ESA Listing Status	ESU Critical Habitat
Chinook Salmon			
	Sacramento River Winter-run	Endangered	Designated
	Upper Columbia River Spring-run	Endangered	Designated
	Snake River Spring/Summer-run	Threatened	Designated
	Snake River Fall-run	Threatened	Designated
	Central Valley Spring-run	Threatened	Designated
	California Coastal	Threatened	Designated
	Puget Sound	Threatened	Designated
	Lower Columbia River	Threatened	Designated
	Upper Willamette River	Threatened	Designated
Coho Salmon			
	Central California Coast	Endangered	Designated
	Southern Oregon/Northern California Coasts	Threatened	Designated
	Lower Columbia River	Threatened	Under Development
Chum Salmon			
	Hood Canal Summer-run	Threatened	Designated
	Columbia River	Threatened	Designated
Sockeye Salmon			
	Snake River	Endangered	Designated
	Ozette Lake	Threatened	Designated
Steelhead Trout			
	Southern California	Endangered	Designated
	Upper Columbia River	Endangered	Designated
	Snake River Basin	Threatened	Designated
	Middle Columbia River	Threatened	Designated
	Lower Columbia River	Threatened	Designated
	Upper Willamette River	Threatened	Designated
	South-Central California Coast	Threatened	Designated
	Central California Coast	Threatened	Designated
	Northern California	Threatened	Designated
	California Central Valley	Threatened	Designated
Bull Trout*			
	NA	Threatened	Designated

*The bull trout is managed by the USFWS and has been designated as threatened for the contiguous U.S. There are no individual ESUs for this species.

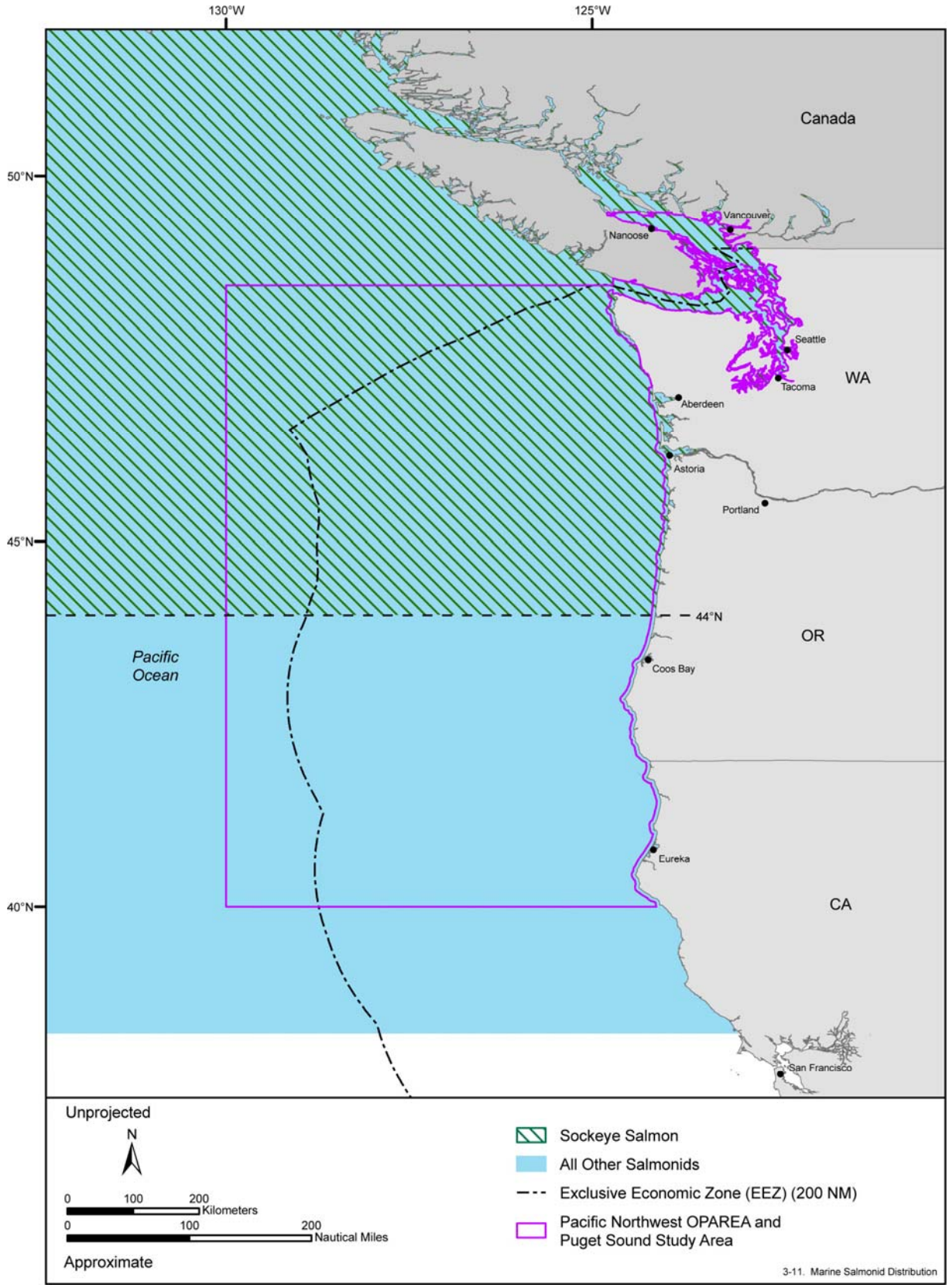


Figure 3-11. Marine salmonid (sockeye salmon, Chinook salmon, chum salmon, Puget Sound pink salmon, steelhead and bull trout) distribution in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source information: Burgner (1991), Augerot and Foley (2005), and HSSRP.[6]

separated into two generalized life-history types: stream-type and ocean-type fish (Myers et al. 1998; PFMC 2000).

Status—Currently, NMFS has identified 17 ESUs of chinook salmon in Washington, Oregon, Idaho, and California. Each ESU is treated as a separate species under the ESA (NMFS 2005l; NMFS 2005c). Of these ESUs, two are endangered (Sacramento River winter-run and Upper Columbia River spring-run), 7 are threatened (Snake River spring/summer-run, Snake River fall-run, Central Valley spring-run, California coastal, Puget Sound, Lower Columbia River, and Upper Willamette River), and one is listed as a species of concern (Central Valley fall-and late fall-run; NMFS 2005l; NMFS 2005h; NMFS 2005c; **Figure 3-12**).

The Columbia River once supported the world's largest chinook salmon run, but currently, the upper Columbia River spring-run ESU is listed as endangered and the lower Columbia River, Snake River spring/summer-run, Snake River fall-run, and upper Willamette River ESU are listed as threatened under the ESA.

Habitat Preference—Chinook salmon are found in freshwater to euhaline waters from the surface to depths of 250 m depending on lifestage.[4] Smaller fry prefer more protected, lower salinity habitats. As fish get larger, they gradually leave the well protected habitats for higher salinity waters (PFMC 2000). After juveniles have advance past the initial marine phase, they prefer depths ranging from 30 to 70 m and are often associated with bottom topography (PFMC 2000). Late juveniles and adults may be pelagic, neustonic, or semi-demersal/semi-pelagic (PFMC 2000). Chinook salmon may be found in water temperatures ranging from 0.0° to 26°C but this may vary depending on lifestage and activity (MBC 1987). Ocean type juveniles are found in waters from 1° to 15°C but few chinook are found at temperatures below 5°C (MBC 1987; PFMC 2000). Juvenile and adult chinook salmon are found in freshwater to euhaline waters (Emmett et al. 1991). Subadults that have migrated to marine waters are found in polyhaline to euhaline waters (Emmett et al. 1991). No substrate preference has been documented for adults in the marine environment (Beauchamp et al. 1983).

Distribution—The chinook salmon's historical range in North America extended from the Ventura River in California to Point Hope, Alaska (Myers et al. 1998). The natural freshwater range for chinook salmon extends throughout the Pacific Rim of North America. This species has been identified from the San Joaquin River in California to the Mackenzie River in northern Canada (Healey 1991). The oceanic range encompasses Washington, Oregon, California, throughout the north Pacific Ocean, and as far south as the U.S./Mexico border (PFMC 2000). The majority of stream-type chinook stocks are found in Alaska, north of 56°N and ocean-type chinook are more common near the center of the species range (Healey 1991).

- Information Specific to the Pacific Northwest OPAREA—Early life history stages for chinook occur in freshwater but juveniles and adults utilize marine habitats within the Pacific Northwest OPAREA. Juvenile chinook prefer coastal areas (less than 55 km) throughout California, Oregon, and Washington, north to the Strait of Georgia and the Inland Passage, Alaska (PFMC 2000). The majority of marine juveniles are found within 28 km of the coast (PFMC 2000). They tend to concentrate around areas of pronounced coastal upwellings (PFMC 2000). Populations originating north of Cape Blanco, Oregon migrate north to the Gulf of Alaska, while populations originating south of Cape Blanco migrate south and west into the waters off California and Oregon (PFMC 2000). Chinook salmon spawning in rivers south of the Rogue River in Oregon rear in marine waters off California and Oregon, whereas, salmon spawning in rivers north of the Rogue River migrate north and west along the Pacific coast (PFMC 2000). In the Fraser and Columbia rivers, adult chinook enter freshwater between March and November, with peaks in spring (March through May), summer (May through July), and fall (August through September; PFMC 2000). Sacramento River winter-run salmon enter freshwater between December and July (PFMC 2000).

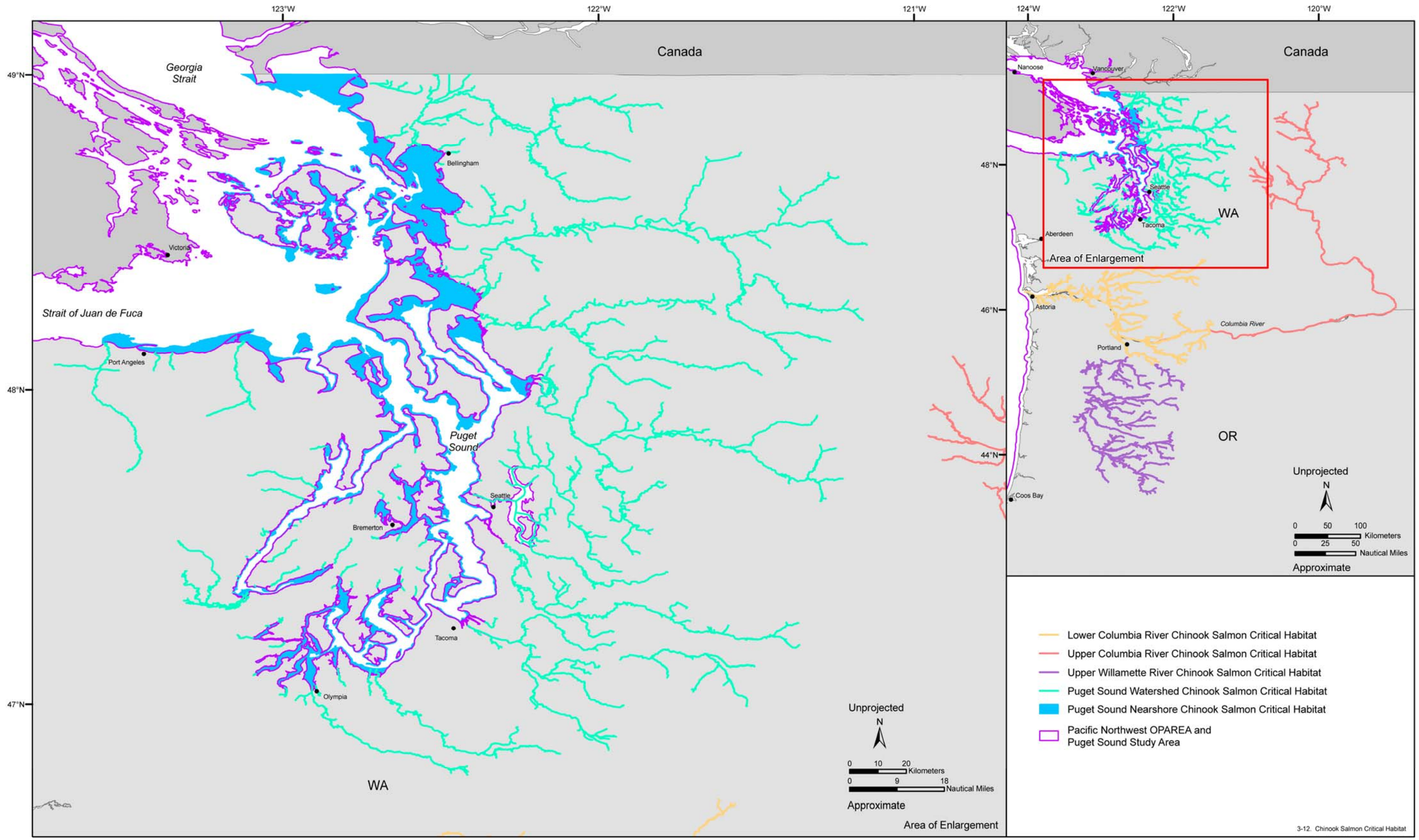


Figure 3-12. Designated critical habitat for chinook salmon in the Puget Sound Study Area and vicinity. Source data: NMFS-NWR.[3]

Behavior and Life History—Chinook salmon exhibit one of the more diverse and complex life history strategies of all Pacific salmon and are separated into two generalized life-history types: stream-type and ocean-type (Myers et al. 1998; PFMC 2000). Timing of migration to seawater for juveniles is highly variable (PFMC 2000). Ocean-type juveniles may migrate to the ocean immediately after hatching but most remain in freshwater for 30 to 90 days (PFMC 2000). Ocean-type juveniles typically inhabit estuaries for several months before migrating to higher salinity waters (PFMC 2000). Stream-type juveniles pass quickly through estuaries, are highly migratory, and may make extensive migrations in the open ocean (PFMC 2000). Fry enter the upper reaches of estuaries in late winter for the more southern populations or early spring for the more northern populations (PFMC 2000). For a year or more, they reside as fry or parr in freshwater where they exhibit downstream dispersal and utilize a variety of freshwater rearing environments before migrating to sea (Healey 1991). They perform extensive offshore oceanic migrations and return to their natal river during the spring and early summer, several months prior to spawning (Healey 1991). Ocean residency varies but may last from 1 to 6 years (Healey 1991). Stream-type adults often enter freshwater in the spring and summer as immature fish and spawn in upper watersheds in late summer or early fall (PFMC 2000). Major ESUs with stream-type life history strategies include upper Columbia River spring ESU and the Snake River spring/summer ESU (Myers et al. 1998).

Ocean-type chinook migrate to the ocean within the first year (typically within a few months) after emergence where they spend an average of 4 to 5 years (Myers et al. 1998; PFMC 2000; Augerot and Foley 2005). Ocean-type chinook salmon spend most of their ocean life in coastal waters, and return to their natal rivers from spring to winter (Healey 1991). Major ESUs with ocean-type life history strategies include: the Puget Sound ESU, Lower Columbia River ESU, and Snake River fall ESU (Myers et al. 1998).

Spawning may range from May/June to December/January depending on location but periods are specific for each run and/or stock (Emmett et al. 1991; Healey 1991; PFMC 2000). Spawning may occur from the tidewater to 3,200 km upstream (Healey 1991). Stream-type and ocean-type spawning populations are separated considerably (Healey 1991). In North America there seems to be a sudden shift from stream-type to ocean-type stocks somewhere around Alaska-British Columbia border (Healey 1991). South of approximately 56°N, stream-type chinook are only found in larger rivers with ocean-type salmon dominating the majority of the runs (Healey 1991).

Chinook salmon may return to their natal streams during any month but there are one to three peaks associated with salmon migratory activity (Healey 1991). These peaks vary between river systems. Northern river systems generally see a single peak in migratory activity around June with the run possible extending through April to August (Healey 1991). As you go farther south, runs occur progressively later (Healey 1991). The Columbia River experiences a late August run and significantly smaller spring and summer runs (Healey 1991). The Klamath River also sees a late August run with a smaller run occurring in the spring (Healey 1991).

Generally, stream-type fish spawn one to two months (spring and early summer) before ocean-type fish (summer and fall) in the central and southern portions of the species range (Healey 1991; PFMC 2000). Larger variations in spawning time may occur in species associated with larger river systems such as the Columbia River (Healey 1991).

In marine environments the chinook's diet consist of crab zoea, rockfish, Pacific sand lance, eulachon, herring, anchovy, copepods, euphausiids, cephalopods, isopods, and amphipods (Beauchamp et al. 1983).

- **Coho Salmon (*Oncorhynchus kisutch*)**

Descriptions—Coho salmon are distinguished by irregular black spots on their back and upper lobe of their caudal fin (PFMC 2000). When sexually mature, they have bright red sides and a bright green back and head (PFMC 2000). Coho may attain lengths greater than 100 cm and attain weights of up to 15 kg.[4]

Status—There are currently 7 ESUs of coho salmon in Washington, Oregon, and California (NMFS 2005h; NMFS 2005c; NMFS 2005l). Of these ESUs, one is endangered (Central California Coast), two are threatened (Southern Oregon/Northern California Coasts and Lower Columbia River) and one is proposed as threatened (Oregon Coast; NMFS 2005l; NMFS 2005c; NMFS 2005h; **Figure 3-13**).

Habitat Preference—Coho salmon are found in fresh water to euhaline water at depths ranging from the surface to 250 m.[4] In the open ocean, coho are thought to stay within 30 m of the surface unless water conditions are considerably warm (Emmett et al. 1991). Marine juveniles are commonly found at depths less than 10 m (PFMC 2000). Oceanic coho are found at temperatures ranging from 4° to 15.2°C but prefer temperatures from 8° to 12°C (Emmett et al. 1991). Eggs, alevins, fry, and parr inhabit freshwater while juveniles and adults are anadromous (Emmett et al. 1991). Smolts, subadults, and adults are found migrating over a variety of substrates (Emmett et al. 1991). Cover availability is more important than substrate selection for juvenile coho (Emmett et al. 1991).

Distribution—Coho salmon are found in freshwater drainages from Monterey Bay, California north along the west coast of North America to Alaska, around the Bering Sea south through Russia to Hokkaido, Japan (CDFG 2002a). Oceanic lifestages can be found from Camalu Bay, Baja California north to Point Hope, Alaska and from there, south to Korea (MBC 1987; Sandercock 1991). In the northeastern Pacific, coho can be found south of 40°N, but only in the coastal waters of the California Current (MBC 1987). Juvenile coho are generally found within 60 km of the California, Oregon, and Washington coasts but the majority are found within 37 km (PFMC 2000). Tagging studies have shown coho originating from Washington and Oregon as far north as 60°N latitude and coho originating from California as far north as 58°N latitude (PFMC 2000). Oregon coho have been taken in offshore waters near Kodiak Island in the northern Gulf of Alaska. Westward migration of coho salmon appears to extend beyond the EEZ beginning at approximately 45°N latitude off the coast of Oregon (PFMC 2000). In strong upwelling years coho are more dispersed offshore, whereas in weak upwelling years they concentrate near submarine canyons and areas of consistent upwelling.

- Information Specific to the Pacific Northwest OPAREA—Early life history stages for coho salmon occur in freshwater, but juveniles and adults utilize marine habitats within the Pacific Northwest OPAREA. Coho from California, Oregon, and Washington, typically remain in coastal waters near their natal stream for at least their first summer before migrating north (PFMC 2000). Three to 5% of the naturally produced yearly coho within Puget Sound and the Strait of Georgia will reside in the Strait of Juan de Fuca throughout their entire ocean residency while others will migrate to the open ocean in late summer (Emmett et al. 1991; PFMC 2000). Puget Sound populations are generally found in the Strait of Juan de Fuca and the coastal waters of Vancouver Island during the summer months (PFMC 2000). As populations leave Puget Sound they can be found migrating northward along the east or west coast of Vancouver Island and out into the Pacific Ocean (PFMC 2000). Coho migrating from Oregon streams may initially be found south of their natal streams due to strong southerly currents (PFMC 2000). These currents weaken during the winter months and the salmon migrate northward (PFMC 2000).

Behavior and Life History—Adult coho migrate into streams where they deposit their eggs in gravel (Sandercock 1991). Eggs incubate throughout the winter and emerge in the spring as free-swimming fry (Sandercock 1991). The fry reside in the stream for a year or more when they begin migrating toward the ocean as smolt (Sandercock 1991). Juveniles spend a minimum of 18 months at sea before returning to their natal streams to repeat the process (Sandercock 1991).

Adult coho salmon migrate to their natal streams from June to February with northern populations beginning their return earlier than southern populations (Emmett et al. 1991; Sandercock 1991). Throughout their range, coho exhibit a variety of return timing patterns (Sandercock 1991). Most juvenile migration occurs from April to August with a peak in May (Emmett et al. 1991). Generally, as you move farther north, estuarine residency time for juveniles increases (PFMC 2000). Upon entering the ocean, coho may spend several weeks or their entire first summer in coastal waters before

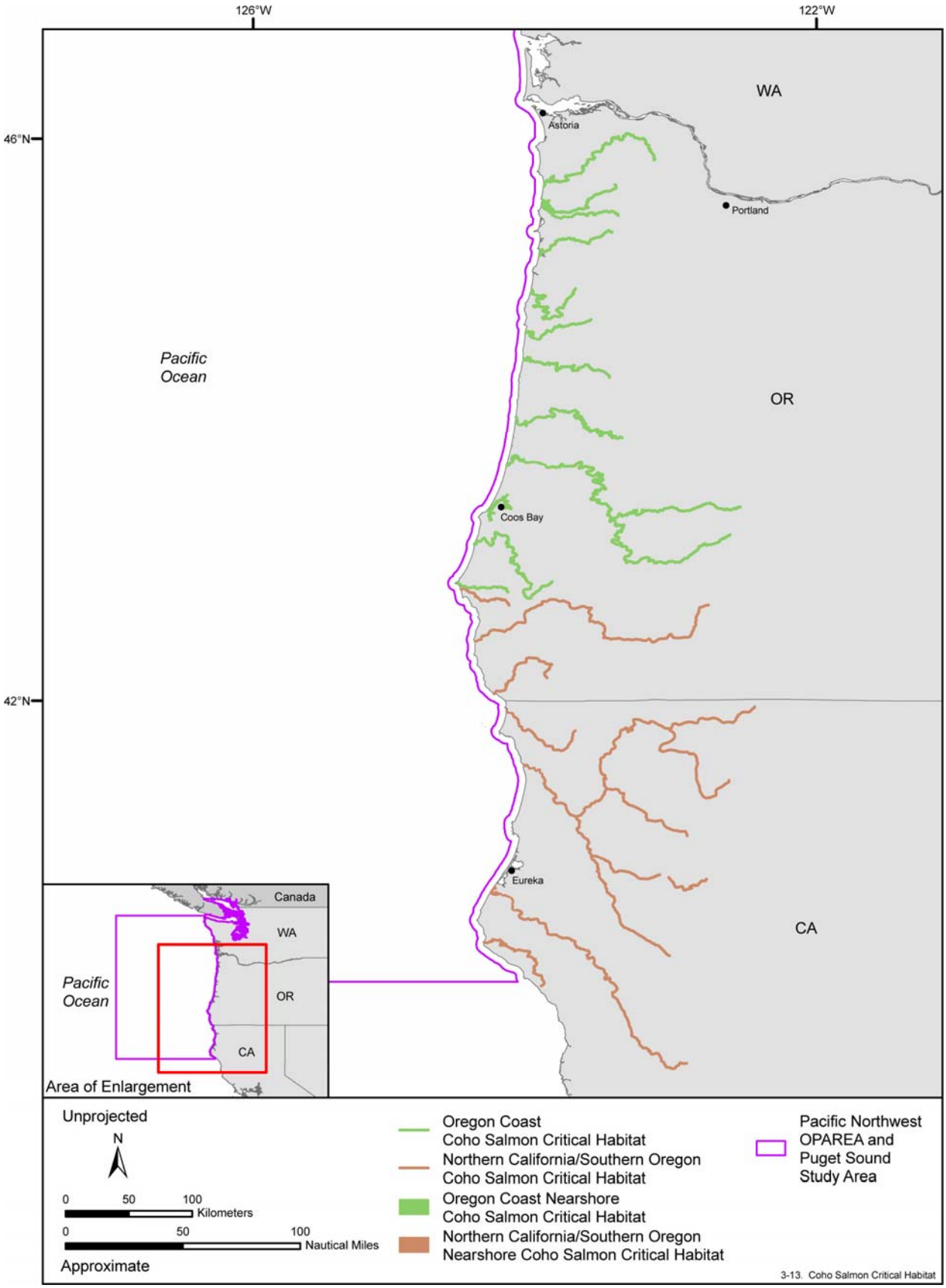


Figure 3-13. Designated critical habitat for coho salmon in the Pacific Northwest OPAREA and vicinity. Source data: NMFS-NWR.[3]

migrating north (PFMC 2000). The later dispersal pattern is the most common within the study area (PFMC 2000). Tag, release, and recovery studies suggests that coho salmon of California origin can be found as far north as southeast Alaska and salmon from Oregon and Washington as far north as the northern Gulf of Alaska (PFMC 2000). The extent of coho migrations appears to extend westward along the Aleutian Island chain ending somewhere around Emperor Seamount (believed to be an area of high prey abundance; PFMC 2000). While the southern extent of the population expands and contracts annually, with Point Conception, California generally considered the faunal break for the coho and other temperate marine species (PFMC 2000). Adult coho may enter freshwater as early as July in the Alaska and as late as December or January in California (Sandercock 1991; PFMC 2000). Summer-run coho may enter rivers exceptionally early (spring or early summer; PFMC 2000). Larger rivers have a wider range of entry times than smaller systems (PFMC 2000).

Four distinct life history patterns occur within Puget Sound and Georgia Strait: 1) ocean migrants that migrate to sea in the spring of the second year; 2) resident fish that migrate to the ocean in the fall of the second year after spending the summer inside Puget Sound/Strait of Georgia; 3) resident fish that go to the ocean in the spring of their third year after 1 year inside Puget Sound/Strait of Georgia; and 4) true residents that spend their entire lives in Puget Sound/Strait of Georgia (Emmett et al. 1991).

In North America, coho generally spawn from October to March with populations found at the northern extent of the species range spawning earlier than those at the southern extent (PFMC Sandercock 1991; 2000). Both spawning and migration times can be highly variable (Sandercock 1991).

Coho salmon are opportunistic feeders who's diet reflects the availability of the prey in their area (Emmett et al. 1991). Ocean-dwelling coho initially feed on decapod larvae, gammarid and hyperid amphipods, euphausiids, terrestrial insects, copepods, cephalopods, Cnideria, gastropods, planktonic annelids, and larval and juvenile fishes (Emmett et al. 1991). As juveniles get larger they become more piscivorous feeding on northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea pallasi*), Pacific sardine (*Sardinops sagax*), juvenile scorpaenids, capelin (*Mallotus villosus*), and other fish species (Emmett et al. 1991).

- **Chum Salmon (*Oncorhynchus keta*)**

Descriptions—Chum salmon are distinguished by the absence of large black spots on their body and fins and a slender caudal peduncle. Adults, white tips on their pelvic and anal fins and maturing fish have a series of dark bars and red coloring on theirs sides (Pauley et al. 1988). Chum salmon may reach 100 cm in length and weigh almost 16 kg.[4]

Status—There are currently four ESUs of chum, two of which (Hood Canal Summer-run and the Columbia River) have been designated as threatened (NMFS 2005h; NMFS 2005l; NMFS 2005c; **Figure 3-14**). The Puget Sound/Strait of Georgia and Pacific Coast ESUs have not yet warranted a designation of threatened or endangered (NMFS 2005l; NMFS 2005c; NMFS 2005h).

Habitat Preference—Chum salmon are found in fresh water to euhaline water at depths ranging from the surface to 250 m.[4] Juveniles are primarily epipelagic and are found from the surface down to 95 m (Emmett et al. 1991). Chum salmon are found at a wide range of temperatures from 3° to 22°C but prefer temperatures from 8.3° to 15.6°C (Pauley et al. 1988). Eggs, alevins, fry, and parr inhabit freshwater while juveniles and adults are anadromous (Salo 1991). Juveniles and adults are found over a variety of substrates (Emmett et al. 1991).

Distribution—Chum salmon have the largest range of natural geographic and spawning distribution of all the Pacific salmon species (Pauley et al. 1988). Historically, in North America, chum salmon occur from Monterey, California to the Arctic coast of Alaska and east to the Mackenzie River which flows into the Beaufort Sea. Present spawning populations are now found only as far south as Tillamook Bay on the northern Oregon coast (Salo 1991). Juvenile chum occur along the coast of

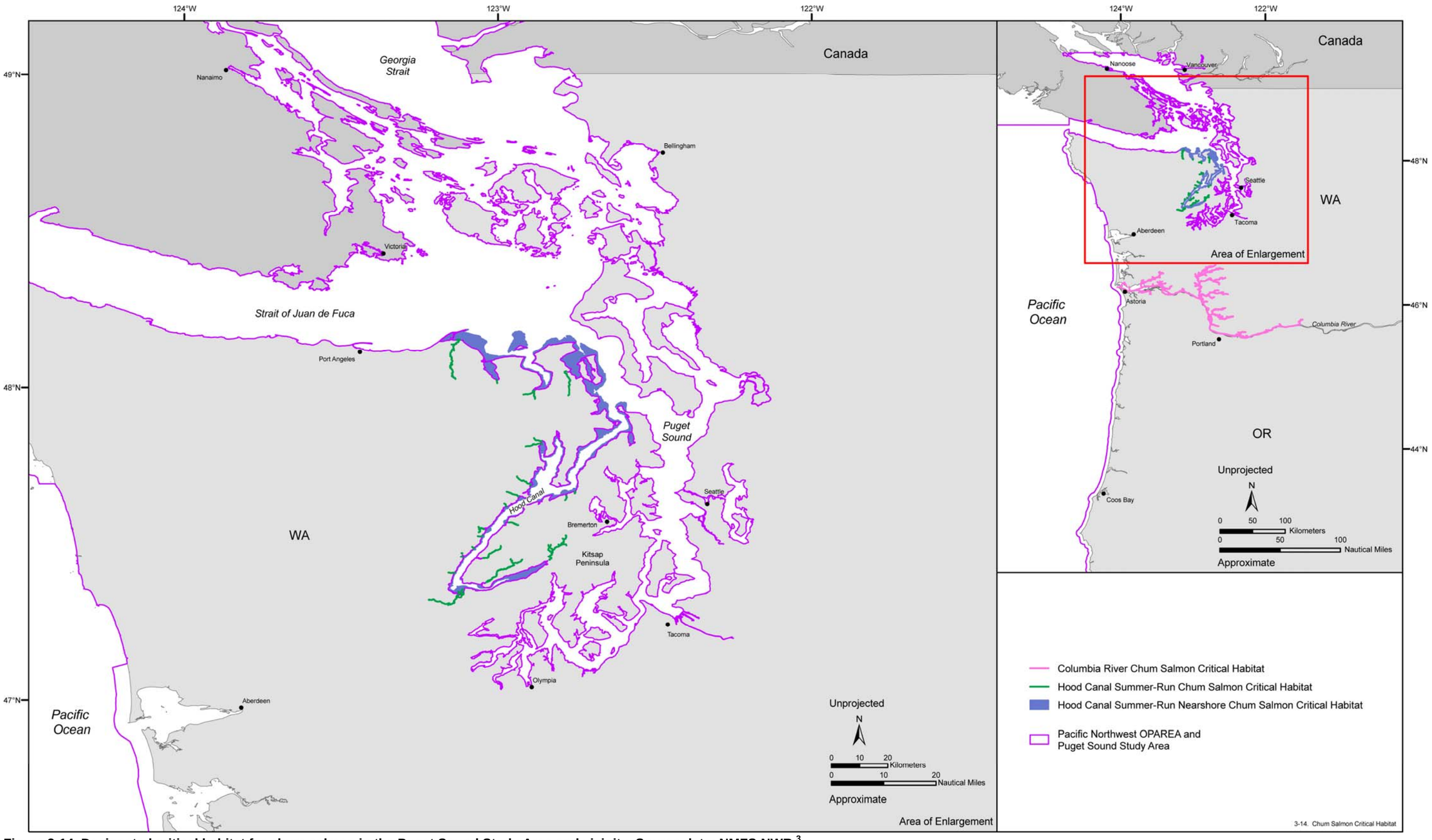


Figure 3-14. Designated critical habitat for chum salmon in the Puget Sound Study Area and vicinity. Source data: NMFS-NWR.[3]

North America and Alaska in a band that extends out to 36 km (Salo 1991). Chum salmon are more dependent on estuaries and marine waters than the other Pacific salmon species with the exception of ocean-type chinook salmon (Salo 1991).

- Information Specific to the Pacific Northwest OPAREA—Early life history stages for chum salmon occur in freshwater but juveniles and adults utilize marine habitats within the Pacific Northwest OPAREA. Chum salmon runs occur in the Washougal, Lewis, Kalama, and Cowlitz watersheds in Washington. Chum salmon spawning runs can be grouped into three seasonal runs; summer, fall and winter. The chum salmon of the Columbia River chum salmon ESU enter freshwater to spawn from early October to mid-November, with a peak return in early November. Peak spawning occurs in late November and is usually complete by early December (WDFW 1993). The chum salmon of the Hood Canal summer chum salmon ESU enter freshwater to spawn from August to mid-September (WDFW 1993). Hood Canal summer chum salmon spawning periods vary from August 15 through early October, dependent upon the watershed (WDFW 1993).

Behavior and Life History—Coho salmon are an anadromous species distributed throughout the North Pacific Ocean (Salo 1991). Chum salmon are highly migratory with fry heading seaward immediately after emergence (Salo 1991). Chum do not have the clearly defined smolt stages that occur in other salmonids; however they are capable of adapting to seawater soon after emergence from the gravel (Salo 1991). Outmigrations of juvenile chum is correlated with the warming of nearshore waters (Salo 1991). They migrate to estuaries during their first spring or summer and spend little time rearing in freshwater (Pauley et al. 1988). Juveniles enter estuaries from March to mid-May where they remain for several months (Emmett et al. 1991). Juveniles may be found in estuaries off the coast of Washington from January through July (Emmett et al. 1991). As chum salmon grow, there is a general movement toward the ocean moving offshore from April to June (Emmett et al. 1991). They then head north along the continental shelf until they reach the Gulf of Alaska; however, some populations never leave Puget Sound (Emmett et al. 1991). Adults return to their natal streams at various ages but generally within two to five years (Salo 1991). For chum salmon, two spawning stocks exist; a northern stock that spawns from June to September and a southern (late-run) stock that spawns from August to January (Emmett 1991). Washington, Oregon, and California stocks are all late-run populations (Emmett 1991).

Chum salmon fry feed on chironomid larvae if they spend extended periods in fresh water (Emmett et al. 1991). Juveniles initially feed on harpacticoid copepods and gammarid amphipods in shallow waters but may also prey upon terrestrial insects and small crustaceans (Emmett et al. 1991). Food limitations may cause juveniles to shift to more pelagic prey such as calanoid copepods, hyperiid amphipods, crustacean larvae, and larvaceans (Emmett et al. 1991). In marine environments, juveniles and subadults feed on euphausiids, squids, pteropods, and fishes (Emmett et al. 1991).

- **Sockeye Salmon (*Oncorhynchus nerka*)**

Description—Sockeye are primarily anadromous and exhibit a more varied life history than other species of Pacific salmon (see Behavior and Life History; Burgner 1991). Their flesh is a darker shade of red which has made them more desirable as a canned product. The most distinguishing characteristic of the sockeye is the distinct color change in both sexes at maturity. Both males and females develop green heads and bright red bodies at this time with the males also developing a distinctive hump on their back (Burgner 1991). During the adult and juvenile ocean migratory phase, sockeye have a bluish back and silver sides. Males have been recorded as large as 81 cm total length while females may grow to approximately 71 cm total length.[4] Maximum recorded weight for sockeye is 7.71 kg.[4]

Status—There are currently seven ESUs of sockeye salmon found in Washington. The Snake River and Ozette lake ESUs have been designated endangered and threatened respectively. Currently, the remaining ESUs do not warrant an ESA listing (NMFS 2005h; NMFS 2005l; NMFS 2005c; **Figure 3-15**).

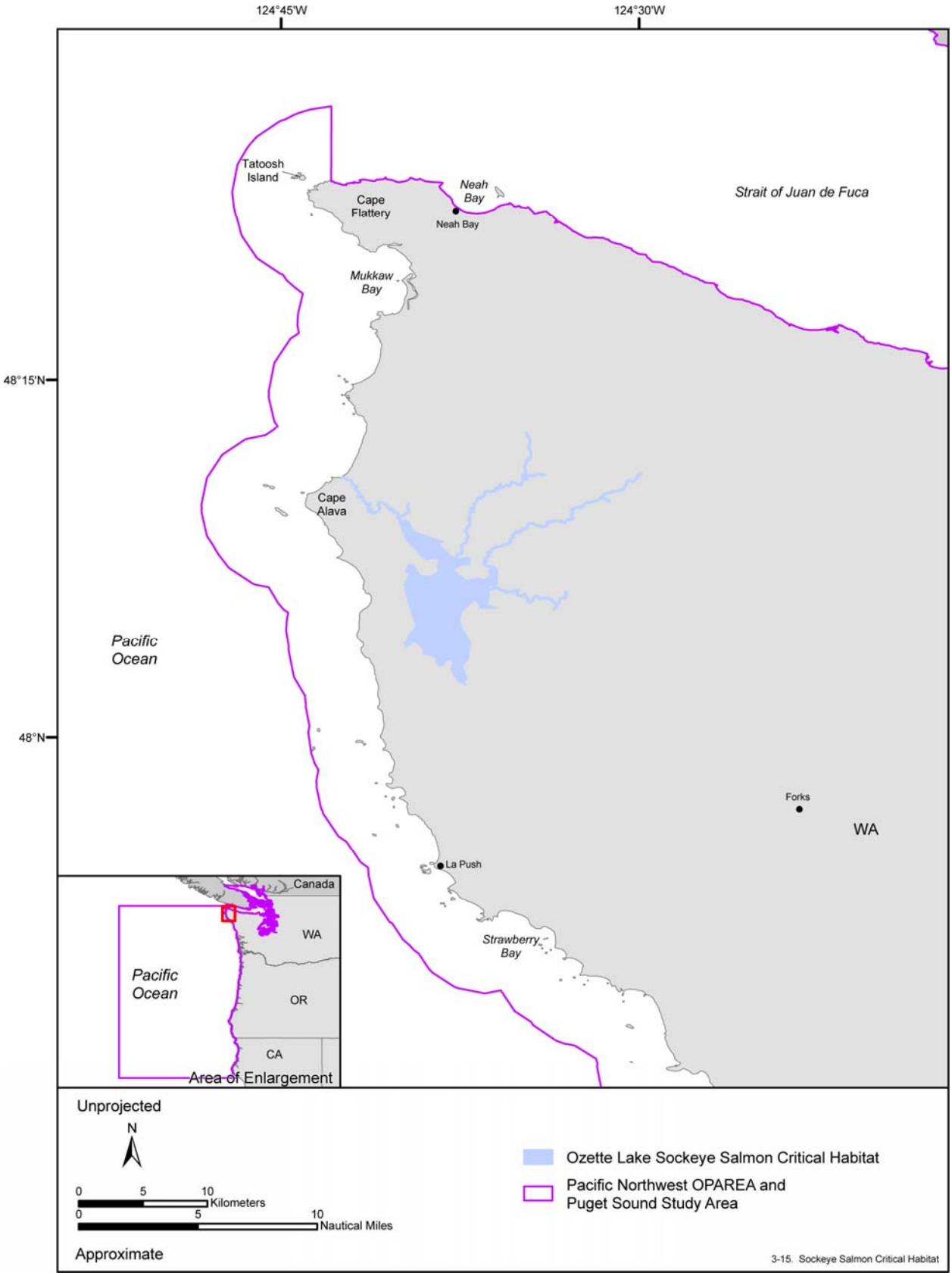


Figure 3-15. Designated critical habitat for sockeye salmon in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NMFS-NWR.[3]

Habitat Preference—Sockeye salmon are found in freshwater to euhaline waters.[3] Young smolts tend to inhabit the upper part of the water column (Pauley et al. 1989). Juveniles in Lake Washington seldom come within 20 m of the surface in any season except spring (Pauley et al. 1989). Little information exists on the vertical distribution of sockeye at sea, however, research suggests that they are found from the surface to a depth of 30 m with a preferred depth from 0 to 15 m (Burgner 1991). Sockeye are found over a wide variety of temperatures (Burgner 1991). They may be found in temperatures ranging from 0.0° to 25°C but this varies with by lifestage.[1] Young sockeye prefer water temperatures between 12° and 14°C. Optimum temperature for adult sockeye has been estimated at 15°C and they avoid temperatures above 18°C (Pauley et al. 1989).There seems to be little correlation between high seas distribution of sockeye and surface salinity (Burgner 1991). There are no habitat preferences for juveniles rearing in lakes or adults in the marine environment (Pauley et al. 1989).

Distribution—Spawning populations of sockeye occur from the Sacramento River in California, north to Kotzebue Sound, but commercially important stocks range from the Columbia River to the Kuskokwim River in the Bering Sea (Burgner 1991). Their oceanic distribution ranges throughout the Pacific Ocean from the Bering Sea south to approximately 45°N (Burgner 1991).

- Information Specific to the Pacific Northwest OPAREA—Early life history stages for sockeye occurs in lakes and streams but juveniles and adults utilize marine habitats within the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Sockeye are abundant in Puget Sound and the Columbia River, which is the southern extent for sizable spawning runs of sockeye (Emmett et al. 1991). A unique stock of sockeye found in Puget Sound spawns in rivers that are not associated with suitable lake habitat, however, these salmon are usually found in low numbers. Columbia River runs have declined substantially due to the construction of dams that block upstream passage. In northern Washington, runs of sockeye exist in Lake Quinaulte and Lake Ozette. The Lake Ozette stock crashed in the mid-1970s and restoration efforts are currently being undertaken to replenish the stock (Pauley et al. 1989).

Behavior and Life History—The sockeye salmon is primarily anadromous but there are also distinct landlocked populations (kokanee) which never migrate to marine waters, spending their entire life cycle in fresh water habitats (Burgner 1991; Emmett et al. 1991).

After emergence, sockeye typically rear in lakes for 1 to 3 years before migrating to the ocean (Burgner 1991). Some populations utilize stream areas for rearing rather than lakes (Burgner 1991). Anadromous sockeye spend 1 to 4 years at sea before returning to their natal streams in the summer and autumn to spawn and eventually die.

Offshore movements of sockeye are complex and are affected by a variety of physical factors (e.g., season, temperature, and salinity) and biological factors (e.g., life stage, age and size, availability and distribution of prey, and stock-of-origin; Burgner 1991). Soon after entering the ocean, juvenile sockeye begin (excluding those from Bristol Bay) moving north into the Gulf of Alaska where they remain along the coastal belt until late-fall or early-winter. They then disperse offshore moving west and south (Emmett et al. 1991). In the Gulf of Alaska, sockeye move north during the spring and summer and south and west during the winter (Emmett et al. 1991). Ocean residency for sockeye last from 1 to 4 years (Pauley et al. 1989). Upon maturing, sockeye in the Pacific Northwest return to fresh water from June to August, peaking in early July (Emmett et al. 1991).

In North America spawning populations are found from the Sacramento River in California, north to Kotzebue Sound (Burgner 1991). Spawning occurs from August to December, peaking in October (Emmett et al. 1991). Sockeye generally spawn in streams associated with lakes where the juveniles rear in the limnetic zone before they smoltify and migrate to the ocean (Pauley et al. 1989; Burgner 1991; Emmett et al. 1991). For this reason, the two largest spawning complexes are the Bristol Bay watershed in southwestern Alaska and the Fraser River watershed in British Columbia, both of which have extensive lake rearing habitats accessible to sockeye (Burgner 1991).

Diet is essentially based on location, time of day, and the age of the fish (Emmett et al. 1991). All free-swimming lifestages are primarily planktivorous. Prey items include cladocerans and copepods as well as aquatic and terrestrial insects. Gammarid amphipods make up the majority of the diet for smolts. Estuarine prey items include euphausiids, fish larvae, juvenile shrimp, insects, amphipods, and mysids. Ocean sockeye feed on euphausiids, hyperiid amphipods, copepods, decopod larvae, pteropods, juvenile and larval fishes, squid, and other invertebrates (Emmett et al. 1991).

- **Steelhead Trout (*Oncorhynchus mykiss*)**

Description—Adult steelhead in marine environments have a steel-blue coloration, silver-colored sides and ventral surface, with distinct black spots (<0.6 cm in diameter) on their dorsal surface, including head, dorsal fin, and tail (Fry 1973). Adults typically weigh 7.0 kg or less with total lengths ranging from 50 to 76 cm for anadromous steelhead (Fry 1973; Froese and Pauly[3]; Schultz 2004).

Status—There are currently 15 ESUs identified for steelhead in Washington, Oregon, Idaho, and California (NMFS 1997a). Ten of these ESUs have designations of either endangered or threatened and have designated critical habitat (NMFS 2005h; NMFS 2005c; NMFS 2005l). The Southern California and Upper Columbia River ESUs are designated as endangered. The ESUs listed as threatened include the Snake River Basin (Idaho), Middle Columbia River, Lower Columbia River, Upper Willamette River, South-Central California Coast, Central California Coast, Northern California, and California Central Valley (NMFS 2005h; NMFS 2005l; NMFS 2005c; **Figure 3-16**).

In North America, steelhead are split into two phylogenetic groups, inland and coastal with both occuring in Washington, Oregon and British Columbia (Busby et al. 1996). Coastal steelhead occur in a diverse array of populations in Puget Sound, coastal Washington and the lower Columbia River with modest genetic differences between populations (Busby et al. 1996). Inland steelhead are represented only by populations in the Columbia and Fraser river basins, and consistent genetic differences have been found between populations in the Snake and Columbia rivers (Busby et al. 1996).

Habitat Preferences—Steelhead are found in fresh water to euhaline water at depths ranging from the surface to 200 m.[3] Water temperatures vary with lifestage; 10°C is optimum with an upper limit of 24°C (Pauley et al. 1986; Froese and Pauly[4]) Eggs, alevins, fry, and parr inhabit freshwater while juveniles and adults may be anadromous or may remain in freshwater. Juveniles and adults occur over a wide variety of substrates and there seems to be no correlation between substrate and distribution.

Distribution—Steelhead trout are found from central California to the Bering Sea and Bristol Bay coastal streams of Alaska. Most streams in the Puget Sound region, and many Columbia and Snake river tributaries have populations of steelhead trout present (Pauley et al. 1986). In this region, steelhead are split into two phylogenetic groups, inland and coastal (Busby et al. 1996). These two groups both occur in Washington, Oregon and British Columbia (Busby et al. 1996), and are separated in the Columbia and Fraser systems in the vicinity of the crest of the Cascade Mountains. Coastal steelhead occur in a diverse array of populations in Puget Sound, coastal Washington and the lower Columbia River with modest genetic differences between populations (Busby et al. 1996). Inland steelhead are represented only by populations in the Columbia and Fraser river basins, and consistent genetic differences have been found between populations in the Snake and Columbia rivers (Busby et al. 1996).

- <u>Information Specific to the Pacific Northwest OPAREA</u>—While early life history stages of the steelhead are found only in freshwater habitats, the later life history stages of the anadromous life form (i.e., juveniles and adults) utilize the marine environment in the OPAREA, Puget Sound Study Area, and vicinity. In Washington coastal populations, total age at maturity is typically 4 years, 2 years in freshwater and 2 years in the ocean. For Columbia River Basin inland populations, total age at maturity is 4 years with 2 years in freshwater, 1 year in the ocean and 1 year in freshwater as an adult prior to spawning (Busby et al. 1996).

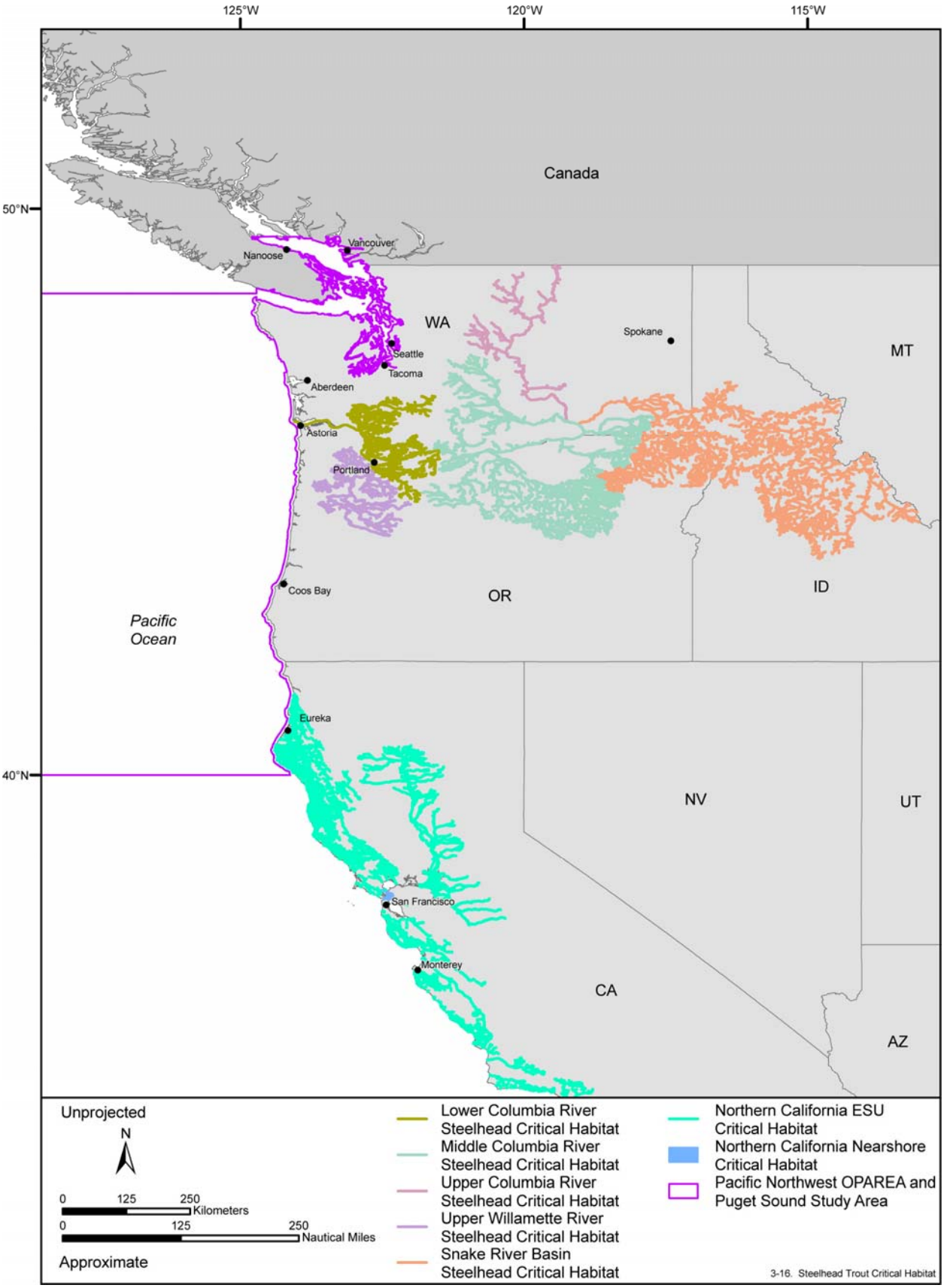


Figure 3-16. Designated critical habitat for steelhead trout in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NMFS-NWR.[3]

Behavior and Life History—Steelhead exhibits a great diversity of life history patterns, and are phylogenetically and ecologically complex. Steelhead may exhibit either an anadromous life style, where they migrate as juveniles from freshwater habitats to marine environments and return to freshwater habitats to spawn, or they may exhibit a freshwater residency, where they spend their entire life in freshwater (NMFS 1997a). Freshwater residents are referred to as rainbow trout. Different life history forms include anadromous and non-anadromous, winter or summer steelhead, inland or coastal groupings, and half-pounder strategies. Anadromous forms spend up to 7 years in freshwater and three years in the ocean prior to their first spawning (Busby et al. 1996). Anadromous steelhead typically spend the first two years of their lives in freshwater, migrate to the marine environment and spend two to three years there, before returning to the freshwater environment to spawn at 4 to 5 years of age (McEwan and Jackson 1996; Schultz 2004).

Steelhead have excellent homing abilities and have been separated into two races depending on their return to their natal stream (winter-run and summer-run; Emmett et al. 1991). Winter-run steelhead migrate upstream during the fall, winter, and early spring, whereas summer-run steelhead migrate during the spring, summer, and early fall (Emmett et al. 1991). Winter steelhead enter their home stream in various stages of sexual maturation from November to April, and spawn within a few months of entering the river between late March and early May (Pauley et al. 1986). They are the most widespread of the two reproductive types. Coastal streams are dominated by winter steelhead, and there are only a few occurrences of inland winter steelhead populations (Busby et al. 1996). In large river systems such as the Columbia River, there are probably fish entering year-round (Emmett et al. 1991). Juveniles generally rear in freshwater for one to four years before migrating to the ocean where they reside from one to five years (Emmett et al. 1991). There is also a “half-pounder” run (mostly summer steelhead) present in southern Oregon and northern California. These populations return to natal streams after only a few months at sea, overwinter, and then migrate back to the ocean (Emmett et al. 1991). Steelhead spend little time in estuaries and are abundant throughout the North Pacific and Gulf of Alaska (Emmett et al. 1991).

Non-anadromous forms of steelhead have been called rainbow or redband trout. For example the inland non-anadromous form is typically called the Columbia River redband trout (Busby et al. 1996). Non-anadromous and anadromous forms co-occur more frequently in inland populations than coastal populations (Busby et al. 1996). In coastal populations where they co-occur, the forms are usually separated by a migration barrier, either natural or man-made (Busby et al. 1996).

Spawning typically occurs from December to June; peaks are in February and March (McEwan and Jackson 1996). Steelhead can spawn more than once (iteroparity), all other species of *Oncorhynchus* spawn once and then die (semelparity). North of Oregon, repeat spawning is relatively uncommon and more than 2 spawning migrations is rare. Iteroparity occurs predominantly in females (Busby et al. 1996).

Adult steelhead feed on a variety of invertebrates, including crustaceans and mollusks inhabiting benthic habitats, as well as smaller species of fish and/or their eggs (Schultz 2004). Young steelhead feed primarily on zooplankton (NMFS-NWR 2004a).

- **Bull Trout (*Salvelinus confluentus*)**

Description—Bull trout distinguishing characteristics include the absence of teeth in the roof of their mouth, the presence of light-colored spots on a dark background (olive green to brown), the absence of spots on their dorsal fin, smaller scales, and differences in skeletal structure (USFWS 2003a). The olive green/brown coloration fades to white on the belly. During spawning the white on the belly will develop varying amounts of red coloration (USFWS 2003a).

Status—There is critical habitat designated for the bull trout for the Klamath River, Columbia River, Jarbridge River, Coastal Puget Sound, and Saint Mary-Belly populations. This critical habitat includes almost 1600 km of shoreline paralleling marine habitat along the coast of Washington (**Figures 3-17** and **3-18**). The bull trout is listed as threatened throughout the contiguous U.S. (USFWS 2005b).

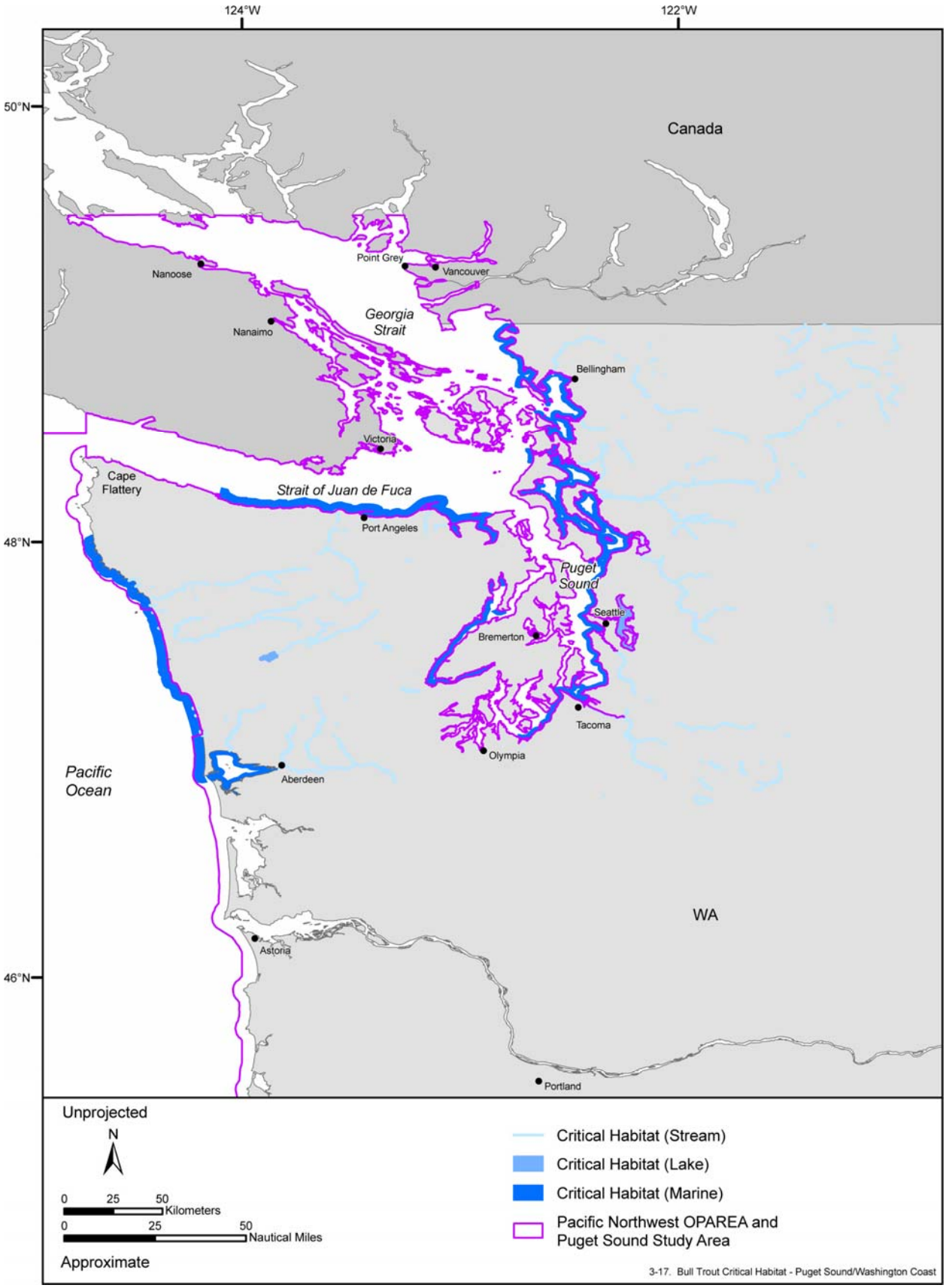


Figure 3-17. Designated critical habitat for bull trout in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: USFWS.[7]

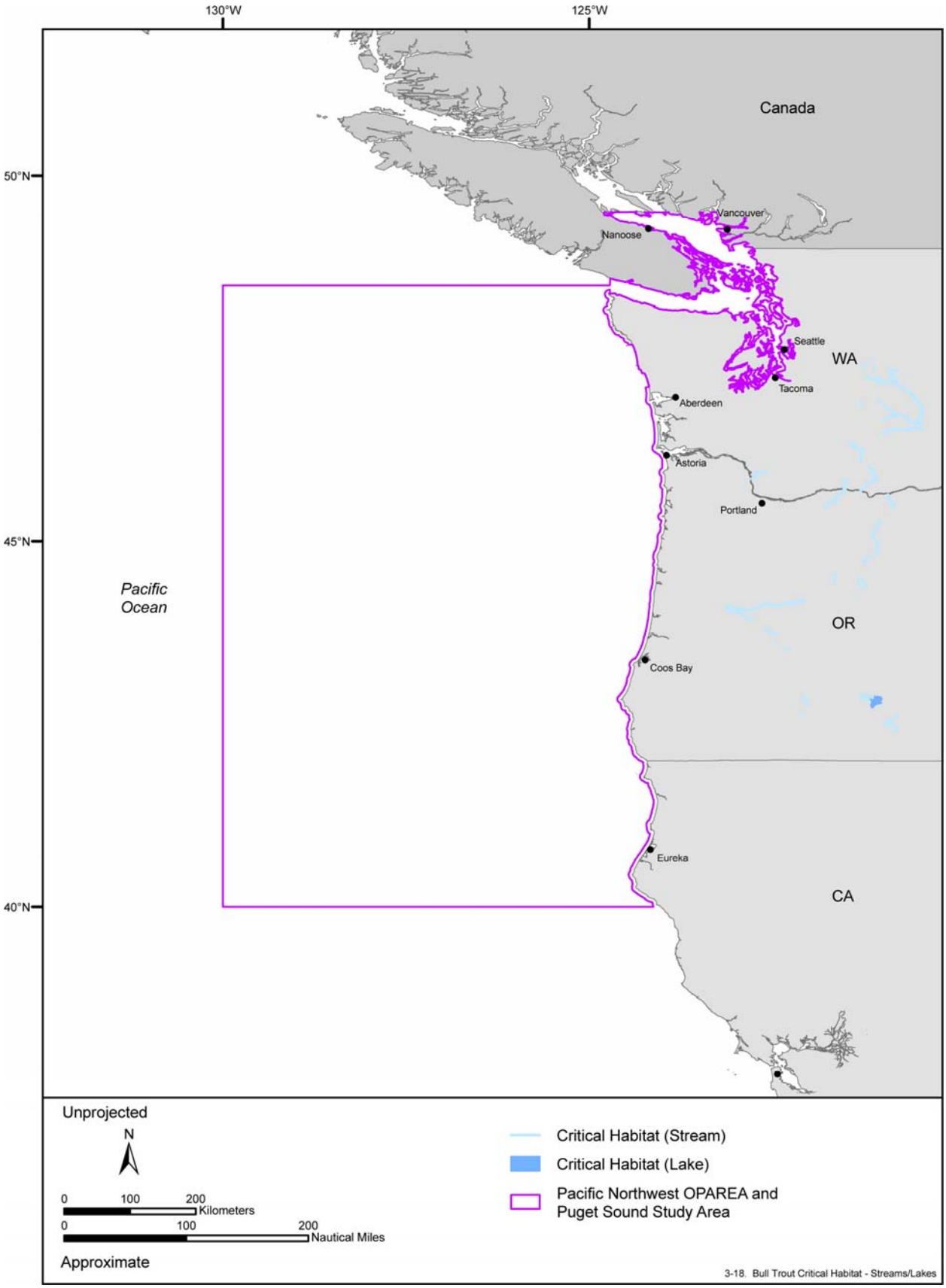


Figure 3-18. Designated critical habitat for bull trout located in streams and lakes in the vicinity of the Pacific Northwest OPAREA and Puget Sound Study Area. Source data: USFWS.[7]

Bull trout are estimated to have occupied about 60 percent of the Columbia River Basin, and presently occur in 45 percent of the estimated historical range.

Habitat Preferences—Bull trout are typically found in fresh water to euhaline water but are rarely anadromous (Froese and Pauly). Individuals found in marine waters typically occur inshore of the 10 m isobath (NMFS-NWR 2004a).Little is known about the temperature requirements of bull trout in marine environments but adult and subadult trout in freshwater typically are not found in temperature greater than 15°C.[5] Eggs, alevins, fry, and parr inhabit freshwater while adults and subadults can be found in river, lakes, or marine waters (NMFS-NWR 2004a). Fry are closely associated with areas around cold-water seeps. This association diminishes as size increases. As bull trout get larger they tend to associate with large boulders and woody debris.[5]

Distribution—Bull trout are native to the Pacific Northwest and western Canada and have historically occurred in major river drainages from about 41°N to 60°N latitude. They range from the southern limits in the McCloud River in northern California and the Jarbidge River in Nevada north to the headwaters of the Yukon River in the Northwest Territories, Canada (USFWS 2003a). The range includes Puget Sound, various coastal rivers of Washington, British Columbia, and southeast Alaska (USFWS 2003a). Bull trout are common in the nearshore areas of Puget Sound, but very little is known about their overall oceanic distribution (NMFS-NWR 2004a).

- Information Specific to the Pacific Northwest OPAREA—Bull trout populations are severely reduced in the Pacific Northwest and no longer occur in northern California. Bull trout have declined in overall range and numbers of fish. Though still widespread, there have been numerous local extirpations reported throughout the Columbia River basin. Although some strongholds still exist, bull trout generally occur as isolated sub-populations in headwater lakes or tributaries where migratory fish have been lost. Although the bull trout distribution in the Coastal-Puget Sound population is less fragmented than the Columbia River population, bull trout subpopulation distribution within individual river systems has contracted and abundance has declined (USFWS 2005b).

Behavior and Life History—Bull trout may exhibit a number of life history strategies. Fish exhibiting a resident life history strategy are non-migratory and spend their entire lives in their natal stream. Migratory life history strategies include fluvial, adfluvial, and anadromous. Migratory bull trout reside as adults or subadults in larger rivers (fluvial), lakes or reservoirs (adfluvial), or marine waters (anadromous), and spawn and rear as juveniles in headwater tributaries (USFWS 2005b).

Anadromous migrations by bull trout is poorly understood but they spend two to three years in freshwater before migrating to estuaries or nearshore marine environments in the spring.[3] Subadults generally spend two summers in the marine environment before reaching maturity and returning to freshwater to spawn.[3] Bull trout spawn in the fall in correlation with falling water temperatures. They prefer to spawn at temperatures below 9°C in unpolluted streams over clean gravel and cobble substrate associated with gentle stream slopes (USFWS 2003a).

Young bull trout generally prey on aquatic insects targeting various fish species as they grow larger. Adult bull trout prey on whitefish, sculpins, and other trout (USFWS 2003a).

3.4.2 Websites Accessed

[1] Marine Resources. Accessed 12 January 2006. http://biology.usgs.gov/s+t/SNT /noframe/ mr181.htm.
[2] Salmon populations. Accessed 12 January 2006. http://www.nwr.noaa.gov/ESA-Salmon-Listings/ Salmon-Populations/
[3] Critical habitat GIS data. Accessed 12 January 2006. http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/CH-GIS-Data.cfm
[4] Fishbase. Accessed 12 January 2006. http://www.fishbase.org/search.php.
[5] Shorezone development literature review – bull trout http://www.ci.bellevue.wa.us/page.asp?view= 2988.

[6] Known ocean ranges of Pacific salmon and steelhead from high seas tagging research. Accessed 5 January 2006. http://www.fish.washington.edu/research/highseas/known_range.html.

[7] Bull Trout. Accessed 29 November 2005. http://www.fws.gov/pacific/bulltrout/.

4.0 FISH AND FISHERIES

4.1 FISH/INVERTEBRATES

The Pacific Northwest OPAREA and Puget Sound Study Area is situated in a region of diverse ichthyofauna and highly productive fisheries (Leet et al. 2001). Predominant ecosystems found in the Pacific Northwest OPAREA and Puget Sound Study Area include nearshore coastal (i.e., rocky intertidal habitats, estuaries), continental shelf (i.e., upwelling zones, inner portion of California Current, benthic habitats), and oceanic systems (i.e., epipelagic, mesopelagic, and bathypelagic). The majority of the fishery resources are found in the epipelagic and benthic areas of the continental shelf ecosystem.[1] Important marine species include coastal pelagics (mackerels, anchovies, herrings, and jacks), shelf and slope groundfish (flatfish, rockfish, roundfish, etc.), salmonids (chinook salmon, coho salmon, chum salmon, sockeye salmon, pink salmon, steelhead, and bull trout), highly migratory (tuna), invertebrates (Dungeness crab, pink shrimp, etc.), and kelp.[1] The Pacific salmon are arguably the most important living marine resource within the Pacific Northwest region.[1] Currently the Pacific Northwest OPAREA and Puget Sound Study Area supports habitats of "endangered" and "threatened" populations of chinook salmon, coho salmon, sockeye salmon, and steelhead (*Oncorphynchus mkiiss*) and bull (*Salvelinus confluentus*) trouts (NMFS 2005h; 2005c). For additional information on these species refer to Section 3.4.

The Pacific Northwest OPAREA falls within the California Current System (CCS) which travels the full length of the U.S. Pacific coast south to Baja Califonia.[1] The CCS is rich in microscopic organisms (i.e., diatoms, tintinnids, and dinoflagellates) which form the base of the food chain in the study area, especially in areas where consistent ocean upwelling occurs along the coast. Grazers like small coastal pelagic fishes and squid depend on this planktonic food supply (diatoms, small plankters, euphausiids, and other zooplanktonic organisms), and in turn are forage for larger species, such as highly migratory species (i.e., sharks, tunas, swordfish) (NMFS-SWR 2006).

Along the Pacific continental margin off northern California, Oregon, and Washington, ichthyofaunal distribution is influenced by the northern half of the CCS (Field et al. 2006; NMFS-NWR 2006). The pelagic ichthyofauna is composed of a small number of endemic coastal and offshore species within a larger mixture of subarctic, transitional, and subtropical species, some of which are at the limits of their geographic limits (Brodeur et al. 2003). North-south differences in the composition and relative distribution of the dominant species is also apparent especially around the Columbia River, Cape Blanco, Oregon, and Cape Mendocino, California as species often differ substantially between these areas (Brodeur et al. 2004).

The continental shelf/slope also supports a large biomass of groundfishes (Dark and Wilkins 1994). Slope (deep-water rockfish: darkblotched, splitnose, and yellowmouth, Pacific ocean perch, shortspine thornyhead) and shelf (bottom rockfish: yellowtail, canary, sharpchin, greenstriped, rosethorn, and redstripe) assemblages exists particularly along the Washington State/Oregon coast (Williams and Ralston 2002). Typically, the groundfish community in the northern CCS exhibits strong-depth gradient in species composition and diversity (Tolimieri and Levin 2006) found in many other demersal fish communities inhabiting shelf and upper slope regions (Colvocoresses and Musick 1984; Jay 1996; Mahon et al. 1998; Mueter and Norcross 2002). However, information is lacking about demersal species in deeper regions or how such depth-related patterns may change with latitude (Tolimieri and Levin 2006).

Various physical and geographic features within the CCS such as northward-flowing California Undercurrent and Davidson Current, ocean upwelling areas, Columbia River plume, submarine canyons (i.e., Astoria), seamounts (i.e., Cobb), large submerged rocky reefs (i.e., Heceta Bank), coastal promontories (i.e., Capes Blanco), and submarine ridges (i.e., Mendocino Escarpment) influence the distribution and abundance of pelagic fishes and groundfishes (Doyle 1992; Dower and Perry 2001; Nasby-Lucas et al. 2002; Williams and Ralston 2002a; Bosley et al. 2004; Emmett et al. 2004; Emmett et al. 2006).

4.2 HABITATS

Habitat consists of the geographic area and the characteristics of that area where species may be found during any phase of their lifestage. Habitat characteristics include geomorphological, physical, biological, and chemical parameters. Interactions between environmental parameters make up habitat and determine the biological niche of a species. Habitat parameters affecting fish distribution throughout the Pacific Northwest OPAREA and Puget Sound Study Area include both physical (depth, substrate, temperature, salinity, and dissolved oxygen) and biological (competitors, predators, and facilitators) variables (NMFS-NWR 2005). Habitat types along the west coast can be separated into two large zoogeographic provinces: the Oregonian (north of Point Conception) and the Californian (south of Point Conception) (Allen and Smith 1988). The Pacific Northwest OPAREA and Puget Sound Study Area falls entirely within the Oregonian Province. The Oregonian province can further be broken down into the following habitat types utilized by managed fishes (NMFS-NWR 2005).

Nearshore (Estuarine and Intertidal Habitats)

- Estuaries: include bays and inlets influenced by both the ocean and river and serve as the transitional zone between fresh and saltwater. These habitats fulfill fish/invertebrate needs for reproduction, feeding, refuge, and other physiological necessities. Major estuaries include Puget Sound, Gray's Harbor, Columbia River, and Yaquina Bay.
- Nearshore biogenic habitats: includes kelp, seagrass, and sponges. The biological component (kelp, seagrass, or sponges) associated with the habitat is generally the feature that makes that habitat suitable for a particular species or life stage (e.g., groundfish).
- Nearshore unconsolidated bottom (silt, mud, gravel, or mixed): composed of small particles (gravel, sand, mud, silt, or mixtures of these particles), which contains little to no vegetation due to the lack of stable surfaces for attachment.
- Nearshore hardbottom: composed of bedrock, boulders, cobble, or gravel/cobble. One of the least abundant benthic habitats, but one of the most important for fishes, especially rockfish (e.g., *Sebastes* spp.), lingcod, and sculpins.
- Nearshore water column: coastal epipelagic zone. Includes egg, juvenile, and larval stages of groundfish commonly associated with macrophyte canopies or drift algae.

Offshore (Shelf and Slope Habitats)

- Offshore biogenic habitats (corals, sponges, etc.): includes structure-forming invertebrates such as corals, basketstars, brittlestars, demosponges, gooseneck barnacles, sea anemones, sea lilies, sea urchins, sea whips, tube worms, and vase sponges.
- Offshore unconsolidated bottom (silt, mud, sand, gravel, or mixed): composed of small particles (gravel, sand, mud, silt, or mixtures of these particles), which contains little to no vegetation due to the lack of stable surfaces for attachment.
- Offshore hardbottom: composed of bedrock, boulders, cobble, or gravel/cobble. Large, mobile, nektobenthic fishes (e.g., rockfish, sablefish, Pacific hake, spotted ratfish, spiny dogfish) are typically associated with this habitat.
- Offshore artificial structures: includes artificial reefs utilized by rockfish.
- Offshore water column: pelagic zone. This area is home to the highly migratory species, other relatively large pelagics, and early life stages of groundfish inhabiting the epipelagic/mesopelagic area or are in association with fronts, current systems, and marcophyte canopies or drift algae.

The marine environment off California, Oregon, and Washington State is collectively known as the Coastal Upwelling Domain (CUD) (NMFS-NWR 2005). The CUD is part of the CCS. This system is described as a broad, meandering, southward-flowing current that extends from the northern tip of Vancouver Island (50°N) to Baja California (25°N) and extends from shore to several hundred miles out (NMFS-NWR 2005). For more information on these oceanographic environments, see Chapter 2.

Even though the coastal upwelling area located along the Pacific coast produces high plankton biomass, unique problems are associated with this environment. The upwelling process transports surface waters and any associated pelagic zooplankton, larval, and juvenile fishes away from the coast and towards the south, removing them from nutrient-rich waters and leaving them in relatively oligotrophic conditions. To avoid this, fish species may spawn during winter months before upwelling occurs (Dover sole, sablefish, and Dungeness crab), migrate to regions where upwelling does not occur (Pacific hake), utilize bays and estuaries where upwelling does not occur (English sole), spawn in rivers (salmonids and eulachon), or give birth to live precocious "juvenile" individuals (NMFS-NWR 2005).

4.2.1 Puget Sound

Estuaries are among the most productive natural systems and important nursery areas that provide food, refuge from predation, and valuable habitat in supporting commercial and recreational fisheries including salmonids, groundfish, shellfish, and bivalves along the west coast (Emmett et al. 1991; Monaco et al. 1992). Most species utilizing this inshore habitat fall into four categories: (1) diadromous species which use estuaries as migration corridors and in some instances, nursery areas; (2) species that use estuaries for spawning, often at specific salinities; (3) species that spawn offshore near the mouth of estuaries and depend on tidal- and wind-driven currents to carry eggs, larvae, or early juveniles into estuarine nursery areas; and (4) species that enter estuaries during certain times of the year to feed on abundant prey (Monaco et al. 1990).

West coast estuarine fish assemblages are structured primarily by salinity and temperature tolerances and the location of turbidity maximum (Meng et al. 1994) but also by bottom topography, substrate, and other physical factors (e.g., vertical relief, slope, crevice size, biological cover) (Pacunski and Palsson 1998). Estuarine benthic communities of the west coast are structured primarily by physical (substrate) and chemical (salinity) factors that reflect the underlying morphology and hydrology of the estuary (Emmett et al. 2000). Rocky shores are described in terms of worldwide zonation patterns (Levings et al. 1983), whereas soft sediments are based on hydrological features (Simenstad 1983; Nichols and Pamatmat 1988), sediment characteristics or water depth (Levings et al. 1983; Llansó 1998), and occurrence of vegetation (Levings et al. 1983; Phillips 1984).

Puget Sound's inshore marine basins comprises two regions: (1) northern: encompassing the international Georgia Basin waterbody (U.S. and Canadian portions of the Strait of Juan de Fuca, Strait of Georgia, and San Juan Archipelago) and (2) southern: delineated by the narrow passages of Admiralty Inlet (Hood Canal) and Deception Pass (Central and Southern Puget Sound).[2]

Nearshore marine environments along Puget Sound's inland waters are a unique zone exhibiting higher species diversity, density, and production than the deeper water marine habitats (Shaffer 2002). Nearshore vegetated habitats consisting of kelp (e.g., bull, *Nereocystis lutekeana* and giant, *Marcocystis integrifolia*), eelgrass (*Zostera marina*), algae (red: nori, *Porphyra* spp., brown: rockweed, *Fucus* spp., and green: sea lettuce, *Ulva* spp.), drift algae (detached intertidal and subtidal kelp that form floating mats), mixed algae (red, brown, and green), and salt marsh-salt tolerant, emergent wetlands along with a rocky/cobble shoreline with Laminarian (understory ulvoid, *Pterygophora california*) cover, provide food (infaunal and bottom-dwelling organisms) and/or shelter for several species of fish, invertebrates (mollusks and crustaceans), and seabirds (Berry and Ritter 1995; Shaffer 1998; Frankenstein 2000; Shaffer 2001; Anchor Environmental L.L.C. and People for Puget Sound 2002).

This nearshore habitat functions as a critical feeding, refuge, and migration corridor for many fish species including salmon, forage fish, and rockfish (Triangle Associates Inc. 2004). Adult fish use nearshore marine waters for migration and feeding; whereas juveniles are known to depend upon these nearshore waters for migrations, feeding, and refuge (Brennan and Higgins 2003). Adult salmon use kelp beds extensively as feeding and staging areas before heading into natal streams to spawn. Juvenile salmon require nearshore healthy wetlands as they transition from freshwater to marine water and from eelgrass/kelp beds during their outward migration once they reach marine waters (Shaffer 2003). Forage or bait fish heavily utilize nearshore areas for spawning, feeding, and migration (Meyer 1997; Bargmann 1998). Forage species, such as the surf smelt (*Hypomesus pretiosus*) and Pacific sand lance

(*Ammodytes hexapterus*) spawn in sandy gravel on intertidal beaches; whereas Pacific herring (*Clupea harengus pallasi*) spawn on littoral zone plants, mainly native eelgrass and red algae, *Gracilariopsis* (Penttila 1997; Moulton 2000; Moulton and Penttila 2000; Moriarity et al. 2002a, 2002b; Sikes et al. 2002). Adult and juvenile rockfish (e.g., brown, black, quillback, copper, yellowtail, and Puget Sound) depend on rocky reef, eelgrass and kelp beds, and drift algae for food and refuge (Love et al. 2002). Rockfish also rely on drift mats, possibly as transportation between nearshore and benthic habitats (Love et al. 2002; Shaffer 2003).

The inshore marine basins of Puget Sound supports an ichthyofauna of 230 species representing 71 families with pelagic (e.g., salmonids, myctophids, etc.), and demersal (e.g., forage fish and groundfish) fishes being the most abundant groups (DeLacy et al. 1972; Somerton and Murray 1976; Miller and Borton 1980; Garrison and Miller 1982; Buckworth 1996; Venier and Kelson 1996; Anchor Environmental L.L.C. and People for Puget Sound 2002; Brennan and Higgins 2003; Palsson et al. 2003b; Nightingale[2]). Pacific salmonids are represented by nine species of salmon and/or trout (Somerton and Murray 1976; Nightingale[2]) with eight of these species being commercially and recreationally harvested (Washington Sea Grant Program 2000). Forage or bait fish, consisting of nine small schooling fish species (anchovies, sand lances, herrings, sardines, and smelts), are a significant prey base for marine mammals, seabirds, and fish populations including salmonids and groundfish (Bargmann 1998). In addition, six of these species are subjected to commercial or recreational fisheries (Bargmann 1998; Washington Sea Grant Program 2000; Nightingale[2]). Groundfish or bottomfish are represented by 86 species dominated by flatfish (15 species), rockfish (26 species), roundfish (including greenlings, sculpins [35 species], sablefish, and cods), and skates, sharks, and chimeras (DeLacy et al. 1972; Somerton and Murray 1976; Miller and Borton 1980; Garrison and Miller 1982; Palsson et al. 1998; Palsson 2001; Palsson et al. 2003b). At least 42% of these species consisting of gadids (three species), flatfishes (six species), rockfishes (eight species), greenlings and sculpins, and others (e.g., spiny dogfish, surfperches, and skates) comprise the recreational/commercial fisheries (Washington Sea Grant Program 2000; Nightingale[2]).

Estuarine invertebrates (e.g., shellfish) are an abundant resource in Puget Sound representing 26 phyla and more than 2,900 species. More than 40 species are distinguished as harvested or classified as recreational/commercial shellfish with the remainder being non-game or unclassified marine invertebrates (West 1997; Washington Sea Grant Program 2000; Shaffer 2001). The harvested or classified recreational/commercial shellfish include gastropods (snails, *Nucella* spp., and pinto or northern abalone, *Haliotis kamtschatkana*), bivalves (native, *Ostrea lurida,* and Pacific, *Crassostrea gigas,* oysters; butter, *Saxidomous gigantea*, Manila littleneck, *Venerupis philippinarum*, Pacific littleneck *Prototheca staminea*, and geoduck, *Panope abrupta* clams; blue mussel, *Mytilus edulis*, and scallops, *Chlamys rubida*, *C. behringiana*, *Hinnites giganteus*), cephalopods (squid and octopus), crustaceans (spot or prawn, *Panadalus platyceros*, coonstripe, *P. hysinotus,* dock*, P. danae,* and pink*, P. jordani* and *P. borealis* shrimps, Dungeness, *Cancer magister*, and red rock, *C. productus* crabs, and barnacles), and echinoderms (purple, *Strongylocentrotus purpuratus*, red, *S. franciscanus*, and green, *S. droebacniensis*, sea urchins). All of these phyla form part of an important intertidal recreational and commercial harvested shell fisheries with some species being cultivated in aquaculture operations (e.g., oysters, geoducks, and other clams) (Ketchen et al. 1983; Emmett et al. 1991; West 1997; Anchor Environmental L.L.C. and People for Puget Sound 2002; Triangle Associates Inc. 2004; Nightingale[2]).

4.2.1.1 Forage Fish

4.2.1.1.1 Forage fish habitat

The shorelines of Puget Sound provide habitat for a multitude of living resources. In recent years, attention has been shifted to the use of these shorelines as spawning habitats for forage fishes. Forage fish and their eggs are an important food source for many organisms (e.g., marine mammals, sea birds, and fishes including salmonids) within in the Puget Sound ecosystem (Bargmann and Schweigert 2005) (Herrera Environmental Consultants Inc. 2005). Six main species of forage fish are found within Puget Sound: Pacific herring, northern anchovy, Pacific sardine, surf smelt, longfin smelt (*Spirinchus thaleichthys*), and Pacific sand lance (Bargmann 1998). These fish occupy similar ecological niches

throughout their range around the Pacific Rim. Due to lack of information and their distribution with Puget Sound, longfin smelt, which historically appeared to have populations in East and West Sounds, Orcas Island, San Juan County and Pacific sardine will not be addressed in this section (Miller and Borton 1980) (Moulton and Penttila 2000). For more information on the Pacific sardine refer to Section 4.4.2.

Forage fish such as the Pacific herring and surf smelt are also targeted commercially and recreationally (Bargmann and Schweigert 2005). Washington State and Canada have implemented management principles primarily based around the Pacific herring which is the most recreationally and commercially targeted forage fish in the region (Bargmann and Schweigert 2005). Because of the schooling nature of forage fish species, they can be easily overharvested (Bargmann 1998). Recreational harvest is relatively insignificant (20%) compared to commercial harvest (80%). Commercial landings of forage fish make up approximately 3% (770 mt annually) of all commercial finfish landings in Washington State (Bargmann 1998). A commercial fishing license is required to fish commercially for any forage fish in state waters (Bargmann 1998). Authorized gear types include gill net, dip bag net, drag seine (i.e., beach seine), purse seine, and lampara seine. There no limit on the number of licenses issued to commercial fisherman for any species of forage fish other than Pacific herring (Bargmann 1998). For more information on licensing for the commercial harvest of herring visit http://wdfw.wa.gov/fish/forage/forage.htm.

Five species of forage fish (Pacific herring, eulachon or Columbia River smelt [*Thaleichthys pacificus*], longfin smelt, surf smelt, and Pacific sand lance) and their spawning grounds have been included on the WDFW "Priority Habitats and Species List" which was established to identify species and habitats of special concern in Washington State (Bargmann 1998). Additionally, surf smelt, Pacific sand lance, and Pacific herring spawning beds have been declared "saltwater habitats of special concern" under the WAC Hydraulic Code Rules 220-110-250. These spawning beds are protected from disturbance by construction projects which may be prohibited or conditioned during certain times of the year (Bargmann 1998). On December 5, 1997, the Washington Fish and Wildlife Commission adopted the "Wild Salmonid Policy" which also directly effects forage fish management (Bargmann 1998). Under the "Wild Salmonid Policy," the following actions are required: 1) ensure no net loss of eelgrass habitat, herring spawning areas or function, intertidal forage fish spawning habitat area or function, and 2) develop reserves for herring spawning habitat (Bargmann 1998). Federal legislation in the 1850s states that tribes which have signed treaties with the federal government have treaty fishing rights. These rights encompass the right to take every form of aquatic animal life, even if it wasn't harvested at the time the treaty was signed. The treaty Indian tribes are not parties to the Forage Fish Management Plan and are therefore not bound by the provisions of the policy or the plan. However, in the north Puget Sound, the WDFW and Lummi, Nooksack, Suquamish, and Swinomish tribes have adopted a formal herring allocation and management plan which they update with annual annexes (Bargmann 1998).

Recent studies have located additional forage fish spawning sites and provide initial information on the Pacific sand lance, Pacific herring, and surf smelt spawning in Puget Sound (Moulton 2000; Moulton and Penttila 2000; Moriarity et al. 2002a, 2002b; Sikes et al. 2002; FSJ 2004a; 2004b; FSJ et al. 2004; Fagergren 2005; Stick et al. 2005) and in Georgia Strait for the Pacific herring and surf smelt (Therriault and Hay 2003; Hay and McCater[27]). Current regulations only protect known spawning sites and do not afford protection to undiscovered spawning habitats. For this reason, additional sampling is needed. Protection of nearshore areas in Puget Sound is vital to the continued reproductive success of these species (Long et al. 2005). For help in the identification of these species refer to Bargmann (1998) and http://wdfw.wa.gov/fish/forage/forage.htm.

Three of the four forage fish species in Puget Sound, Pacific herring, Pacific sand lance, and surf smelt have documented spawning sites within the following Naval training areas: Dabob Bay Range Complex and NUWC Keyport. In addition, the surf smelt utilizes spawning areas along the Pacific coast in W237A (Bargmann 1998) and Pacific herring spawning sites have been documented south of Nanoose Range in Nanoose Bay from Nankivell Point to Taylor Bay.[27] **Table 4-1** provides a list of Naval restricted areas in the Puget Sound Study Area where forage fish spawning sites have been located.

Table 4-1. Forage fish spawning sites within various Naval restricted areas in the Puget Sound Study Area. "X" = Occurs and "+" = Does Not Occur.

Naval Restricted Areas	Forage Fish Species		
	Pacific Sand Lance	*Surf Smelt*	*Pacific Herring*
Naval Submarine Base, Bangor	X		
Naval Undersea Warfare Center, Keyport		X	X
Naval Ordnance Center, Port Hadlock, Indian Island	X	X	X
Naval Radio Station, Jim Creek	+	+	+
Naval Fuel Depot, Manchester	X		X
Naval Air Station, Whidbey Island	X		
Naval Air Station, Everett	+	+	+
Bremerton Naval Hospital, Ostrich Bay	X	X	
Navy's Jackson Park Housing facility, Ostrich Bay	X	X	
Puget Sound Naval Shipyard, Charleston Beach	X	X	
Naval Submarine Base Bangor security zone	X		
Pier No. 23 (Army Pier), Blair Waterway, Commencement Bay	+	+	+
Cresent Harbor Explosive Ordnance Units Training Area	X	X	X
Strait of Juan de Fuca, naval air-to-surface weapon range, restricted area	+	+	+
Hood Canal and Dabob Bay, naval non-explosive torpedo testing area	X	X	X
Strait of Juan de Fuca, eastern end, off westerly shore of Whidbey Island	+	+	+
Admiralty Inlet, entrance, naval restricted area	+	+	+
Port Gardner, Everett Naval Base, naval restricted area	+	+	+
Hood Canal, Bangor, naval restricted areas	X		
Port Orchard Passage, naval restricted area			X
Sinclair Inlet, naval restricted areas	X	X	
Carr Inlet, naval restricted areas			X
Dabob Bay, Whitney Point, naval restricted area	X	X	
Port Townsend/Indian Island/ Walan Point, naval restricted area	X		X
Naval Undersea Warfare Center Division, Newport (Dabob Bay)	X	X	X

Source: 33 CFR 334.1180 – 1270; 33 CFR 165.1321; Penttila (1997); Bargmann (1998); Stick et al. (2005)

The distribution, habitats preference (substrate, temperature), life history (migration, movements, spawning), and common prey species for the Pacific herring, surf smelt, Pacific sand lance, and northern anchovy are provided in the following paragraphs:

- **Herrings (Clupeidae)**

  - **Pacific Herring (*Clupea harengus pallasi*)**

    Distribution—Pacific herring range from northern Baja California, Mexico to Bering Sea and northeast to the Beaufort Sea, then along the Asian coast from the Arctic Ocean to Korea and Japan (Love et al. 2005). Pacific herring have historically been one of the most abundant fishes in Puget Sound but major stocks in the Washington State area (i.e., Cherry Point) have seen dramatic declines.[3] There are at least 18 stocks that spawn in Puget Sound and one along the Washington Coast in Willapa Bay.[4]

    Habitat Preference— Pacific herring spawning grounds are very specific consisting of vegetation (eelgrass or fibrous red algal, *Gracilariopsis*) or shallow water substrate in subtidal or intertidal habitats (0 to 3 m in tidal elevation) (Bargmann 1998; Bargmann[1]; **Figures 4-1**, **4-2**, and **4-3**). Spawning grounds include sheltered inlets, sounds, bays, and estuaries (Lassuy 1989). Herring eggs are adhesive and stick to the substrate they were deposited on until hatching (Snohomish County Public Works 2001). The specificity of Pacific herring spawning grounds makes them very vulnerable to shoreline development and documented sites are protected by the WAC Hydraulic Code Rules 220-110-271 which govern the extent which bulkheads or fills can intrude seaward of the high tide line (Bargmann 1998; WDFW[2]).

    Life History—Spawning occurs in consistent areas each year from late January to April peaking in February and March (Lassuy 1989; Snohomish County Public Works 2001) and may occur anywhere between the high tide mark and 12 m (Sikes et al. 2002). Hatching is temperature dependent and may last from 10 to 14 days (Bargmann 1998). After hatching, the larvae drift with water currents for two weeks to three months while feeding on plankton (Snohomish County Public Works 2001). During their first summer, juveniles primarily inhabit nearshore waters (Lassuy 1989). Puget Sound stocks of young herring spend their first year of life in Puget Sound (Bargmann 1998). Juveniles may migrate offshore after their first summer or they may remain inshore until they are sexually mature (Lassuy 1989). At sexual maturity (two to four years of age) they migrate back to their spawning grounds (Bargmann 1998). Like salmon, Pacific herring generally return to their natal spawning area, however, unlike most salmonids, they are iteroparous and able to spawn annually for several consecutive years (Bargmann 1998; Bargmann[1]). Although homing is not as accurate as that demonstrated by salmon, herring spawning populations seem to maintain some biological separation. Stock specific characteristics may include unique age structures, distinctive spawning times, and prespawner holding area behavior. Prior to spawning, ripening adult herring congregate and hold in a region usually adjacent to the spawning grounds (WDFW[4]; **Figures 4-1**, **4-2**, and **4-3**). Adults may move into these holding areas weeks or even months before spawning season (Lassuy 1989). Depth of holding areas and their distance from spawning sites varies between stocks (Lassuy 1989).

    Common Prey Species—Pacific herring prey primarily upon planktonic crustaceans such as calanoid copepods as well as cumaceans, gammarid amphipods, and mysids (Simenstad et al. 1979; Lassuy 1989).

- **Smelts (Osmeridae)**

  - **Surf Smelt (*Hypomesus pretiosus*)**

    Distribution—Surf smelt range from Long Beach, southern California to the north side of Alaska Peninsula at Izembek Bay and Gulf of Alaska (Miller and Lea 1972; Mecklenburg et al. 2002). This species is common throughout the marine waters of Washington State, from the Columbia River to the Canadian border and southernmost Puget Sound.[3] Recent research on the spawning habitats of the surf smelt has greatly increased the number of known spawning grounds within Puget Sound (greater than 400 km of spawning beaches) (Penttila 1997; Snohomish County Public Works 2001).

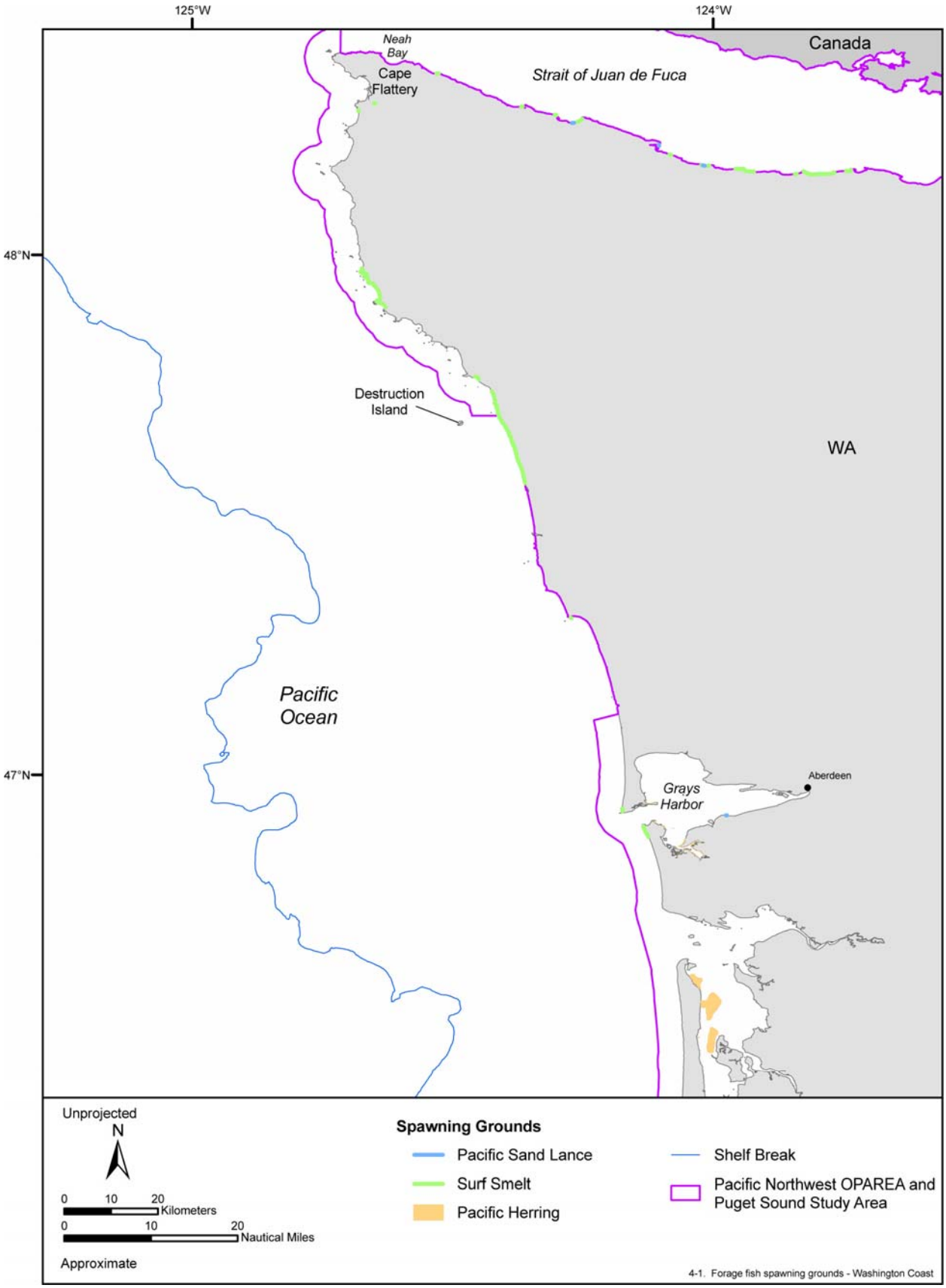


Figure 4-1. Documented forage fish spawning grounds and holding areas along the Washington coast and the Strait of Juan de Fuca. Source data: Bargmann (2005).

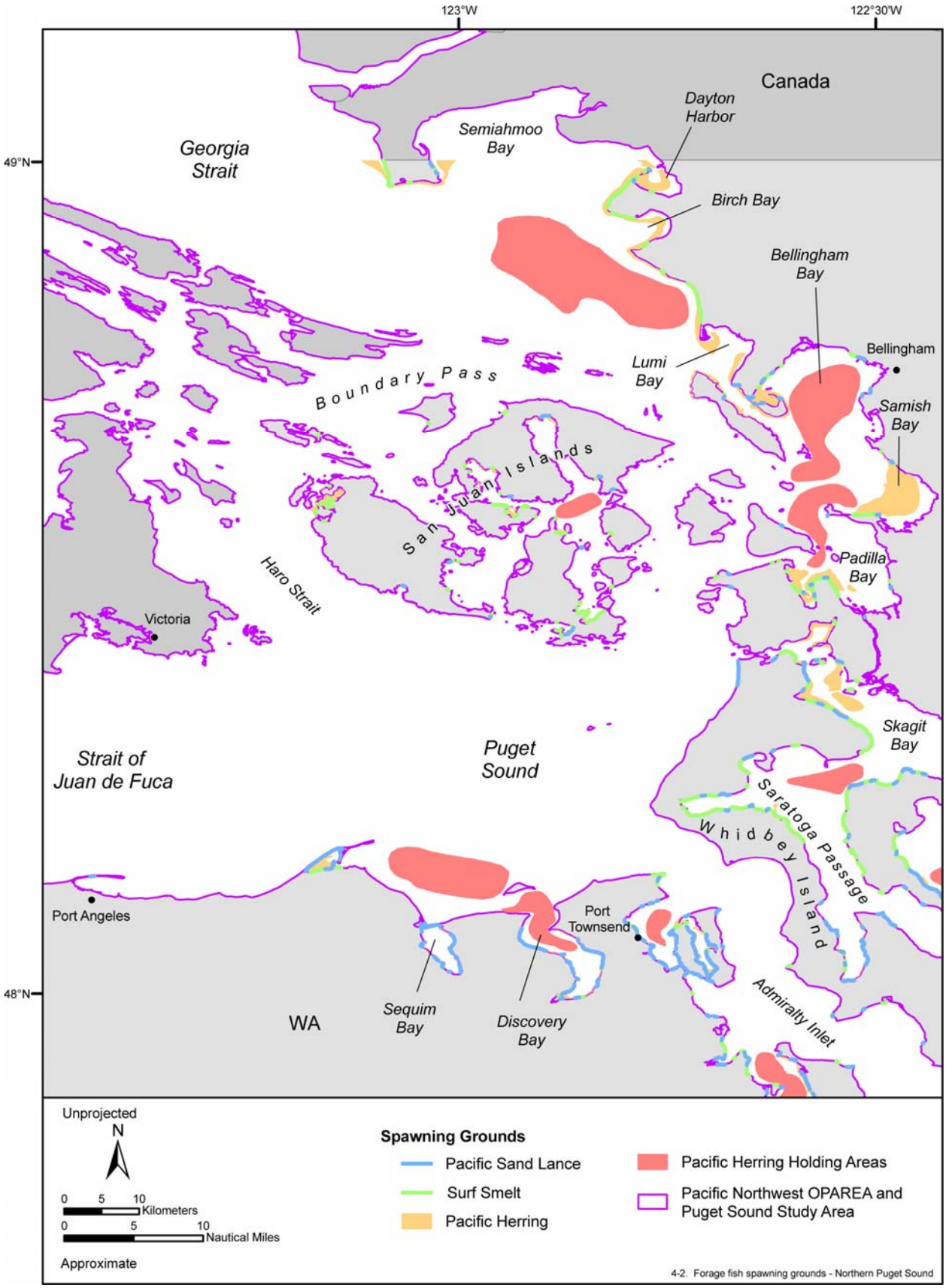


Figure 4-2. Documented forage fish spawning grounds and holding areas in northern Puget Sound. Source data: Bargmann (2005).

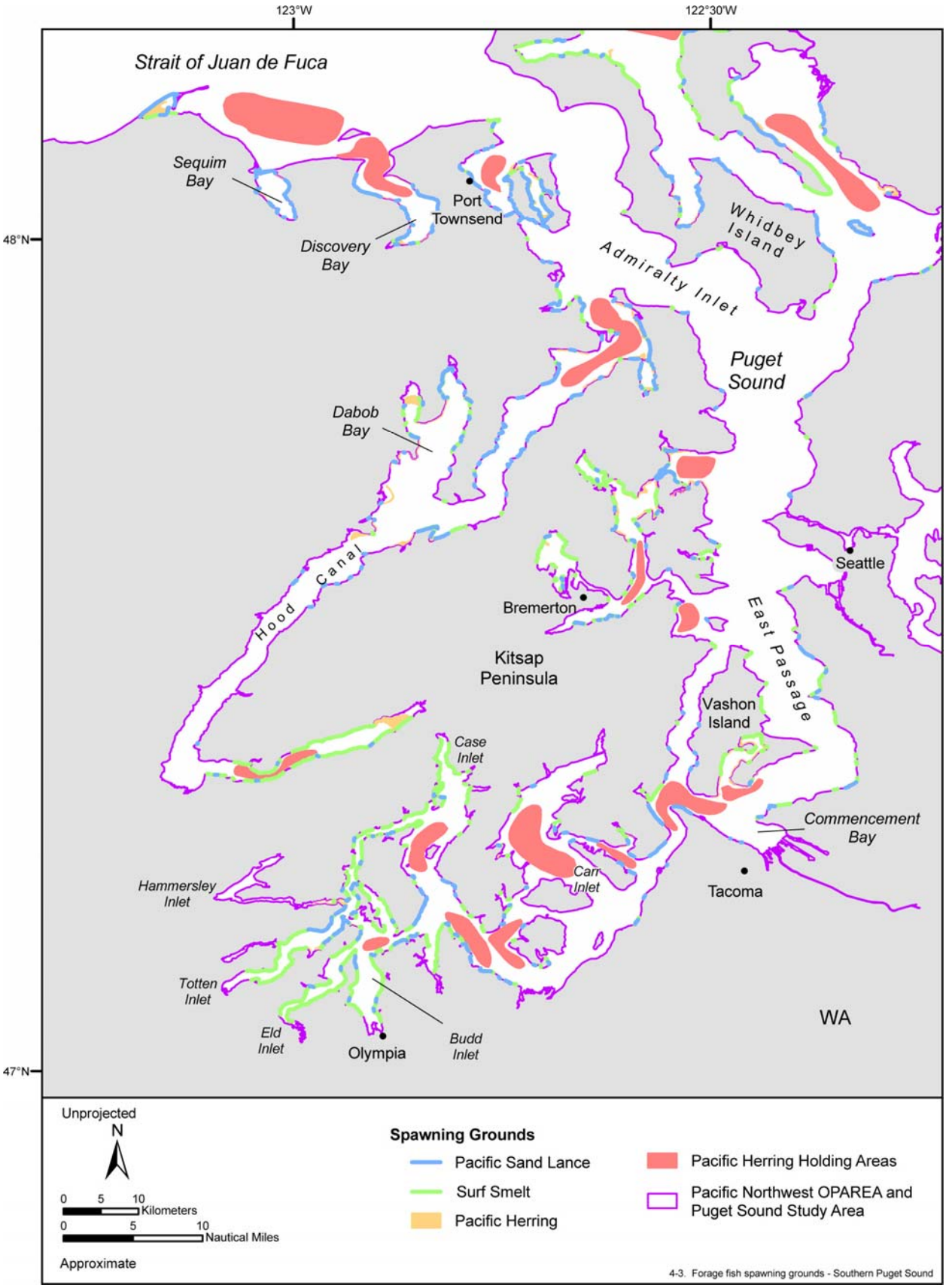


Figure 4-3. Documented forage fish spawning grounds and holding areas in southern Puget Sound. Source data: Bargmann (2005).

Habitat Preference—Spawning habitats are present throughout the Puget Sound basin (Penttila 1997; **Figures 4-1**, **4-2**, and **4-3**). Surf smelt and sand lance eggs often occur in the same substrate and it is estimated that approximately 20% of the shoreline in Puget Sound may be used by surf smelt/Pacific sand lance as spawning habitat (Penttila 1997). Spawning occurs over one-third of the intertidal zone and extends a few meters seaward of the mean high high water line (Penttila 1997). Surf smelt deposit and incubate their eggs in bands of motile coarse sand and fine gravel formed by the transport of beach material from wave action, upland erosion, and long-shore transport (Penttila 1997). Spawning coincides with high tides and eggs are deposited in waters less than 0.5 m in depth (Penttila 1997). The small sticky eggs adhere tightly to beach surface substrate (Bargmann 1998; Snohomish County Public Works 2001). The habitat preferences of the sand lance make it very vulnerable to anthropogenic impacts (bulkhead/fill structures intruding into the intertidal zone from adjacent uplands, alteration or disruption of the natural erosion and longshore transport of beach substrate, and oiling) such as shoreline development and manipulation (Bargmann 1998). All documented surf smelt spawning sites in Washington State are protected under WAC Hydraulic Code Rules 220-110-271. Currently, there are no known mitigation processes suitable for the replacement of surf smelt spawning habitat (Bargmann 1998).

Life History—Surf smelt distribution and seasonal usage of spawning habitats is poorly understood (Penttila 1997). Surf smelt often spawn in the same area each year and year-round spawning occurs at several sites (e.g., San Juan Islands) throughout Puget Sound (Penttila 1997). Spawning occurs intermittently over a several month spawning season which typically leads to eggs of varying ages incubating together (Penttila 1997). Wave action disperses the eggs throughout the top few inches of beach material where they incubate for two to five weeks depending on temperature (Bargmann 1998). Ambient temperature has been shown to have a great effect on the incubation period of fertilized eggs. When temperatures are cooler during the winter months, hatching may occur in 27 to 56 days, whereas those brooded during the summer months may hatch within 10 to 15 days (Moriarity et al. 2002a). Larvae then spend five weeks to three months drifting in water currents. Juveniles rear in the nearshore waters of Puget Sound where they feed on plankton (Snohomish County Public Works 2001). Adults return to Puget Sound to spawn after one to two years at sea. They are capable of spawning in successive years and live from four to five years of age (Snohomish County Public Works 2001).

Common Prey Species—Surf smelt prey primarily on epibenthic (flabelliferan isopods) and pelagic organisms including cumaceans, larvaceans, and calanoid copepods (Simenstad et al. 1979).

- **Sand Lances (Ammodytidae)**

  - **Pacific Sand Lance (*Ammodytes hexapterus*)**

Distribution—Pacific sand lance range from Sea of Japan to Aleutian Islands, Bering Sea, and western Canadian Arctic to Balboa Island, and south to southern California (Miller and Lea 1972; Mecklenburg et al. 2002). This species is widespread within Puget Sound, Strait of Juan de Fuca, and the coastal estuaries of Washington State. They are most commonly noted in more localized areas, such as the eastern Strait and Admiralty Inlet.[4] Recent research on the spawning habitats of the Pacific sand lance has dramatically increased the number of known spawning grounds within Puget Sound (greater than 225 km of potential sand lance spawning grounds) (Penttila 1997).

Habitat Preference—Sand lance are often found in waters less than six m in depth but may be found as deep as 100 m (Robards et al. 1999). Sand lance and surf smelt eggs often occur in the same substrate and it is estimated that approximately 20% of the shoreline in Puget Sound may be used by Pacific sand lance/surf smelt as spawning habitat (Penttila 1997; Bargmann 1998; **Figures 4-1**, **4-2**, and **4-3**). Pacific sand lance deposit their eggs in upper 40% of intertidal gravelly beaches (Penttila 1997). Spawning may occur in a wide variety of wave action regimes

ranging from sheltered areas to areas of moderate wave action (Penttila 1997). Sand lance prefer spawning substrates ranging form pure sand to mixed sand-gravel gravel (Penttila 1997). Spawning coincides with periods of high tide and occurs in waters less than a meter deep (Penttila 1997). This species substrate preference is highly specific (fine gravel and sandy substrate) and ranges up to and includes the intertidal zone (Robards et al. 1999). Characteristic spawning substrates are well washed, drained, and unpacked containing coarse sands and little mud or silt (Robards et al. 1999). The specificity of sand lance spawning habitats results in patchy distribution and makes it highly vulnerable to habitat alterations (burial under bulkhead-fill structures, movement of beach sediments, and oiling) (Bargmann 1998; Robards et al. 1999). Spawning sites are currently considered when reviewing shoreline project designs in Washington State under the WAC Hydraulic Code Rules 220-110-271. Currently, there are no known mitigation processes suitable for the replacement of surf smelt spawning habitat (Bargmann 1998). Crepuscular vertical movements have been observed between benthic substrates (where they tend to bury themselves) and pelagic waters (where they school and forage) (Robards et al. 1999). They are typically not found in the water column during the winter months but are more commonly found buried in intertidal and shallow subtidal substrates (Robards et al. 1999). Adults feed in open water during the day and burrow into the sand at night (Snohomish County Public Works 2001).

Life History—Spawning occurs from early November through mid-February followed by a one month incubation period (Penttila 1997; Bargmann 1998). Eggs may still be present on beaches through late March (Penttila 1997). Larvae spend four weeks to three months drifting in water currents. Juveniles rear in the nearshore waters of Puget Sound where they feed on plankton (Snohomish County Public Works 2001). Sand lance are abundant in preferred habitats during the spring and summer months and remain inactive or hibernate during the remainder of the year (Robards et al. 1999). During the early summer, adult sand lance are the most dominant lifestage present whereas during late summer juveniles are dominant as they recruit to nearshore populations (Robards et al. 1999). Sand lance typically reach sexual maturity in their second year with females maturing more slowly than males (Robards et al. 1999).

Common Prey Species—Pacific sand lance prey upon calanoid copepods and gammarid amphipods (Simenstad et al. 1979). Larvae feed on phytoplankton, dinoflagellates, and diatoms (Robards et al. 1999). Juveniles greater than 10 millimeters (mm) in length feed on copepod nauplii and euphausiids (Robards et al. 1999). Other prey includes crustaceans, amphipods, isopods, mysids, harpacticoid copepods, larvaceans, annelids, polychaetes, juvenile bivalves and gastropods, insect flotsam, fish larvae, fish eggs, and invertebrate fishes (Robards et al. 1999).

- **Anchovies (Engraulidae)**

  - **Northern Anchovy (*Engraulis mordax mordax*)**

Distribution—Northern anchovy range from Queen Charlotte Islands, British Columbia to Cabo San Lucas, southern Baja California and Gulf of California (Miller and Lea 1972; Love et al. 2005). Their center of abundance is from Magdalena Bay to San Francisco, California. Their occurrence in Washington State waters is sporadic and unpredictable.[4] The northern stock (Vancouver Island, Canada to north of San Francisco) forms a resident population in Puget Sound (Washington Sea Grant Program 2000).

Habitat Preference—Anchovies are a pelagic species that are particularly susceptible to changes in water temperature (Fagergren 2005). Spawning is temperature dependent and occurs in waters ranging from 10.0° to 23.3°C (Fagergren 2005). Due to their pelagic nature, anchovies do not depend on specific areas of shoreline for spawning and therefore there are currently no areas of habitat concern (Bargmann 1998). For this reason, the northern anchovy is not depicted in **Figures 4-1**, **4-2**, or **4-3**.

Life History—Anchovies are thought to move inshore in the spring and summer and offshore in the fall and winter (Fagergren 2005). Spawning season ranges from mid-June to mid-August but locations are not well identified (Bargmann 1998). It appears the major spawning area for the northern stock is the Columbia River and, possibly, the Fraser River (Bargmann 1998) as is evident from eggs which have been observed in the southern Strait of Georgia, mid-Dabob Bay, mid-Saratoga Passage, and Skagit Bay (Washington Sea Grant Program 2000). Larvae may reach maturity at the end of the first year (100 mm in length) but the majority reach maturity near the end of their second year (approximately 150 mm in length) (Fagergren 2005). The majority of the anchovy population is found offshore but during summer months, anchovies may be found occupying inshore areas (e.g., Gray's harbor, Willapa Bay, or the Columbia River mouth) and San Juan Islands (Bargmann 1998; Washington Sea Grant Program 2000).

Common Prey Species—Northern anchovy prey upon phytoplankton and zooplankton (MBC 1987).

4.3 EPISODIC OCEANOGRAPHIC EVENTS

The influence of the California Current on the physical and biological environment of the Pacific Northwest OPAREA and Puget Sound Study Area undergoes significant year-to-year fluctuations. Its impact is also affected by larger-scale climate variations, such as El Niño-La Niña or PDO (Hickey 1993).

Dramatic changes resulting from extreme El Niño-La Niña years (1998 to 2002) off northern Washington State to central Oregon shifted gradually from a community dominated by southern species (mackerels and hake) to one dominated by northern species (squid, smelts, and salmon) with the small pelagic species (sardines, herring, and anchovy) showing no consistent trends in abundance over time (Brodeur et al. 2005).

4.3.1 El Niño

During years experiencing an El Niño event, there is an overall northward shift of tropical and temperate species (Cross 1987; Cross and Allen 1993). Rockfish (*Sebastes* spp.) are particularly sensitive to El Niño, with these events resulting in recruitment failure and adults demonstrating reduced growth, and ultimately a decline in biomass is exhibited and poor overall condition in the region becomes evident (Lenarz et al. 1995; Moser et al. 2000). Salmon are also affected by El Niño depending on the preferred water depth by species. Salmon that prefer more shallow habitats such as coho, are more likely to be effected by El Niño than other salmon species (e.g. chinook) (PFMC 2003d).

4.3.2 La Niña

Past La Niña events have not had such a dramatic impact on ichthyofauna and marine invertebrate populations as El Niño events. Nevertheless, La Niña years can result in below normal recruitment for many invertebrate species (e.g., rock crabs), and larval rockfish abundance has been reportedly low during years experiencing La Niña events (Lundquist et al. 2000). Additionally, cooling trend years (i.e., 1999 La Niña event) can result in increased abundance and commercial landings of traditionally temperate species in more southerly locations (Hayward 2000; Lluch-Belda et al. 2003, 2005).

4.4 ESSENTIAL FISH HABITAT FISH AND INVERTEBRATE SPECIES

The PFMC develops FMPs for all fisheries occurring within the boundary of the EEZ in the Pacific Northwest OPAREA and Puget Sound Study Area from Point Delgada in Cape Mendocino, northern California to the U.S./Canadian border. The MSFCMA, as amended by the SFA, contains provisions for the identification and protection of habitat essential to production of federally managed species. The NMFS and regional FMCs develop EFH descriptions for federally managed fish species and include them in their respective FMPs. The FMPs identify and describe the EFH, describe the EFH impacts (fishing and non-fishing), and suggest measures to conserve and enhance the EFH. The FMPs also identify the HAPC where one or more of the following criteria are demonstrated: (a) ecological function; (b) sensitivity

to human-induced environmental degradation; (c) development activities stressing habitat type; or (d) rarity of habitat. In addition to the EFH status, some of these species are assigned status categories in conjunction with the ESA and various federal or international agencies. Currently, there are no existing HAPCs in the PFMC region (Moncada et al. 2004) except for the recently designated groundfish HAPCs (NMFS-NWR 2006).

A total of 98 fish and invertebrate species with designated EFH occur in the Pacific Northwest OPAREA and Puget Sound Study Area (**Table 4-2**). They are grouped into the Pacific Salmon Species (three species), Coastal Pelagic Species (CPS: 13 species), Pacific Coast Groundfish Species (75 species), and Highly Migratory Species (HMS: seven species). The status, distribution, habitat preference (substrate, depth, temperature, and salinity), life history (migration, movements, and spawning), common prey species, and EFH designations of the species complexes and/or individual species are provided below (PFMC 1998b; 1998a; 2000; 2003c). Eight euphausiid shrimp species that form the bulk of the krill community in the CCS have been added to the CPS FMP under Amendment 12 (PFMC 2006) and have designated EFH (NMFS-SWR 2006). In addition, seven rockfish species have been added to the Groundfish FMP under Amendment 16-3. These include the chameleon (*Sebastes phillipsi*), dwarf-red (*S. rufinanus*), freckled (*S. lentiginosus*), half-banded (*S. semicinctus*), pinkrose (*S. simulator*), pygmy (*S. wilsoni*), and swordspine (*S. ensifer*). Currently, information is insufficient to define EFH for these seven species (NMFS 2004d).

The marine and estuarine waters of the inshore basins of Puget Sound are designated EFH for the salmonids, coastal pelagic, and groundfish (PFMC 1998b; 1998a; 1999b; **Tables 4-3** and **4-4**). The marine extent of salmon, coastal pelagic species, and Pacific coast groundfish EFH includes all those waters from the nearshore and tidal submerged environments within Washington State, Oregon, and California state territorial waters out to the EEZ (370.4 km) offshore between the Canadian border to the north and the Mexican border to the south, except for the salmon, which is to north of Point Conception, California (PFMC 1998b; 1998a; 1999b). EFH has not been designated for HMS in the marine and estuarine waters of Puget Sound's inshore basins. Of the seven HMS that occur in the Pacific Northwest OPAREA and Puget Sound Study Area, only the common thresher shark and blue shark have been reported as rare sightings around San Juan Islands (1972) and in Puget Sound (1881, 1882, and 1917), respectively (DeLacy et al. 1972; Miller and Borton 1980; DeVaney[5]).

4.4.1 Pacific Salmon Species

Pacific salmon (genus *Oncorhynchus*) range from San Francisco Bay, California, northward around the Pacific rim and southward along the coasts of Russia, Japan, and Korea (Eggers 2004). There are seven species of Pacific salmon; two species, masu (*Oncorhynchus masou*) and amago (*O. rhodurus*) only occur in Asia, and five species, sockeye (*O. nerka*), pink (*O. gorbuscha*), chum (*O. keta*), chinook (*O. tshawytscha*), and coho (*O. kisutch*) reproduce in North America and Asia (Groot and Margolis 1991). In general, the life history of Pacific salmon includes: incubation, hatching and emergence in freshwater, migration to the ocean, and subsequent initiation of maturation and return to freshwater for completion of maturation and spawning (Myers et al. 1998). Salmon are anadromous, meaning that they migrate up rivers and streams from the sea to spawn in freshwater. Pacific salmon spawn in gravel beds in rivers, streams and along lake-shores where females lay their eggs in nests or "redd" (Groot and Margolis 1991; DFO 2002). Depending on the species, they spend between one to seven years at sea, with most making extensive and complicated migrations (Groot and Margolis 1991; Eggers 2004). Generally, Pacific salmon return to their natal rivers to spawn and, with few exceptions, die soon after (Augerot and Foley 2005). The death of these salmon returns much needed nutrients from the ocean to the otherwise nutrient-poor streams (Quinn 2005). Anadromy and the strong fidelity of homing to their natal streams have resulted in the development of many reproductively isolated subpopulations (little inbreeding occurs between salmon from one river and another) (Quinn 2005) referred to as stocks (Groot and Margolis 1991). These subpopulations are exposed to different physical and biotic factors such as temperature, flow, gravel size, predators, prey, competitors, and pathogens (Quinn 2005). These variations between streams has lead to the evolution of specializations to help the salmon survive in their home rivers (Quinn 2005). These distinct habitat dynamics require these subpopulations be managed individually rather than as a species

Table 4-2. The fish and invertebrate species with EFH designated in the Pacific Northwest OPAREA and Puget Sound Study Area.

Pacific Salmon Species

Chinook salmon (*Oncorhynchus tshawytscha*)
Coho salmon (*Oncorhynchus kisutch*)
Puget Sound pink salmon (*Oncorhynchus gorbuscha*)

Coastal Pelagic Species

Northern anchovy (*Engraulis mordax*)
Jack mackerel (*Traxchurus symmetricus*)
Pacific sardine (*Sardinops sagax*)
Pacific mackerel (*Scomber japonicus*)
Market squid (*Loligo opalescens*)

Krill
Euphausia exima
Euphausia gibboides
Euphausia pacifica
Euphausia recurva
Nematocelis difficilis
Nyctiphanes simplex
Thysanoessa gregaria
Thysanoessa spinifera

Pacific Coast Groundfish Species

Flatfish
Arrowtooth flounder (*Atheresthes stomias*)
Butter sole (*Isopsetta isopleis*)
Curlfin sole (*Pleuronichthys decurrens*)
Dover sole (*Microstomus pacificus*)
English sole (*Parophrys vetulus*)
Flathead sole (*Hippoglossoides elassodon*)
Petrale sole (*Eopsetta jordani*)
Rex sole (*Glyptocephalus zachirus*)
Rock sole (*Lepidopsetta polyxstra/L. bilineata*)
Sand sole (*Psettichthys melanostictus*)
Starry flounder (*Platichthys stellatus*)
Pacific sanddab (*Citharichthys sordidus*)

Rockfish
Aurora rockfish (*Sebastes aurora*)
Bank rockfish (*Sebastes rufus*)
Black rockfish (*Sebastes melanops*)
Black-and-yellow rockfish (*Sebastes chrysomelas*)
Blackgill rockfish (*Sebastes melanostomus*)
Blue rockfish (*Sebastes mystinus*)
Bocaccio (*Sebastes paucispinis*)
Bronzespotted rockfish (*Sebastes gilli*)
Brown rockfish (*Sebastes auriculatus*)
Canary rockfish (*Sebastes pinniger*)
Chilipepper (*Sebastes goodei*)
China rockfish (*Sebastes nebulosus*)
Copper rockfish (*Sebastes caurinus*)
Cowcod (*Sebastes levis*)
Darkblotched rockfish (*Sebastes crameri*)
Dusky rockfish (*Sebastes variabilis*)
Flag rockfish (*Sebastes rubrivinctus*)
Gopher rockfish (*Sebastes carnatus*)
Grass rockfish (*Sebastes rastrelliger*)
Greenblotched rockfish (*Sebastes rosenblatti*)
Greenspotted rockfish (*Sebastes chlorostictus*)
Greenstriped rockfish (*Sebastes elongatus*)

Rockfish (continued)
Harlequin rockfish (*Sebastes variegates*)
Olive rockfish (*Sebastes serranoides*)
Pacific ocean perch (*Sebastes alutus*)
Pink rockfish (*Sebastes eos*)
Quillback rockfish (*Sebastes maliger*)
Redbanded rockfish (*Sebastes babcocki*)
Redstripe rockfish (*Sebastes proriger*)
Rosethorn rockfish (*Sebastes helvomaculatus*)
Rosy rockfish (*Sebastes rosaceus*)
Rougheye rockfish (*Sebastes aleutianus*)
Sharpchin rockfish (*Sebastes zacentrus*)
Shortbelly rockfish (*Sebastes jordani*)
Shortraker rockfish (*Sebastes borealis*)
Silvergray rockfish (*Sebastes brevispinis*)
Speckled rockfish (*Sebastes ovalis*)
Splitnose rockfish (*Sebastes diploproa*)
Squarespot rockfish (*Sebastes hopkinsi*)
Stripetail rockfish (*Sebastes saxicola*)
Tiger rockfish (*Sebastes nigrocinctus*)
Vermilion rockfish (*Sebastes miniatus*)
Widow rockfish (*Sebastes entomelas*)
Yelloweye rockfish (*Sebastes ruberrimus*)
Yellowmouth rockfish (*Sebastes reed*i)
Yellowtail rockfish (*Sebastes flavidus*)

Thornyhead
Longspine thornyhead (*Sebastolobus altivelis*)
Shortspine thornyhead (*Sebastolobus alascanus*)

Roundfish
Cabezon (*Scorpaenichthvs marmoratus*)
Kelp greenling (*Hexagrammos decagrammus*)
Lingcod (*Opiodon elongatus*)
Pacific cod (*Gadus macrocephalus*)
Pacific flatnose (*Antimora microlepis*)
Pacific grenadier (*Coryphaenoides acrolepis*)
Pacific hake (*Merluccius productus*)
Sablefish (*Anoplopoma fimbria*)

Skates, Sharks, and Chimeras
Big skate (*Raja binoculata*)
California skate (*Raja inornata*)
Longnose skate (*Raja rhina*)
Leopard shark (*Triakis semifasciata*)
Soupfin shark (*Galeorhinus zyopterus*)
Spiny dogfish (*Squalus acanthias*)
Spotted ratfish (*Hydrolagus colliei*)

Highly Migratory Species

Sharks
Common thresher shark (*Alopias vulpinus*)
Bigeye thresher shark (*Alopias superciliosus*)
Shortfin mako shark (*Isurus oxyrinchus*)
Blue shark (*Prionace glauca*)

Tunas
Albacore tuna (*Thunnus alalunga*)
Northern bluefin tuna (*Thunnus orientalis*)

Swordfish
Broadbill swordfish (*Xiphias gladius*)

Source: Turgeon et al. (1998); Nelson et al. (2004); McLaughlin (2005)

Table 4-3. Pacific salmon species complex, coastal pelagic species, and Pacific coast groundfish species and life history-stages with designated EFH in the Puget Sound Study Area.

Group/Family/Species	Adult	Spawning/Mating	Juvenile	Larvae	Eggs/Parturition
Pacific Salmon Species					
Chinook Salmon	X		X		
Coho Salmon	X		X		
Puget Sound Pink Salmon	X		X		
Coastal Pelagic Species					
Northern Anchovy	X	X	X	X	X
Pacific Sardine	X				
Pacific Mackerel	X				
Market Squid	X				
Pacific Coast Groundfish Species					
Flatfish					
Arrowtooth Flounder	X	X	X		
Butter Sole	X	X	X		
Curlfin Sole	X				
Dover Sole	X	X	X		
English Sole	X	X	X	X	X
Flathead Sole	X	X	X		
Petrale Sole	X		X		
Rex Sole	X	X	X		
Rock Sole	X	X	X		
Sand Sole	X	X	X		
Starry Flounder	X	X	X	X	X
Pacific Sanddab	X		X	X	X
Rockfish					
Black Rockfish	X		X		
Blue Rockfish	+				
Bocaccio	X	+	X	X	
Brown Rockfish	X	+	+	X	
Canary Rockfish	+	+	X		
China Rockfish	X		X		
Copper Rockfish	X		X	+	
Darkblotched Rockfish	X		X		
Greenstriped Rockfish	+				
Pacific Ocean Perch	X		X		

Table 4-3. Continued.

Group/Family/Species	Adult	Spawning/Mating	Juvenile	Larvae	Eggs/Parturition
Pacific Coast Groundfish (continued)					
Rockfish (continued)					
Quillback Rockfish	X		X	+	
Redbanded Rockfish	X				
Redstripe Rockfish	+				
Rosethorn Rockfish	X		X		
Rosy Rockfish	+				
Rougheye Rockfish	X		+		
Sharpchin Rockfish	X		+		
Silverygray Rockfish	+				
Splitnose Rockfish	X				
Stripetail Rockfish	X				
Tiger Rockfish	X		X		
Vermilion Rockfish	X	+	X		
Widow Rockfish	+				
Yelloweye Rockfish	X				
Yellowtail Rockfish	X	+	X		
Thornyhead					
Shortspine Thornyhead	X		X		
Roundfish					
Cabezon	X	X	X	+	X
Kelp Greenling	X	X	X	X	X
Lingcod	X	X	X	X	X
Pacific Cod	X	X	X	X	X
Pacific Hake (Whiting)	X		X		
Sablefish	X		X		
Skates/Sharks/Chimeras					
Big Skate	X	X	X		X
California Skate	X				
Longnose Skate	X				
Spiny Dogfish	X	X	X		X
Spotted Ratfish	X				

Legend:
+ = Life history-stage potentially occurs in area

Source: DoN (2002a); NOAA[6]

Table 4-4. Pacific salmon species complex, coastal pelagic species, and Pacific coast groundfish species with EFH designated occurrences within various Naval training areas in the Puget Sound Study Area. R = Rare, UC = Uncommon, C = Common, and N/A = Not/Applicable.

Group/Family/Species	SESEF	Nanoose Range	Darrington OPAREA*	Hood Canal	NUMC Keyport Range
Pacific Salmon Species					
Chinook Salmon	C	C	N/A	C	C
Coho Salmon	C	C	N/A	C	N/A
Puget Sound Pink Salmon	C	C	N/A	C	N/A
Coastal Pelagic Species					
Northern Anchovy	N/A	N/A	N/A	UC	UC
Pacific Sardine	N/A	R	N/A	N/A	UC
Pacific Mackerel	N/A	N/A	N/A	N/A	N/A
Market Squid	UC	N/A	N/A	N/A	N/A
Pacific Coast Groundfish Species					
Flatfish					
Arrowtooth Flounder	C	UC	N/A	C	C
Butter Sole	C	C	N/A	C	C
Curlfin Sole	N/A	C	N/A	N/A	N/A
Dover Sole	C	C	N/A	C	C
English Sole	C	C	N/A	C	C
Flathead Sole	C	UC	N/A	C	C
Petrale Sole	C	R	N/A	C	C
Rex Sole	C	R	N/A	C	C
Rock Sole	C	UC	N/A	C	C
Sand Sole	C	C	N/A	C	C
Starry Flounder	C	C	N/A	C	C
Pacific Sanddab	R	R	N/A	C	UC
Rockfish					
Black Rockfish	C	N/A	N/A	C	C
Blue Rockfish	N/A	N/A	N/A	N/A	N/A
Bocaccio	C	N/A	N/A	C	C
Brown Rockfish	N/A	N/A	N/A	C	C
Canary Rockfish	C	N/A	N/A	N/A	N/A
China Rockfish	UC	N/A	N/A	N/A	N/A
Copper Rockfish	C	R	N/A	C	C
Darkblotched Rockfish	UC	N/A	N/A	N/A	N/A
Greenstriped Rockfish	C	UC	N/A	C	N/A
Pacific Ocean Perch	UC	N/A	N/A	N/A	N/A
Quillback Rockfish	C	UC	N/A	C	C

Table 4-4. (continued).

Group/Family/Species	SESEF	Nanoose Range	Darrington OPAREA*	Hood Canal	NUMC Keyport Range
Pacific Coast Groundfish (continued)					
Rockfish (continued)					
Pacific Ocean Perch	UC	N/A	N/A	N/A	N/A
Quillback Rockfish	C	UC	N/A	C	C
Redbanded Rockfish	N/A	N/A	N/A	N/A	N/A
Redstripe Rockfish	UC	N/A	N/A	UC	N/A
Rosethorn Rockfish	N/A	N/A	N/A	N/A	N/A
Rosy Rockfish	N/A	N/A	N/A	N/A	N/A
Rougheye Rockfish	N/A	N/A	N/A	N/A	N/A
Sharpchin Rockfish	N/A	N/A	N/A	N/A	N/A
Silverygray Rockfish	N/A	N/A	N/A	N/A	N/A
Splitnose Rockfish	N/A	N/A	N/A	UC	N/A
Stripetail Rockfish	N/A	N/A	N/A	UC	N/A
Tiger Rockfish	N/A	N/A	N/A	N/A	N/A
Vermilion Rockfish	UC	N/A	N/A	N/A	N/A
Widow Rockfish	N/A	N/A	N/A	N/A	N/A
Yelloweye Rockfish	R	R	N/A	N/A	N/A
Yellowtail Rockfish	N/A	UC	N/A	C	N/A
Thornyhead					
Shortspine Thornyhead	N/A	UC	N/A	N/A	N/A
Roundfish					
Cabezon	N/A	UC	N/A	UC	C
Kelp Greenling	C	N/A	N/A	N/A	C
Lingcod	C	R	N/A	C	UC
Pacific Cod	C	UC	N/A	C	C
Pacific Hake (Whiting)	UC	C	N/A	C	C
Sablefish	C	N/A	N/A	C	C
Skates/Sharks/Chimeras					
Big Skate	R	UC	N/A	UC	UC
California Skate	N/A	N/A	N/A	N/A	N/A
Longnose Skate	R	UC	N/A	UC	UC
Spiny Dogfish	C	C	N/A	C	C
Spotted Ratfish	C	C	N/A	C	UC

*Darrington OPAREA only includes airspace above 10,000 ft

Source: Delacey et al. (1972), Miller and Borton (1980), Garrison and Miller (1982), DoN (2002a), Palsson et al. (2003a)

(Quinn 2005). Three species of Pacific salmon have EFH designated within the Pacific Northwest OPAREA and Puget Sound Study Area (PFMC 2000). Additionally, none of these Pacific salmon species are currently listed on the International Union for Conservation of Nature and Natural Resources (IUCN) red list of threatened species.[8]

Three of five species of salmon that occur along the U.S. west coast have EFH designation in Puget Sound Study Area (PFMC 2000; **Tables 4-3** and **4-4**). Anadromous salmon depend on the ecological integrity and connectivity of a suite of habitats extending from the natal freshwater spawning or rearing streams to estuaries and then to coastal, shelf, and offshore waters for their growth (Duffy et al. 2005). The relative importance of estuarine and coastal marine environments differs within and among the various salmon species due to differences in residence times and utilization of these environments (Duffy et al. 2005). Coho and chinook salmon typically migrate to sea after extended periods of rearing as juveniles in freshwaters; whereas the Puget Sound pink salmon does not rear long in freshwater and migrates to sea soon after emergence from natal gravel beds (PICES 2004). Juvenile salmon reside mainly in nearshore intertidal waters which provide five key functions: migration corridors, food production, physiological refuge, refuge from predators, and high-energy refuge (i.e., high flows, wave action) (Thorpe 1994; Anchor Environmental L.L.C. and People for Puget Sound 2002). After achieving some size threshold or after a temporal cue (e.g., a specific residence time), salmon reportedly move from shallow nearshore to offshore surface waters in estuarine and marine waters (Duffy et al. 2005).

EFH species are discussed in the following subsections and listed in **Table 4-2**. Status and EFH designations for Pacific Salmon Species are discussed as a group, while individual species information (e.g., distribution, habitat preference, life history, and common prey species) is presented for each individual species. For help in the identification of these species refer to Groot and Margolis (1991) and Froese and Pauly.[7]

Status—Pacific salmon are federally protected by the designation of evolutionarily significant units (ESUs). ESUs are defined by NMFS as a population that is "substantially reproductively isolated from conspecific populations and represents an important component in the evolutionary legacy of the species" (WCSBRT 2003). In addition to ESUs, the ESA requires the NOAA and the USFWS to designate "critical habitat" for species listed under the ESA. "Critical habitat" is defined as: 1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and 2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation (NOAA n.d.). Currently, there are five species of Pacific salmonids that have ESUs with critical habitat designated within the Pacific Northwest OPAREA and Puget Sound Study Areat (NMFS 2005h; NMFS 2005c; USFWS 2005b). Because these species are considered "threatened" or "endangered", their status is addressed in Section 3.4.

EFH Designations—The geographic extent of marine EFH for chinook, coho, and Puget Sound pink salmon include all marine waters within the EEZ north of Point Conception, California (PFMC 2000; **Figure E-1**). The PFMC (2000) defines freshwater EFH as all streams, lakes, ponds, wetlands, tributaries, and other water bodies currently viable and most of the habitat historically accessible to salmon within Washington State, Oregon, Idaho, and California.

HAPC—Currently, the PFMC has not designated any HAPCs for Pacific salmon species (PFMC 2000).

- **Chinook Salmon (*Oncorhynchus tshawytscha*)**

  Distribution—The chinook salmon's historical range extended from the Ventura River in California to Point Hope, Alaska in North America (Myers et al. 1998). The natural freshwater range for chinook salmon extends throughout the Pacific rim of North America. This species has been identified from the San Joaquin River in California to the Mackenzie River in northern Canada (Healey 1991). The oceanic range encompasses Washington State, Oregon, California, throughout the north Pacific Ocean, and as far south as the U.S./Mexico border (PFMC 2000).

Habitat Preference

Depth: Chinook salmon are found in freshwater to euhaline waters from the surface to depths of 250 m depending on lifestage.[7] They spawn in rivers at depths ranging from 0 m to 10.0 m with a preferred depth of greater than 0.24 m for spring and fall salmon and greater than 0.30 m for summer salmon (Beauchamp et al. 1983). The depth of the redd is inversely related to water velocity (PFMC 2000). Juvenile chinook range from 0.0 to 1.2 m while inhabiting streams, lakes, sloughs, and rivers and continue to stay near the surface during their initial marine stages (Beauchamp et al. 1983; PFMC 2000). After juveniles have advanced past the initial marine phase, they prefer depths ranging from 30 to 70 m and are often associated with bottom topography (PFMC 2000). Late juveniles and adults may be pelagic, neustonic, or semi-demersal/semi-pelagic (PFMC 2000).

Temperature: Chinook salmon may be found in water temperatures ranging from 0° to 26°C but this may vary depending on lifestage and activity (MBC 1987). Adult chinook salmon prefer water temperatures less than 14°C but can survive in deep pools in the summer with surface temperatures of 23°C (Beauchamp et al. 1983; PFMC 2000). Chinook cannot spawn at temperatures above 22°C (Beauchamp et al. 1983). Ideal spawning temperatures range from 5.6° to 13.9°C but spawning can occur from 4.4° to 18.0°C (Beauchamp et al. 1983). Eggs and alevin can tolerate temperatures as high as 18.1°C with alevin being more tolerant of lower temperatures (0.0°C – alevin, 1.6°C – eggs) (MBC 1987). Temperatures from 5.8° to 14.2°C promote the best egg development and 11.0°C is the optimum temperature for both eggs and fry (Beauchamp et al. 1983). Optimum temperature for fingerlings is 17.0°C with freshwater juveniles found in waters from 7.4° to 25.0°C. Ocean-type juveniles are found in waters from 1° to 15°C but few chinook are found at temperatures below 5°C (MBC 1987; PFMC 2000).

Salinity: Juvenile and adult chinook salmon are found in freshwater to euhaline waters (Emmett et al. 1991). Subadults that have migrated to marine waters are found in polyhaline to euhaline waters (Emmett et al. 1991). Chinook eggs only develop in freshwater, but larvae can tolerate 15 practical salinity units (psu) at hatching with larger individuals able to handle greater salinity changes (Emmett et al. 1991). Within three months of hatching, larvae can tolerate full seawater (Emmett et al. 1991). Chinook fry appear unable to survive an immediate transfer from freshwater to 30 psu, but they are clearly capable of tolerating a transfer to 20 psu (Healey 1991).

Dissolved Oxygen: Chinook salmon can survive when resting with dissolved oxygen levels as low as 2.0 parts per million (ppm) and migrating adults may pass through waters with dissolved oxygen levels as low as 3.5/4.0 ppm (Beauchamp et al. 1983; Emmett et al. 1991).

Substrate: Adult chinook salmon spawn in gravel ranging from 6 to 14 centimeters (cm) in diameter. Gravel substrates range from 1.3 to 10.2 cm in diameter (Beauchamp et al. 1983). Chinook salmon require enough current on spawning beds to ventilate the eggs during incubation (Beauchamp et al. 1983). No substrate preference has been documented for adults in the marine environment (Beauchamp et al. 1983).

Movements and migrations: As chinook salmon grow they move from shallow littoral habitats into deeper river channels inhabiting pools, riffles, off-channel habitat, and undercut banks. Large woody debris or boulder structures provide cover and shelter from predation and storm events. Riparian vegetation provides the following to chinook salmon rearing: shade for temperature regulation, vegetation inputs for food resources, and stream bank stabilization from roots and large woody debris recruitment. Fry and smolt inhabit freshwater from 1 to 18 months (Beauchamp et al. 1983). Timing of migration to seawater for juveniles is highly variable (PFMC 2000). Ocean-type juveniles may migrate to the ocean immediately after hatching but most remain in freshwater for 30 to 90 days (PFMC 2000). Some chinook migrate seaward as fingerlings in the late summer of their first year while others, particularly in less-productive or cold-water systems, migrate as young-of-the-year fish (PFMC 2000). Significant variations of fingerling and yearling migrants within a population may occur from year to year (PFMC 2000). Ocean-type juveniles typically inhabit estuaries for several months before

migrating to higher salinity waters (PFMC 2000). Fry enter the upper reaches of estuaries in late winter for the more southern populations or early spring for the more northern populations (PFMC 2000). Regardless of time of entry, ocean-type chinook spend from one to three months in estuaries (PFMC 2000). Smaller fry prefer more protected, lower salinity habitats. As fish get larger, they gradually leave the well protected habitats for higher salinity waters (PFMC 2000).

Reproduction: Chinook salmon are gonochoristic, oviparous, and semelparous (Emmett et al. 1991). Spawning may range from May/June to December/January depending on location but periods are specific for each run and/or stock (Emmett et al. 1991; Healey 1991; PFMC 2000). Spawning may occur from the tidewater to 3,200 km upstream in the Yukon River (Healey 1991). Chinook spawning populations are relatively small but increase in numbers with increased stream size (Healey 1991). Rivers associated with the northern and southern limits of the species range (e.g., Sacramento-San Joaquin River system) tend to support populations as large or larger than those in major rivers near the middle of the range (e.g. Columbia and Fraser Rivers) (Healey 1991). Stream-type and ocean-type spawning populations are separated considerably (Healey 1991). Alaskan spawning populations are predominately stream-type, and all Asian spawning stocks are apparently stream-type (Healey 1991). In North America there seems to be a sudden shift from stream-type to ocean-type stocks near the Alaska-British Columbia border (Healey 1991). South of approximately 56°N, stream-type chinook are only found in larger rivers with ocean-type salmon dominating the majority of the runs (Healey 1991).

Chinook salmon may return to their natal streams during any month but there are one to three peaks associated with salmon migratory activity (Healey 1991). These peaks vary between river systems. Northern River systems generally see a single peak in migratory activity around June with the run possible extending through April to August (Healey 1991). The Columbia River experiences a late August run and significantly smaller spring and summer runs (Healey 1991). The Klamath River also sees a late August run with a smaller run occurring in the spring (Healey 1991).

Generally, stream-type fish spawn one to two months (spring and early summer) before ocean-type fish (summer and fall) in the central and southern portions of the species range (Healey 1991; PFMC 2000). Larger variations in spawning time may occur in species associated with larger river systems such as the Columbia River (Healey 1991). Chinook salmon may spawn at depths ranging from a few centimeters to several meters in streams from two to three m wide to large rivers (PFMC 2000). Chinook redd range in size from 2 to 40 m^2. Redd depth is inversely related to water velocity ranging from 10 to 700 cm deep in water velocities from 10 to 150 centimeters per second (cm/sec) (Healey 1991). Typically, chinook redd are 5 to 15 m^2 in areas with water velocities from 40 to 60 cm/sec (PFMC 2000). The large size of chinook eggs allows them to withstand higher water velocities than other species of salmon but a small surface-to-volume ratio may make them more sensitive to dissolved oxygen levels (PFMC 2000).

Life History—Chinook salmon exhibit one of the more diverse and complex life history strategies of all Pacific salmon and are separated into two generalized life-history types: stream-type and ocean-type fish (Myers et al. 1998; PFMC 2000). The majority of stream-type chinook stocks are found in Alaska, north of 56°N (Healey 1991). For a year or more, they reside as fry or parr in freshwater where they exhibit downstream dispersal and utilize a variety of freshwater rearing environments before migrating to sea (Healey 1991). They perform extensive offshore oceanic migrations and return to their natal river during the spring and early summer, several months prior to spawning (Healey 1991). Ocean residency varies but may last from one to six years (Healey 1991). Stream-type adults often enter freshwater in the spring and summer as immature “bright” fish and spawn in upper watersheds in late summer or early fall (PFMC 2000). Stream-type life history strategies, with long rearing periods that require more stable or less degraded habitats, may be adapted to watersheds or parts of watersheds that are more productive and less susceptible to dramatic changes in water flow, as (Healey 1991). ESUs with stream-type life history strategies include: upper Columbia River spring ESU; and Snake River spring/summer ESU (Myers et al. 1998).

Ocean-type chinook are found near the center of their species range and migrate to the ocean within the first year (typically within a few months) after emergence where they spend an average of four to five years (Myers et al. 1998; PFMC 2000; Augerot and Foley 2005). Estuaries may be more important than freshwater environments in the life history of ocean-type chinook due to longer time spent there (PFMC 2000). Juvenile chinook utilize estuaries for rearing, physiological transition, and refugia, and tend to congregate in areas where estuary morphology favors detritus retention, such as weed beds, salt marshes, and braided or meandering channels (Healey 1991). Ocean-type chinook salmon spend most of their ocean life in coastal waters, and return to their natal river during the spring, summer, fall, late fall and winter (Healey 1991). Ocean-type chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of rivers, and spawn within a few days or weeks of freshwater entry (Healey, 1991). ESUs with ocean-type life history strategies include: Puget Sound ESU, Lower Columbia River ESU, and Snake River fall ESU (Myers et al. 1998).

There is further life history variation within each type, which allows full utilization of freshwater, estuarine and ocean environments. In order to complete these life history strategies successfully, chinook salmon need access to freshwater, estuarine, coastal and open ocean environments. In these environments they require adequate water quantity and quality, temperature, velocity, shelter, food resources, riparian vegetation, space, and safe passage conditions (Healey 1991).

Common Prey Species—The primary food source for chinook salmon in freshwater habitats is postulated to be adult and larval insects (Healey 1991). Diets vary considerably from estuary to estuary but chinook utilize a wide range of prey including: gammarid amphipods, insects, mysids, isopods, copepods, and fish larvae (Beauchamp et al. 1983; Healey 1991). As chinook grow and move into marine environments, their diets shift to consist of crab zoea, rockfish, Pacific sand lance, eulachon, herring, anchovy, copepods, euphausiids, cephalopods, isopods, and amphipods (Beauchamp et al. 1983).

- **Coho Salmon (*Oncorhynchus kisutch*)**

Distribution—Coho salmon are found in freshwater drainages from Monterey Bay, California north along the west coast of North America to Alaska, around the Bering Sea south through Russia to Hokkaido, Japan (CDFG 2002a). Oceanic lifestages can be found from Camalu Bay, Baja California north to Point Hope, Alaska and from there, south to Korea (MBC 1987; Sandercock 1991). In the northeastern Pacific, coho can be found south of 40°N, but only in the coastal waters of the California Current (MBC 1987).

Habitat Preference

Depth: Coho salmon are found in fresh water to euhaline water at depths ranging from the surface to 250 m.[7] In marine environments, both juveniles and adults stay within 10 m of the surface unless water conditions are considerably warm (Emmett et al. 1991). Eggs and alevins are found buried in gravel bottoms from 8 to 15 cm deep (MBC 1987). Adult coho need a minimum water depth of 18 cm to spawn (Laufle et al. 1986). Fry and smolt prefer variable depths with fry ranging from 0.3 to 1.2 m, generally associated with submerged riffle areas. Avoidance of strong currents and predators seems to be the most important factor in determining habitat for young fish (Laufle et al. 1986; PFMC 2000).

Temperature: Eggs and alevins are found at temperature from 4.4° to 21°C but optimal incubation occurs between 4.4° and 13.3°C (Emmett et al. 1991). Juvenile coho can tolerate stream temperatures ranging from 0° to 26°C with no abrupt changes (PFMC 2000). They prefer streams ranging from 10° to 15°C and growth ceases at 20.3°C due to increased metabolic rate (Laufle et al. 1986; Emmett et al. 1991; PFMC 2000). Oceanic coho are found at temperatures ranging from 4.0° to 15.2°C but prefer temperatures from 8° to 12°C (Emmett et al. 1991).

Salinity: Eggs, alevins, fry, and parr inhabit freshwater while juveniles and adults are anadromous (Laufle et al. 1986).

Dissolved Oxygen: Embryos and juveniles require the highest dissolved oxygen concentrations. Embryo survival is sharply reduced at dissolved oxygen levels less than 8.0 ppm, whereas juvenile food consumption is reduced at levels less than 4.0 ppm (Laufle et al. 1986; Emmett et al. 1991). Levels below 2.0 ppm for extended periods of time are lethal (PFMC 2000).

Substrate: Smolts, subadults, and adults migrate over a variety of substrates (Emmett et al. 1991). Cover availability is more important than substrate selection for juvenile coho (Emmett et al. 1991). Spawning occurs on beds composed of gravel ranging from 1.3 to 10.2 cm in diameter and, unlike other salmon, coho redd can contain approximately 10% mud (Emmett et al. 1991).

Movements and migrations: Adult coho salmon migrate to their natal streams from June to February; the higher the latitude, the earlier the return (Emmett et al. 1991; Sandercock 1991). There is also a tendency for fish that enter streams early to move further upstream than those that migrate later (Sandercock 1991). Throughout their range, coho exhibit a variety of return timing patterns (Sandercock 1991). Migration into streams is very dependent on flow conditions (Sandercock 1991). Impassable conditions may become passable during elevated flow conditions (e.g. sand collecting at stream mouths) and conversely, certain obstacles may be more easily traversed during low flow conditions (e.g., obstacles acting as water velocity barriers) (Sandercock 1991). Migration upstream generally occurs when temperatures range from 7.2° to 15.6°C, depths are greater than 18 cm, and water velocity is less than 2.44 m/sec (Sandercock 1991). Juveniles reside in freshwater for about a year (longer in northern streams) before migrating to the ocean (Emmett et al. 1991; PFMC 2000). Most juvenile migration occurs from April to August with a peak in May (Emmett et al. 1991). Generally, higher latitudes result in an increase in estuarine residency time for juveniles (PFMC 2000). Upon entering the ocean, coho may spend several weeks or their entire first summer in coastal waters before migrating north (PFMC 2000). The later dispersal pattern is the most common within the Pacific Northwest OPAREA and Puget Sound Study Area (PFMC 2000). Tag, release, and recovery studies suggests that coho salmon of California origin can be found as far north as southeast Alaska and salmon from Oregon and Washington as far north as the northern Gulf of Alaska (PFMC 2000). The extent of coho migrations appears to extend westward along the Aleutian Island chain ending somewhere around Emperor Seamount (believed to be an area of high prey abundance) (PFMC 2000). While the southern extent of the population expands and contracts annually, Point Conception, California is generally considered the faunal break for the coho and other temperate marine species (PFMC 2000). Adult coho may enter freshwater as early as July in the Alaska and as late as December or January in California (Sandercock 1991; PFMC 2000). Summer-run coho may enter rivers exceptionally early (spring or early summer) (PFMC 2000). Larger rivers have a wider range of entry times than smaller systems (PFMC 2000).

Reproduction: Coho salmon are gonochoristic, oviparous, and semelparous (Emmett et al. 1991). In North America, coho generally spawn from October to March with populations found at the northern extent of the species range tend to spawn earlier than those at the southern extent (Sandercock 1991; PFMC 2000). Both spawning and migration times can be highly variable (Sandercock 1991).

Preferred spawning grounds for coho salmon can best be described as clean, coarse gravel (PFMC 2000). They typically spawn in small streams with water velocities ranging from 0.08 to 0.70 m/sec, with preferred velocities between 0.3 and 0.5 m/sec (Emmett et al. 1991; PFMC 2000). Stream depths range from 0.05 to 0.66 m in areas of gradient increases and moderate currents (e.g. pool tailouts and riffles) (Emmett et al. 1991; PFMC 2000). Redd size is typically 1.5 m^2 and is constructed of relatively silt-free gravel ranging from 0.2 to 10.0 cm in diameter (PFMC 2000). Redd must be well-oxygenated and located near cover (PFMC 2000).

Life History—Adult coho migrate into streams where they deposit their eggs in gravel (Sandercock 1991). Coho are semelparous, which means adult salmon die soon after spawning (Sandercock 1991). Eggs incubate throughout the winter and emerge in the spring as free-swimming fry

(Sandercock 1991). The fry reside in the stream for a year or more when they begin migrating toward the ocean as smolt (Sandercock 1991). Juveniles spend a minimum of 18 months at sea before returning to their natal streams to repeat the process (Sandercock 1991).

Common Prey Species—Coho salmon are opportunistic feeders with a diet that reflects the availability of the prey in their area (Emmett et al. 1991). Emerging fry feed on a variety of invertebrates including spiders, mites, and snails (Emmett et al. 1991). Parr feed on invertebrates and possibly other salmon in stream environments, but in reservoirs their diets consists of zooplankton, insects, and amphipods (Emmett et al. 1991). Juveniles feed on amphipods, insects, mysids, decapod larvae, and larval and juvenile fishes in estuarine environments (Emmett et al. 1991). Ocean-dwelling coho initially feed on decapod larvae, gammarid and hyperiid amphipods, euphausiids, terrestrial insects, copepods, cephalopods, Cnideria, gastropods, planktonic annelids, and larval and juvenile fishes (Emmett et al. 1991). As juveniles get larger they become more piscivorous, feeding on northern anchovy, Pacific herring, Pacific sardine, juvenile scorpaenids, capelin (*Mallotus villosus*), and other fish species (Emmett et al. 1991).

- **Puget Sound Pink Salmon (*Oncorhynchus gorbuscha*)**

Distribution—Puget Sound pink salmon can be found in rivers and small streams from northern California north around Alaska and into Canada's Northwest Territory (Mackenzie River) (Bonar et al. 1989; Emmett et al. 1991). Their oceanic distribution in the Pacific ranges from north of 40°N around Attu Island, through the Bering Sea, and into the Beaufort Sea (Emmett et al. 1991; PFMC 2000). In Asia, this species occurs from Hokkaido, Japan north to the Arctic Ocean (Emmett et al. 1991; PFMC 2000). Washington State supports some of the southernmost consistently exploitable spawning runs for pink salmon (Bonar et al. 1989; Emmett et al. 1991).

Habitat Preference

Depth: Pink salmon are found in fresh water to euhaline water at depths ranging from the surface to 250 m.[7] Current velocity and substrate play a more important role in habitat selection during spawning than depth (Bonar et al. 1989). Spawning depths range from 30 to 100 cm but preferred depths range from 20 to 25 cm (Heard 1991).

Temperature: Lethal temperature limits for pink salmon are 0.0°C and 25.6°C with preferred temperatures ranging from 5.6° to 14.4°C (Emmett et al. 1991). Optimal temperature for pink salmon is 10.1°C (Bonar et al. 1989). Pink salmon generally spawn at temperatures ranging from 7.2° to 12.8°C (Bonar et al. 1989). Preferred incubation temperatures range from 4.4° to 13.3°C (Bonar et al. 1989).

Salinity: Pink salmon eggs and alevins are primarily in freshwater but can withstand salinities of 18 psu for extended periods of time and salinities as high as 33 psu for brief periods (Emmett et al. 1991). Fry adapt quickly to high salinity levels and juveniles can tolerate a wide range of salinities (Bonar et al. 1989).

Dissolved Oxygen: Embryos and alevins need well oxygenated water (>6.0 ppm) with preferred levels at or near saturation (Bonar et al. 1989; Emmett et al. 1991). In juveniles, growth, food consumption, and food utilization can all be affected by low dissolved oxygen levels (Bonar et al. 1989). Low dissolved oxygen levels can also hamper swimming performance in migrating adults (Bonar et al. 1989).

Substrate: Spawning adults, as well as eggs and alevins, prefer gravel ranging from 1.3 to 10.2 cm in diameter (Emmett et al. 1991). Fry, juveniles, and adults do not show any preference for particular substrates (Emmett et al. 1991).

Movements and migrations: Generally, pink salmon move quickly from their natal stream after emergence from gravel (Emmett et al. 1991; PFMC 2000). Pink salmon, on average, spend less time in fresh water after emergence than any of the Pacific salmon species (Heard 1991). Some stocks of pink salmon stocks can grow and reproduce successfully without leaving freshwater (Heard 1991). There are wide variations in downstream migration between regions, years, and streams (Heard 1991). Seaward migration peaks in late March and mid-May for pink salmon in British Columbia, Washington State, and Oregon. Downstream migration occurs around late-February in the Fraser River (Heard 1991). These seaward movements seem to be influenced by a variety of factors including general size and location of the spawning stream, characteristics of adjacent shoreline, marine basin topography, tidal fluctuations, current patterns, physiological and behavioral changes, and possible different genetic characteristics between stocks (Heard 1991). The majority of juvenile pink salmon pass directly through the estuaries, using the nearshore habitat instead, some stocks however, do spend one to two months residing in estuaries (PFMC 2000). Heard (1991) noted that pink salmon may enter coastal environments through any of the following routes: long open straits with large inland waters often interspersed with islands such as Tatar Strait, Cook Inlet, Strait of Georgia, and Puget Sound; complex interconnecting fiords and channels common to much of central British Columbia, southeastern Alaska, parts of Prince William Sound, and Kodiak Island; and, relatively open areas, generally with more or less direct access to major seas, bays, or open ocean, such as the Alaska Peninsula, Bristol Bay, and much of the Far East. Juvenile salmon found in Puget Sound from October to November are probably a resident stock that never migrates to the open ocean (Heard 1991). Pink salmon exhibit schooling behavior immediately after entering marine waters (PFMC 2000). During early marine life, they spend the majority of their time along shorelines in waters only a few centimeters deep (Heard 1991). As pink salmon grow they begin to migrate to the open ocean with larger juveniles making the first migrations (Heard 1991). Tagging studies suggest that pink salmon from Puget Sound and the Fraser River leave these waters very quickly and migrate northward along the coast of British Columbia and southeastern Alaska from July through October (Heard 1991). Catch summaries indicate a second southwest migration of pink salmon along the south-central Alaska and Alaska Peninsula coastline from August to October (Heard 1991). After northward migrations to approximately Yakutat, Alaska, Washington State, pink salmon move out into the Gulf of Alaska where they follow the main current in the gyre. From the gyre, they migrate southward during their first fall and winter at sea and then shift northward during the following spring and summer (PFMC 2000). Afterward, they move south, entering coastal waters as they head for their natal streams (PFMC 2000). Homeward migrations for pink salmon may be relatively direct or may include significant divergence (Heard 1991). Pink salmon migrate to the open ocean and return to coastal waters with remarkable consistency from year to year forming the basis for coastal fisheries (Heard 1991). Factors influencing a timely return include abundance of a particular brood, unusual oceanographic features, or characteristics of odd-year and even-year abundance patterns in the region (Heard 1991). Adult pink salmon enter freshwater from June to September, with northern populations entering earlier than southern populations (PFMC 2000). From mid-July (Dungeness River) to September, odd-year pink salmon from Puget Sound typically enter freshwater. Both even and odd-year pink salmon use the Snohomish River with the even-year populations entering three to four weeks earlier (Heard 1991).

Reproduction: Pink salmon have the most consistent life history of any of the Pacific salmon (Bonar et al. 1989). The pink salmon's spawning cycle is so consistent that fish running in even-numbered years are absolutely isolated from fish running in odd-numbered calendar years resulting in no gene flow between the stocks (Bonar et al. 1989). Generally spawning occurs in freshwater close to the sea or in the intertidal zone, however, they may spawn several miles upstream (Bonar et al. 1989). Pink salmon are considered the most specialized of the Pacific salmon due to their lack of dependence on freshwater (Bonar et al. 1989). Spawning times generally range from late August through early October for the majority of their distribution (Bonar et al. 1989).

Preferred spawning grounds for pink salmon include clean course gravel in shallow pools and riffles exposed to moderately fast currents (Heard 1991). Water velocities associated with pink salmon spawning grounds range from 30 to 140 cm/sec with average velocities from 60 to 80 cm/sec (Heard 1991). Preferred spawning depths range from 20 to 25 cm but they may spawn as deep as 150 cm

(Heard 1991). In dry years, nests may be found as shallow as 10 to 15 cm (Heard 1991). Pink salmon select sites with gradient increases and fast currents (PFMC 2000). They prefer beds consisting of coarse gravel and a few large cobblestones, a mixture of sand, and a small amount of silt (Heard 1991). Eggs are deposited from August to October in Washington State and British Columbia. In Puget Sound and the upper Dungeness River they are deposited slightly earlier than elsewhere in northern Washington State (PFMC 2000).

Life History—Pink salmon are the most abundant of the Pacific salmon species and have the simplest and most specialized life history (Heard 1991). Fry migrate quickly to sea after emergence where they make extensive feeding migrations (Heard 1991). Pink salmon spend approximately 18 months in the ocean where they grow rapidly before returning to their natal streams to spawn and die (Heard 1991).

Common Prey Species—Juvenile pink salmon feed on pelagic copepods and other epibenthic and planktonic organisms (Bonar et al. 1989). Juveniles found in southeastern Alaska and Puget Sound feed on harpacticoid copepods, copepod nauplii, invertebrate eggs, tunicates, and barnacle larvae (Bonar et al. 1989). Pink salmon found in marine waters feed on amphipods, fish, euphausiids, copepods, squid, and crustacean larvae. Amphipods and crustaceans were the most important prey items for nearshore fish, whereas, offshore fish preferred copepods and euphausiids (Bonar et al. 1989).

4.4.2 Coastal Pelagic Species

The CPS is managed under the CPS FMP and consists of 13 species (four finfish, one invertebrate, and eight crustaceans) representing six families (anchovies, jacks, herrings, mackerels, squids, and krill). All CPS species have EFH designated within the Pacific Northwest OPAREA and Puget Sound Study Area and all occur within the EEZ of Canada, Mexico, and the U.S. The CPS FMP is an outgrowth of the northern anchovy FMP implemented in 1978. Amendment 8 of this FMP (renamed CPS FMP) was updated to include the management of the entire CPS fishery along the Pacific coast of the U.S. and includes the Pacific sardine, northern anchovy, Pacific (chub) mackerel, jack mackerel, and market squid (PFMC 1998b). On March 13, the PFMC adopted CPS FMP Amendment 12 which prohibited harvest of all krill species in the U.S. EEZ and also designated EFH for all eight species that extends along the length of the Pacific coast from the shoreline to the 1,829 m isobath and to depth a 400 m. No HAPCs were identified for the euphausiid species (PFMC 2006).

Three of the finfish species and the one invertebrate that occur along the U.S. west coast have EFH designation in Puget Sound Study Area (PFMC 1998b; **Tables 4-3** and **4-4**). These species often school near shallow water areas in Puget Sound (USACE 2001). Of the four species, only the northern anchovy and Pacific sardine (pilchard) are considered part of the forage fish resources in Puget Sound which contribute to a major portion of the diet of other fishes, seabirds, and marine mammals (Bargmann 1998). The northern anchovy abundance in nearshore areas varies from year to year due to changes in behavior (Bargmann 1998). Eggs have been observed in the plankton during the spring in the southern Strait of Georgia, mid-Dabob Bay, mid-Saratoga Passage, and Skagit Bay with young-of-the-year being observed during the summer in San Juan Islands (Miller and Borton 1980; Washington Sea Grant Program 2000). Pacific sardine are also uncommon in Puget Sound (Garrison and Miller 1982). Due to the restrictions placed on the sardine fisheries after its collapse, this species is becoming more abundant during the warmer months (Bargmann 1998; PFMC 1998b).

EFH species are discussed in the following subsections and listed in **Table 4-2**. Status and EFH designations for CPS finfish and invertebrate are discussed as a group, while individual species information (e.g., distribution, habitat preference, life history, and common prey species) is presented for each species. All krill species have EFH designation. Currently, information is insufficient to describe EFH for any life stage of six of the krill species with respect to abundance, distribution, and life history characteristics. Status of the krill are discussed as a group, while individual EFH designation and information (e.g., distribution, habitat preference, life history, and common prey species) is presented for the two cold-water euphausiid species which are used to characterize the entire krill group (NMFS-SWR

2006). For help with the identification of the CPS finfish and krill species refer to Eschmeyer (1983) and Wikipedia[26], respectively. Additionally, Froese and Pauly[7] provides photographs of the finfish species.
Status—Recent stock assessments indicate that both of the actively managed species (Pacific sardine and Pacific mackerel) are increasing in relative abundance while none of the monitored stocks (northern anchovy, jack mackerel, and market squid) managed under the CPS FMP are considered overfished (PFMC 2002; 2003a; NMFS 2004f; 2004b; 2005k; 2005e). Additionally, none of the managed and/or monitored species are currently listed on the IUCN red list of threatened species.[8]

EFH Designations—EFH is identified for the CPS complex (finfish and invertebrate) as one management unit and is based upon a thermal range bordered within the geographic area where a CPS species occurs at any life stage; where the CPS have occurred historically during periods of similar environmental conditions; or where environmental conditions do not preclude colonization by the CPS (PFMC 1998b; **Figure E-2**).

For the study area, the east-west, EFH geographic boundary for each CPS is defined as all marine and estuarine waters from the shoreline to the limits of the EEZ, above the thermocline, where SSTs range between 10° to 26°C. The southern geographic boundary occurs south of the U.S./Mexico border, where SSTs exceed 26°C (extent of species thermal tolerance). The northern boundary is more dynamic due to the seasonal cooling of the SST and corresponds to the position of the 10°C isotherm, which varies both seasonally and annually (PFMC 1998b).

HAPC—Currently, there are no existing HAPCs listed for the finfish and invertebrate CPS (PFMC 1998b).

- **Anchovies (Engraulidae)**

  - **Northern Anchovy (*Engraulis mordax*)**

    Distribution—Northern anchovy range from the Queen Charlotte Islands, British Columbia, to Cabo San Lucas, southern Baja California; but has recently colonized the Gulf of California (Jacobson 1992; Bergen and Jacobson 2001; Love et al. 2005). The population is divided into northern, central, and southern subpopulations, or stocks (Kucas 1988). Only the northern subpopulation whose geographic range extends from Vancouver Island, Canada to north of San Francisco, California, occurs within the study area (Vrooman and Smith 1970). The central subpopulation, the bulk of which is located in the Southern California Bight (SCB), supports significant commercial fisheries in the U.S. and Mexico (PFMC 1998b).

    Habitat Preference—All life stages of the northern anchovy are found in the near surface waters over various substrates in the EEZ (Hart 1973; Squire and Smith 1977). Adults are oceanic-neritic occurring from the surface to 300 m in waters located 157 km offshore, whereas juveniles are epipelagic and often highly abundant in shallow nearshore areas and estuaries (<90 m) (Methot 1989). Adults can also be abundant in nearshore areas and estuaries (Emmett et al. 1991). Larvae and eggs are neritic and epipelagic out to 480 km offshore with larvae being distributed from the surface to 75 m, but usually in the upper 50 m, and eggs from the surface to 50 m, but normally in the upper 20 m (Hart 1973; Emmett et al. 1991). Northern anchovy typically occur in water temperatures ranging from 10° to 25°C: adults/juveniles - 5° to 25°C, larvae - 14° to 17.4°C, and eggs - 10° to 23.3°C (Emmett et al. 1991). From Oregon to Vancouver Island, the northern anchovy overwinters in the upper mixed layer temperatures ranging from 8° to 9°C (Brewer 1976). Adults, juveniles, and larvae can be found in estuarine and marine waters, while eggs are found in euhaline waters (32 to 35 psu) (Simenstad 1983).

    Life History—Northern anchovy do not take extensive migrations, but undergo inshore-offshore movements and alongshore movements (MBC 1987). They form large schools from the surface down to 55 m during the fall and winter and small, scattered schools, often 14 m below the surface in the spring and summer (Love 1996). During the fall, very large schools may also be found at depths of 110 to 220 m along submarine canyons and over deep banks and basins (Love 1996; Starr et al. 1998). Northern anchovy undertake diel vertical migrations during the

summer, descending to depths of 110 to 183 m during the day and ascending to the surface at night (MBC 1987). Adults, juveniles, and larvae form small low-density schools during the day and disperse into a thin surface layer at night (Emmett et al. 1991). Within the study area, adults and juveniles move into estuaries during spring and summer, then return to the ocean in the fall (Emmett et al. 1991).

Northern anchovy are gonochoristic, oviparous, and iteroparous with external fertilization. This species is a batch spawner that reproduces at night in the upper, mixed layer of the water column (<10 m) from nearshore out to 482 km, but normally within 100 km of the shoreline (Baxter 1966; Hart 1973; Hunter and Macewicz 1980). Spawning occurs from Barkley Sound and the Strait of Georgia, British Columbia to Magdalena Bay, Baja California and in the Gulf of California but primarily between Point Conception and Point San Juanico, Baja California (MBC 1987). Within the Pacific Northwest OPAREA and Puget Sound Study Area, the spawning season is more restricted taking place off Oregon (between 43° and 47°N latitude) 65 to 157 km offshore of the Columbia River from June to August and off the Fraser River, British Columbia in July and August (Baxter 1966; Hart 1973; Love 1996). Females spawn eggs at intervals as short as six to eight days. Preferred spawning temperature is between 12° to 15°C (Methot 1989).

Common Prey Species—Northern anchovy prey upon phytoplankton and zooplankton, primarily planktonic crustaceans (euphausiids and large copepods), arrowworms, and fish larvae (MBC 1987; PFMC 1998b).

- **Jacks (Carangidae)**

  - **Jack Mackerel (*Trachurus symmetricus*)**

Distribution—Jack mackerel range throughout the northeastern Pacific, from the Pacific coast of the U.S. to an offshore limit approximated by a line running from Cabo San Lucas, southern Baja California, to the eastern Aleutian Islands, Alaska. Much of its geographical range lies outside the EEZ (MacCall and Stauffer 1983).

Habitat Preference—All lifestages of the jack mackerel are pelagic (Eschmeyer et al. 1983). Adults occur offshore from the surface to 403 m, but are most abundant at depths ranging from 9 to 73 m; whereas juveniles are found at depths of 9 to 55 m around floating debris, kelp beds, piers, oil drilling platforms, shallow rock banks, and islands (Hart 1973; MacCall and Stauffer 1983). Larvae and eggs are distributed from the surface to 140 m up to 2,400 km offshore, but are found normally within the upper 50 m of the water column (MBC 1987). Jack mackerel typically occur in water temperatures ranging from 10° to 27°C: adults - 11° to 27°C, juveniles - 13° to 27°C, and larvae/eggs - 10° to 19.5°C (Hart 1973; MacCall and Stauffer 1983; PFMC 1998b). All life stages are found in euhaline waters (32.0 to 34.5 psu) (MacCall and Stauffer 1983).

Life History—Jack mackerel demonstrate migratory patterns onshore-offshore and along the coast. They are more common on offshore banks during late spring, summer, and early fall than during the remainder of the year (PFMC 1998b). Fish longer than 45 cm generally occur further offshore of northern California, Oregon, and Washington State as solitary or loose aggregations, whereas fish less than 45 cm are more abundant in southern California waters in dense schools (Hart 1973; Love 1996).

Jack mackerel are oviparous and multiple spawners reproducing in the epipelagic (MBC 1987; Mason 1992). Spawning occurs between 25° and 47°N latitude from 64 to 1,800 km offshore at temperatures of 14° to 16°C (Love 1996). Spawning grounds are located off southern California and northern Baja California from 64 to 577 km offshore February to October with peak activity from March to July (MacCall and Prager 1988). Spawning also occurs within the Pacific Northwest OPAREA offshore of Oregon from 160 to 1,600 km and off Washington State from 320 to 1,800 km August to October (MacCall and Stauffer 1983; Mason and Bishop 2001).

Common Prey Species—Jack mackerel prey upon zooplankton (copepods, pteropods, euphausiids), juvenile squid, and northern anchovy (Hart 1973; Feder et al. 1974; PFMC 1998b).

- **Mackerels and Tunas (Scombridae)**

  - **Pacific Mackerel (*Scomber japonicus*)**

Distribution—Pacific or chub mackerel circumnavigate temperate and tropical seas (Collette and Nauen 1983; Love 1996). In the northeastern Pacific, this species ranges from Banderas Bay (Puerto Vallarta), Mexico, to southeastern Alaska (Hart 1973) and is common from Monterey Bay, California, to Cabo San Lucas, Baja California. Pacific mackerel are most abundant south of Point Conception, California (MBC 1987; PFMC 1998b).

Habitat Preference—All lifestages of the Pacific mackerel are primarily pelagic, to a lesser extent epipelagic or mesopelagic, over the continental slope (Collette and Nauen 1983). Adults are commonly found from the surface to depths of 300 m within 30 km of shore near shallow banks, but may be distributed as far as 400 km offshore (Konno 1992; Konno et al. 2001). Juveniles occur off sandy beaches and in open bay kelp beds from the surface to 50 m (PFMC 1998b). Larvae occur from the surface to 66 m; whereas most eggs are found in the upper 20 m, but occur at depths down to 176 m (MBC 1987). Pacific mackerel typically occur in water temperatures ranging from 10° to 26°C: adults - 10° to 22.2°C, juveniles - 10° to 26°C, and larvae/eggs - 14°C (MBC 1987; Love 1996; PFMC 1998b). This species is found at salinities of 33.5 to 35.0 psu (Collette and Nauen 1983).

Life History—Pacific mackerel migrate north in summer and south in winter (MBC 1987) In the northeastern Pacific, they move coastwise between Tillamook, Oregon and Magdalena Bay, Baja California. Northerly movement is increased during summer months during El Niño events (MacCall et al. 1985). There is also an inshore-offshore migration off California, with increased inshore abundance taking place from July to November and peak offshore abundance from March to May (PFMC 1998b). Larval Pacific mackerel undertake diel vertical migrations, ascending to the surface at night (MBC 1987). Pacific mackerel often school with other pelagic species, particularly jack mackerel, Pacific sardine, and Pacific bonito (*Sarda chiliensis*) (Collette and Nauen 1983).

Pacific mackerel are oviparous (Love 1996) and batch spawners with actively spawning fish capable of spawning every day or every other day (PFMC 1998b; Starr et al. 1998). Three spawning stocks of Pacific mackerel occur along the Pacific coasts of the U.S. and Mexico: Gulf of California; Cabo San Lucas; and along the Pacific coast north of Punta Abreojos, Baja California (Collette and Nauen 1983; MBC 1987; PFMC 1998b). Within the Pacific Northwest OPAREA, the northeastern Pacific stock spawn from Eureka, California, south to Cabo San Lucas in Baja California (MBC 1987). Spawning occurs in schools at night, generally within the upper 72 m of the water column between 3 and 320 km off shore peaking from late April to July (MacCall and Prager 1988). Like most small pelagic species, Pacific mackerel have indeterminate fecundity and seem to spawn whenever sufficient food is available and appropriate environmental conditions prevail (Dickerson et al. 1992).

Common Prey Species—Pacific mackerel prey upon pelagic crustaceans (copepods, pteropods, euphausiids), juvenile squid, fish larvae, and small fish (anchovy) (Hart 1973; Collette and Nauen 1983).

- **Herrings (Clupeidae)**

  - **Pacific Sardine (*Sardinops sagax*)**

Distribution—Sardine (genus *Sardinops*) inhabit coastal subtropical and temperate waters within the eastern boundary currents of the Atlantic and Pacific oceans, and the western boundary

currents of the Indo-Pacific oceans (PFMC 1998b). Off the Pacific coast of North America, Pacific sardine comprise three separate subpopulations or stocks: a northern stock (northern Baja California to Alaska), a southern stock (off Baja California), and a Gulf of California stock (Wolf and Smith 1992; Wolf et al. 2001).

Habitat Preference— Pacific sardine are pelagic throughout their life cycle and are typically the most abundant fish species in the California Current (Barnes et al. 1992). Dramatic changes in their distribution and abundance, which are probably related to environmental conditions, exist in sardine populations around the world (Lluch-Belda et al. 1991). Within the Pacific Northwest OPAREA and Puget Sound Study Area, during times of high abundance, Pacific sardine are found from the tip of Baja California (23°N latitude) to southeastern Alaska (57°N latitude). However, during periods of low abundance, sardine are not found in commercial quantities north of Point Conception, California and are restricted to waters off southern and central Baja California (PFMC 1998b). Currently, very little is known about the mechanisms responsible for Pacific sardine distribution (McFarlane and Beamish 1988). This species is found in estuaries but is most common in nearshore and offshore domains along the coast (PFMC 1998b). Pacific sardine typically occur in water temperatures ranging from 10° to 26°C: adults/juveniles - 10° to 26°C, larvae - 13° to 16°C, and eggs - 13° to 15°C (Lluch-Belda et al. 1991).

Life History—Pacific sardine are highly mobile, moving seasonally along the coast with no significant overlap occurring between the northern and southern stocks (Radovich 1982). Older adults may move from spawning grounds in southern California and northern Baja California to feeding grounds off the Pacific Northwest and Canada. Younger adults (ages two to four) appear to migrate to feeding grounds primarily in central and northern California. Juveniles occur in nearshore waters off northern Baja California and southern California (PFMC 1998b). Larvae and eggs occur nearly everywhere adults are found (Lo et al. 1996).

Pacific sardine are oviparous and multiple-batch spawners with an annual fecundity that is highly age-dependent and/or size-dependent. Spawning occurs year-round in loosely aggregated schools in the upper 50 m of the water column. Eggs and larvae are concentrated 50 to 150 km offshore when abundance is high and concentrated closer to shore when abundance is low (Butler et al. 1993; Starr et al. 1998). These patterns are dependent on both SST and sardine density (PFMC 1998b).

The spatial and temporal (seasonal) distribution of spawning in the Pacific sardine is influenced by water temperature. During periods of warm water incursions, the center of sardine spawning shifts northward and spawning extends over a longer period of time (PFMC 1998b). Recent spawning has been concentrated in the region offshore and just north of Point Conception, California (Lo et al. 1996). In the southern stock, spawning peaks April to August between Point Conception and Magdalena Bay, Baja California and January to April in the Gulf of California (PFMC 1998b). Within the Pacific Northwest OPAREA and Puget Sound Study Area, spawning has also observed in the Columbia River Plume off Tillamook Head, Oregon in 1994 (Bentley et al. 1996) and off British Columbia in 1992 (PFMC 1998b).

Common Prey Species—Pacific sardine prey upon phytoplankton, fish larvae, and zooplankton (copepods) (Wolf et al. 2001).

- **Squids (Loliginidae)**

  - **Market Squid (*Loligo opalescens*)**

Distribution—Market or opalescent squid range throughout the California and Alaska current systems, from the southern tip of Bahia Asuncion, Baja California, Mexico (23°N) to southeastern Alaska (55°N) (Dickerson and Leos 1992). They are common between Monterey Bay, California and Punta Eugenio, Baja California, and are found north of Puget Sound only during, or shortly after, El Nino years (Cailliet et al. 1979; Yaremko 2001).

Habitat Preference—Market squid are typically found in pelagic waters over the continental shelf from the surface to depths of at least 800 m (Yaremko 2001). Adults are primarily neritic from the surface to 460 m and occasionally are located in tidepools (MBC 1987). Juveniles are also neritic with smaller individuals inhabiting the surface to 15 m and larger individuals from the surface to 200 m (Recksiek and Kashiwada 1979). Paralarvae (or hatchlings) have been located in nearshore waters (7 km) above the 80 m depth (Zeidberg and Hamner 2002); whereas eggs occur on mud-sand bottoms at depths of 15 to 50 m in semi-protected bays (Roper et al. 1984). Market squid typically occur in water temperatures ranging from 10° to 26°C: adults/eggs - 7° to 17°C and juveniles - 13° to 20°C. This species lives in euhaline waters (MBC 1987).

Life History—Market squid migrate from pelagic waters to nearshore areas over sandy habitats for spawning (Dickerson and Leos 1992; Yaremko 2001). Vertical distribution by squid during daylight hours ranges from 100 to 600 m. At night, adults are located closer to the water's surface, within the upper 100 m of the water column (Zeidberg and Hamner 2002). The migration patterns of juveniles and prespawning adults are unknown (CDFG 2005).

Market squid are oviparous and semelparous (Roper et al. 1984). Spawning squid concentrate in dense schools with most activity involving groups of six to eight individuals (MBC 1987). Factors that determine ideal spawning grounds have not been precisely identified (PFMC 1998b). Known major spawning areas include shallow, semi-protected nearshore areas with sandy or mud bottoms adjacent to submarine canyons (PFMC 1998b). In these locations, egg deposition is between depths of 5 to 55 m in the water column and most common between 20 to 35 m. Market squid spawn from Barkley Sound, British Columbia to South Coronado Island, Baja California (MBC 1987). Spawning occurs year-round: off southern California during the fall-spring, off central California during spring-fall, off Oregon from May to July, and off Washington State and British Columbia from May to September (Roper et al. 1984; NMFS-NWR 2004c). Year-round spawning suggests that stock abundance is not dependent on spawning success during a single short season, or a single spawning area (Yaremko 2001). Spawning is continuous and eggs of varying developmental stages may be present at one site. Paralarvae are dispersed from egg beds by ocean currents and occur most commonly inshore, concentrated in areas where water masses converge (Zeidberg and Hamner 2002).

Common Prey Species—Market squid prey upon copepods, euphausiids, small crustaceans (sergestid shrimp), small fish (northern anchovy), and other squid (PFMC 1998b).

- **Krill**

The krill community within the west coast EEZ is dominated by eight euphausiid shrimp species represented by the family Euphausiidae. Krill provide a critical link in oceanic food webs between phytoplankton food and upper level predators. Many of these upper level predators are commercially important fish (e.g., groundfish, highly migratory, coastal pelagic, salmonids, etc.), cephalopods, and ecologically important protected marine mammals and seabirds (Phillips 1964; Alverson and Larkins 1969; Pinkas et al. 1971; Karpov and Cailliet 1979; Benson et al. 2002; Ainley et al. 2005). As major inhabitants and herbivores encompassing the transition zone of the CCS, krill act as particularly efficient conduits of nutrients and primary production from the various upwelling areas off the coast to the higher trophic levels of the broader marine ecosystem. In addition, they provide a buffer against the possible development of a degraded ocean system that might result from a buildup of excessive algal blooms in coastal waters (Bakun and Weeks 2004).

All eight species comprising the euphausiid community have EFH designation. The following krill species: *Nictiphanes simplex, Nematocelis difficilis, Thysanoessa gregaria, Euphausia recurva, E. gibboides,* and *E. eximia* are usually less abundant, prefer the deep layers of the thermocline, or are only abundant during strong El Nino years (Brinton and Townsend 2003). The two cold-water species, *E. pacificia* and *T. spinifera*, form large, dense surface or near-surface aggregations, support commercial harvesting, and have substantial information with respect to abundance, distribution, and life history characteristics are described in the following paragraphs (NMFS-SWR 2006).

Status—Large-scale commercial fishing of krill does not occur in California, Oregon, or Washington State waters. California and Oregon imposed a ban on landing and krill fishing in 2000 and 2003, respectively. Under Washington State law, it is unlawful to sell krill, possess krill for commercial purposes, or deliver krill for commercial purposes from state or offshore waters (NMFS-SWR 2006). None of the krill species are currently listed on the IUCN red list of threatened species.[8]

- **North Pacific krill *(Euphausia pacifica)***

Distribution—*Euphausia pacifica* is broadly distributed across the North Pacific occurring from the California Current west across the Pacific to Japanese waters. It ranges throughout the subarctic Pacific, including the Gulf of Alaska and as far south as 25°N (Brinton 1981).

Habitat Preference—*E. pacific* is oceanic generally occurring within the west coast EEZ from the surface to bottom depths of 400 m. This species is found seaward to the outer boundary of the EEZ and beyond with its highest densities occurring within the inner third of the EEZ (NMFS-SWR 2006). Within the Pacific northwest region (<3 to 110 NM from the coast), adults and juveniles can be found throughout both inshore and offshore areas, whereas larvae are often most abundant in upwelling areas. Larvae are generally inshore of the 1,823 m in mid-summer and offshore over the deeper waters of the continental shelf during the rest of the year (Gómez-Gutiérrez et al. 2005). Off Oregon, the greatest concentration of adults appears to be located within 10 to 20 NM either side of the shelf break (~200 m isobath) (Gómez-Gutiérrez et al. 2005).

Life History—This species performs extensive vertical migrations. Adults live at a daytime depth of 200 to 400 m (occasionally down to 1,000 m) rising during the night towards the surface often concentrating in the upper 20 to 50 m (NMFS-SWR 2006). Their upward movement is inhibited by temperatures (>20°C) Iguchi and Ikeda 2005). The North Pacific krill has been reported to form surface swarms during the day for feeding and reproductive purposes.[26]

E. pacific is a batch spawner broadcasting eggs freely into the water column where they sink upon entry. Under optimal feeding conditions, females could spawn every two months (NMFS-SWR 2006). Recruitment occurs year-round off Oregon (Heceta Bank and Cape Blanco areas), northern California (Bodega Canyon, Cordell Bank, etc.), and southern California (Channel Islands with distinct peaks being associated with upwelling periods) (Chess et al. 1988; Croll et al. 1998; Fiedler et al. 1998; Ainley et al. 2005; Ressler et al. 2005; Tynan 2005; NMFS-SWR 2006). Recruitment typically is prolonged occurring in open ocean and more exposed coastal areas moving along the coastline from mid-Baja California (February to April) to southern California (May to July), Monterey Bay (spring and summer) and Oregon (August to December) (NMFS-SWR 2006). Off Washington State, there is one large recruitment pulse in the spring and a lesser one in late summer (NMFS-SWR 2006). Due to their shorter life span and relatively few cohort pulses, maximum stock size is reached immediately after successful recruitment of a single cohort (Siegel 2000). In general, there is no spawning stock-recruitment relationship, highest recruitment occurs from spring/summer cohorts with lesser recruitments in autumn and winter (NMFS-SWR 2006). Reproductive swarms are common along the shelf-break area (NMFS-SWR 2006). Within the various inland basins, such as Puget Sound and Strait of Georgia, spawning takes place over a relatively short period in the spring (Feinberg and Peterson 2003).

Common Prey Species—*E. pacific* preys primarily upon phytoplankton, particularly diatoms, small zooplankton, as well as fish eggs and larvae (J.C. Field et al. 2001; Wikipedia[26]).

EFH Designations— (NMFS-SWR 2006; **Figure E-3**)

- Larvae/Juveniles/Adults—EFH is identified in the Pacific Northwest OPAREA as inner boundary of the U.S. west coast EEZ (beyond 3 NM) seaward to the 1,829 m isobath from the surface to 400 m deep extending from the U.S./Mexico north to the U.S./Canadian border.

- ***Thysanoessa spinifera***

Distribution—*Thysanoessa spinifera* occurs in the northeast Pacific ranging from southeastern Bering Sea south to northern Baja California (NMFS-SWR 2006).

Habitat Preference—*T. spinifera* is a coastal species occurring mainly shoreward of the shelf break with its highest concentrations over the continental shelf and slope (NMFS-SWR 2006). This species is found primarily over the shelf and shelf-break waters from 1 to 40 NM off the coast especially between 3 and 15 NM from shore in water less than 100 m deep. Adults occur in the outer shelf, shelf-break, and slope waters beyond (9.7 NM) from the coast, whereas juveniles and larvae are restricted to relatively shallow inner shelf waters less than 9.7 NM from shore (NMFS-SWR 2006). Brinton and Townsend (2003) reported *T. spinifera* disperses extensively offshore toward the main flow of the California Current.

Life History—This species undertakes diel vertical migrations within its relatively shallow depth range (<100 m) (Chess et al. 1988). It is the most predictable and extensive daytime surface swarmer along the California coast from Tomales bay south to the Channel Islands (Fiedler et al. 1998). Mass strandings have been reported along Oregon beaches to as far south as La Jolla, California (NMFS-SWR 2006).

T. spinifera is a batch spawner with adhesive eggs which help maintain recruits in the neritic zone thus preventing offshore dispersal to less productive waters (NMFS-SWR 2006). Spawning season is prolonged, lasting from spring through summer (May to July) coincident with the peak of the upwelling season (Brinton 1981). Adults are thought to swarm, breeding over a protracted spawning season along the coast from British Columbia (March through July with a late May peak), Oregon (May through October or November), northern California (April through June/July, and central and southern California (August through October (NMFS-SWR 2006). Subadults are also known to swarm near the surface in late summer and fall (Schoenherr 1991; Fiedler et al. 1998). Within the inland basins (e.g., Puget Sound, Strait of Georgia region of British Columbia), spawning occurs over a relatively short period in the spring (Feinberg and Peterson 2003).

Common Prey Species—*T. spinifera* preys primarily upon unicellular phytoplankton, primarily diatoms along with small zooplankton and fish eggs/larvae (J.C. Field et al. 2001; Wikipedia[26]).

EFH Designations—(NMFS-SWR 2006; **Figure E-3**)

- o Larvae/Juveniles/Adults—EFH is identified in the Pacific Northwest OPAREA as inner boundary of the U.S. west coast EEZ (beyond 3 NM) seaward to the 914 m isobath from the surface to 100 m deep extending from the U.S./Mexico north to the U.S./Canadian border.

4.4.3 Pacific Coast Groundfish

The Pacific Coast Groundfish FMP manages 80+ species found within the continental margins and waters along the U.S. west coast. These species are broken into the following groups: 12 flatfish (11 right-eye and one left-eye flounders), 52 rockfish, two thornyheads, one scorpionfish, eight roundfish, and seven assorted skates, sharks, and chimaeras. EFH designation is based upon the aquatic habitat necessary for groundfish production in supporting a long-term sustainable fisheries and contributing to a healthy ecosystem (PFMC 1998a). According to Amendment 16-3 to the Pacific coast groundfish FMP, the following rockfish species: chameleon (*Sebastes phillipsi*), dwarf-red (*S. rufinanus*), freckled (*S. lentiginosus*), half-banded (*S. semicinctus*), pinkrose (*S. simulator*), pygmy (*S. wilsoni*), and swordspine (*S. ensifer*) have been added to the FMP. Three of these species (chameleon, half-banded, and the pinkrose) occur in the Pacific Northwest OPAREA and Puget Sound Study Area. Limited information covering distribution, depth, habitat, migration/spawning, and prey species, if available, is present in **Table 4-5**. Currently, information is lacking to define EFH for these additional species (NMFS 2004d).

Table 4-5. Pacific Northwest groundfish species life history information.

Family/ Species	Range/Depth	Habitat	Migration/ Parturition	Prey
Rockfish				
Chameleon Rockfish	Point St. George, northern California to Nine Mile Bank, southern California/ 174 to 274 m	Rocky substata	No Information	No Information
Half-banded Rockfish	Northern Washington to Bahia de Sebastian Vizcaino, central Baja California/ 15 to 402 m	Boulder fields, high-relief rock, cobblestones, mud, sand, bottom superstructure, shell mounds, pipelines of some oil platforms	Large schools/southern California, December to April, peaking in February	Zooplankton: krill, calanoid copepods, larvaceans, gammarid amphipods, crustacean larvae
Pygmy Rockfish	Kenai Peninsula, northern Gulf of Alaska to Cortes Bank, southern California/ 29 to 383 m	Boulders, rocky areas, cobblestones	Large schools, mixed schools with Puget Sound, sharpchin, and redstripe rockfish/No Information	No Information

Source: Love et al. (2002; 2005)

Approximately 49 of the 82 PFMC managed Pacific coast groundfish species that occur in the Pacific Northwest OPAREA have EFH designation in Puget Sound Study Area (**Tables 4-3** and **4-4**; **Figure E-4**). Depending on their lifestage, they may live in kelp or eelgrass beds, rocky reef hardbottoms, hexactinellid sponge reefs, or areas with sandy or muddy sea floors (Simenstad et al. 1979; Palsson 1998; USACE 2001; Jamieson and Chew 2002). Many of these groundfish species utilize the shallow intertidal areas of Puget Sound and the Straits as nursery habitats. These areas provide refuge from predation and productive source of food when these fish shift from pelagic to demersal habitats (West 1997).

Description—Approximately 75 of the 82 PFMC managed groundfish species are known to occur in the Pacific Northwest OPAREA and Puget Sound Study Area (PFMC 1998a). These groundfish species occupy a variety of ecosystems, encompassing different physical and biological attributes at various stages in their life histories and utilizing habitats ranging from estuaries to the limits of the EEZ. Research on the life histories and habitats of these species varies in completeness. This lack of complete life history information for some species limits the characterizations of this diverse multispecies group. To summarize the ecological variation among the species found in the study area, limited information for individual species will be presented, when available. Short biological characterizations covering the distribution, habitat preference (substrate, depth, temperature, and salinity), life history (migration, movements, and spawning), and common prey species for each species are presented following the EFH designations (PFMC 1998a). For help in the identification of groundfish species refer to the following literature: Eschmeyer (1983), Lamb and Edgell (1986), Kramer and O'Connell (2003), Kramer et al. (1995), Love et al. (2002), Ebert (2003), and Froese and Pauly[7].

Status—According to NMFS (2004f) and PFMC (2003b), five groundfish within the Pacific Northwest OPAREA and Puget Sound Study Area (bocaccio, canary rockfish, darkblotched rockfish, widow rockfish, yelloweye rockfish, Pacific ocean perch) are designated as overfished (NMFS 2006a).

Eleven additional groundfish species (sablefish, Dover sole, English sole, Petrale sole, arrowtooth flounder, chilipepper, yellowtail rockfish, shortspine thornyhead, longspine thornyhead, black rockfish, and cabezon) are identified as emphasis species. Emphasis species are described as groundfish stocks that are particularly susceptible to bycatch (PFMC 2004a). Two of these emphasis species, the black rockfish and shortspine thornyhead, have been determined to be subject to overfishing (NMFS 2005k).

The cowcod, bocaccio, and Georgia Basin Pacific hake are listed by NMFS (2004h) as species of concern in the Pacific Northwest OPAREA and Puget Sound Study Area. Five groundfish species are on the IUCN Red List of Threatened Species.[8] Bocaccio is considered critically endangered due to an estimated reduction of at least 80% of its population over the last 10 years or three generations.[8] The shortspine thornyhead is considered endangered due to an estimated reduction of at least 50% of its population over the last 10 years or three generations.[8] The leopard shark is listed as lower risk/conservation dependent, big skate is listed as a lower risk but near threatened.[8] The spiny dogfishes' northeast Pacific subpopulation is listed as vulnerable due to the fisheries overexploitation of this species because of its late maturity, low capacity to reproduce, longevity, generation time (25 to 40 years), and a low intrinsic population rate increase of 2 to 7% per year.[8] According to the FAO, the leopard and soupfin sharks are listed as category 4 because they are slow-growing species of limited reproductive potential that are targeted by both commercial and recreational fisheries and have their nurseries in shallow coastal waters adjacent to highly populated areas that are subject to intensive fishing (Castro et al. 1999).

Distribution—Rockfish are the most diverse Pacific coast groundfish species, in terms of habitat use. This group may be common in nearshore areas or inhabit deeper waters on the shelf. West coast groundfish occur throughout the limits of the EEZ and occupy a diverse range of habitats during their life history. Habitats may be large, due to dispersion of eggs and larvae, or small as is the case with adults of many nearshore rockfish, which have strong affinities for particular locations or substrate types. Mud, sand, gravel, and exposed rocky areas, along with associated biological communities (i.e., phytoplankton, zooplankton, and kelp beds) compose the varied benthic habitats for groundfish on the continental margin. In addition to the geological bathymetry and physical topography, the California Current and its counter current, and long- and short-term climatic conditions also play a major role in determining the size and distribution of groundfish habitat (PFMC 2003b; 2004a).

Within the Pacific Northwest OPAREA and Puget Sound Study Area, groundfish are currently managed based on distinction between nearshore, continental shelf, and continental slope ecosystems. These ecosystems can be characterized by combinations of the habitat composites described below.

EFH Designations—EFH has been identified by the PFMC (1998a) for the Pacific coast groundfish as one management unit:

The revised Pacific coast groundfish EFH includes all waters from the mean higher high water level (MHHW) to depths less than or equal to 3,500 m or the upriver extent of saltwater intrusions (upstream and landward to where ocean-derived salts measure less than 0.5 psu during the period of average annual flow). EFH has also been designated for seamounts in waters deeper than 3,500 m and areas designated as HAPCs not already included in the above criteria (NMFS-NWR 2006; NMFS 2006b; **Figure E-4**). This would include all areas where Habitat Suitability Probability (HSP) is greater than zero for at least one lifestage of one groundfish species (NMFS-NWR 2006). HSP refers to the probability that the habitat is suitable for the management unit species (NMFS-NWR 2005). For more information on HSP and EFH text descriptions for individual species refer to Appendix B of the Pacific Coast groundfish FMP (PFMC 2005g; 2005a; 2005f; 2005b; 2005c). EFH designation was developed using a precautionary approach based on known maximum depth distribution of all lifestages of management unit species. This approach was necessary due to uncertainties concerning the relative value of different habitats to individual groundfish or lifestages, and therefore to the extent of EFH. Thus, EFH encompasses all known suitable habitat for groundfish and an additional buffer to account for gaps in information concerning the distribution of species/lifestages (NMFS-NWR 2006; NMFS 2006b). EFH is described in the following paragraphs.

All lifestages of the Pacific coast groundfish occur within the Pacific Northwest OPAREA and Puget Sound Study Area. Reproductive adults are separated into spawning (external fertilization, release eggs/sperm) represented by flatfish, roundfish, scorpionfish, and thornyheads and mating (internal fertilization, release live young) represented by rockfish (*Sebastes*) and sharks (i.e., soupfin, leopard, spiny dogfish). Skates and chimeras have internal fertilization (mating adults) but produce egg cases into the water to develop (Love et al. 2002; McCain et al. 2005).

HAPC—HAPCs have been designated for both areas (e.g., seamounts) and habitat types based on one or more of the following criteria (NMFS-NWR 2005; NMFS 2006b; **Figure 4-4**):

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

HAPCs based on habitat types may vary over time. For this reason, **Figure 4-4** is only an approximation of their location. These HAPCs may also overlap with each other or with specific areas designated as HAPCs. Defining characteristics of habitat-type HAPCs that are found in the Pacific Northwest OPAREA and Puget Sound Study Area are described below.

- Estuaries—The inland extent of the estuary HAPC is defined as MHHW, or the upriver extent of saltwater intrusion, defined as upstream and landward to where ocean-derived salts measure less than 0.5 psu during the period of average annual low flow. The seaward extent is an imaginary line closing the mouth of a river, bay, or sound; and to the seaward limit of wetland emergents, shrubs, or trees occurring beyond the lines closing rivers, bays, or sounds. This HAPC also includes those estuary-influenced offshore areas of continuously diluted seawater (Cowardin et al. 1979).
- Canopy Kelp—HAPC includes those waters, substrate, and other biogenic habitat associated with canopy-forming kelp species (e.g., *Macrocystis* spp. and *Nereocystis* sp.).
- Seagrass—HAPC includes those waters, substrate, and other biogenic features associated with eelgrass species (*Zostera* spp.), widgeongrass (*Ruppia maritima*), or surfgrass (*Phyllospadix* spp.).
- Rocky Reefs—HAPC includes those waters, substrates, and other biogenic features associated with hard substrate (bedrock, boulders, cobble, gravel, etc.) to MHHW.

Areas of interest are discrete areas that are of special interest due to their unique geological and ecological characteristics. The following areas of interest are designated HAPCs within the Pacific Northwest OPAREA:

- Washington—All waters and sea bottoms in the state waters shoreward from the 3 NM boundary of the territorial sea shoreward to MHHW.
- Oregon—Daisy Bank/Nelson Island, Thompson Seamount, and President Jackson Seamount.
- California—Mendocino Ridge.

Flatfish

♦ **Righteye Flounders (Pleuronectidae)**

- **Arrowtooth flounder (*Atheresthes stomias*)**

  Distribution—Arrowtooth flounder range from Commander Islands and east coast of Kamchatka to Cape Navarin, Bering Sea to Aleutian Islands and Gulf of Alaska to Santa Barbara, southern California with the highest concentration north of Cape Blanco, Oregon (Allen and Smith 1988; Dark and Wilkins 1994; Kramer et al. 1995; Mecklenburg et al. 2002).

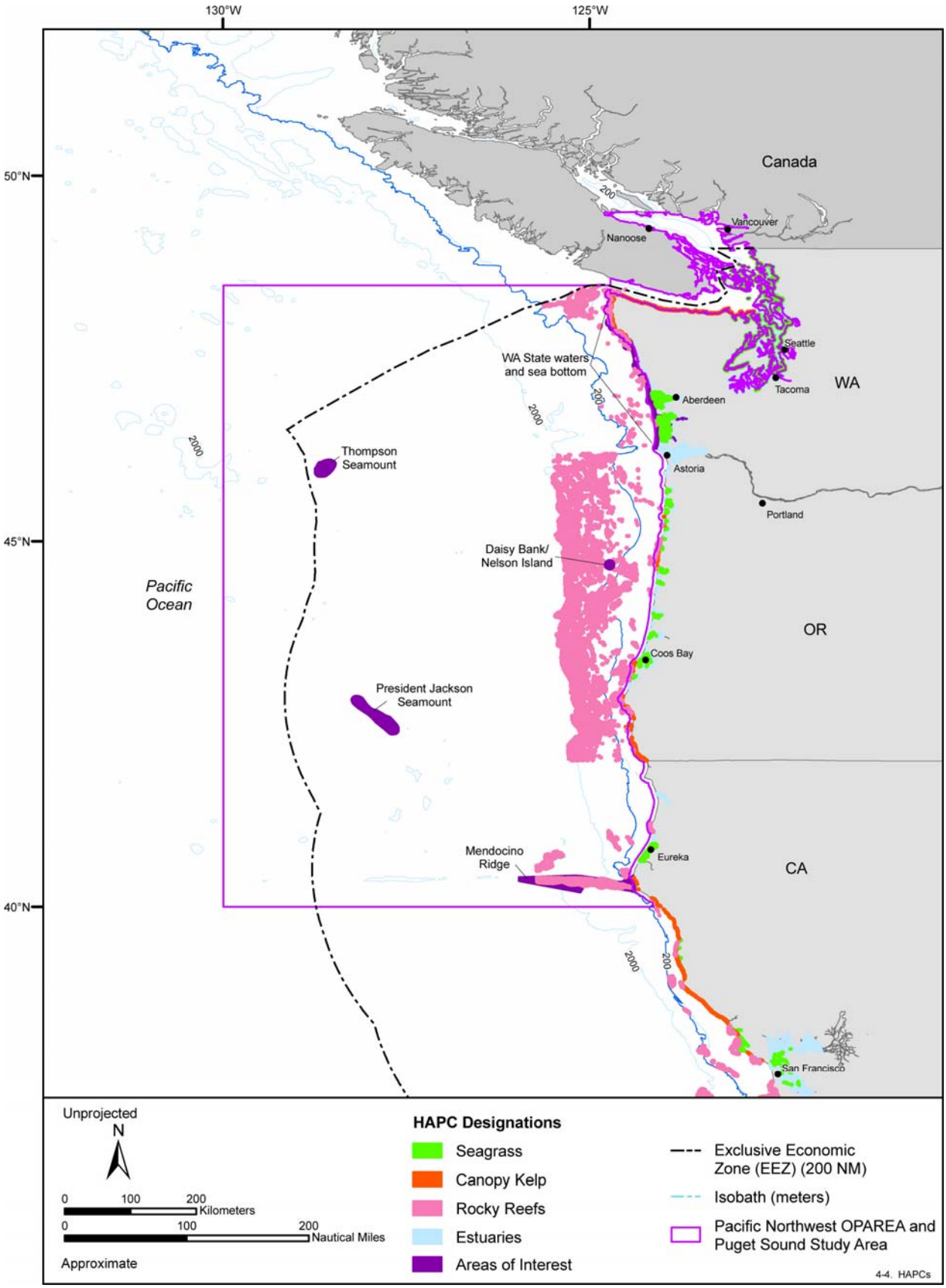


Figure 4-4. Groundfish HAPCs designated in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: Terralogic GIS, Inc. (2005a, 2005b, 2005c, 2005d).

Habitat Preference—Arrowtooth flounder is the dominant flounder species on the continental shelf from the western Gulf of Alaska to Oregon (McCain et al. 2005). Adult and juveniles are demersal and sublittoral-bathyal occurring from depths of 9 to 1,145 m with young juveniles found in shallow waters (<200 m) and older juveniles and adults at water depths ranging from 50 to 500 m (Dark and Wilkins 1994; Love et al. 2005). These lifestages commonly inhabit sand or sandy gravel substrata, but occasionally are found over low-relief rock-sponge bottoms (McCain et al. 2005). Larvae are neritic in water less than 200 m, but occasionally may be found at depths up to 3,100 m (Hart 1973; McCain et al. 2005). Eggs are pelagic occurring in midwater from 75 m to over 300 m (Casillas et al. 1998). Arrowtooth flounders typically reside in water temperatures ranging from sub-zero to 9°C: adults – 0° to 9°C, juveniles – sub-zero° to 5°C, larvae – 6.6° to 8.0°C, and eggs – 3.7° to 6.8°C. All lifestages occur exclusively in euhaline waters (McCain et al. 2005).

Life History—Arrowtooth flounder exhibit a strong migration from shallow water (50 m) summer feeding grounds on the continental shelf to winter/spring deep-water (500 m) spawning grounds over the continental slope (McCain et al. 2005). This species also tends to move into deeper water as its matures (Dark and Wilkins 1994).

Arrowtooth flounders are oviparous with external fertilization and batch spawners, reproducing off the coast of Washington State between fall and winter (McCain et al. 2005) and in Puget Sound during the winter months (Garrison and Miller 1982).

Common Prey Species—Arrowtooth flounder prey upon crustaceans (ocean pink shrimp [*Pandalus jordani*] and krill) and fish (gadids, herring, and walleye pollock) (Hart 1973; McCain et al. 2005).

- **Butter sole (*Isopsetta isopleis*)**

Distribution—Butter sole range from the southeastern Bering Sea and Aleutian Islands (west to Amchitka Island) to Ventura, southern California (Miller and Lea 1972; Kramer et al. 1995; Love et al. 2005).

Habitat Preference—Butter sole inhabit shallow water areas on muddy or silty bottoms (Kramer et al. 1995) and occasionally are found in waters at depths of 2 m or less to 425 m (Eschmeyer et al. 1983; Allen and Smith 1988). This species is usually found in coastal waters within 18 km of shore and have been reported from Puget Sound (McCain et al. 2005). Adults are demersal, whereas the larvae and eggs are pelagic (Casillas et al. 1998).

Life History—Information is unavailable on the migrations and movements of the butter sole (McCain et al. 2005).

Spawning in the butter sole takes place primarily in coastal areas from February to April at depths of 27 to 64 m (Casillas et al. 1998; Matarese et al. 2003). Larvae are abundant in nearshore coastal water off Oregon and Washington State in the winter and spring (McCain et al. 2005).

Common Prey Species—Butter sole prey upon polychaetes, mollusks, amphipods, and sea stars (McCain et al. 2005).

- **Curlfin Sole (*Pleuronichthys decurrens*)**

Distribution—Curlfin sole range from the Aleutian Islands off northwest coast of Unimak Island and Gulf of Alaska to just south of Punta San Juanico, southern Baja California (Miller and Lea 1972; Kramer et al. 1995; Mecklenburg et al. 2002; Love et al. 2005).

Habitat Preference—Curlfin sole occur on softbottom habitats from the surfzone to a depth of 349 m (Miller and Lea 1972), but most commonly in water shallower than 90 m (Eschmeyer et al. 1983; Kramer et al. 1995). Adults are demersal while eggs are pelagic (Casillas et al. 1998).

Life History—Information is unavailable on the migrations and movements of the curlfin sole (McCain et al. 2005).

Spawning in the curlfin sole occurs from late April to August (Eschmeyer et al. 1983).

Common Prey Species—Curlfin sole prey upon benthic organisms such as polychaete worms, nudibranchs, echiuroid proboscises, crustacean (possibly crab) eggs, and brittle star fragments (McCain et al. 2005).

- **Dover Sole (*Microstomus pacificus*)**

Distribution—Dover sole range from northwestern and southeastern Bering Sea and Aleutian Islands from Stalemate Bank to just south of Punta San Juanico, southern Baja California (Hagerman 1952; Hart 1973; Love et al. 2005).

Habitat Preference—Dover sole is the dominant flatfish on the continental shelf and slope from Washington State to southern California (Allen and Smith 1988). Regarded as an inner shelf-mesobenthal species (Allen and Smith 1988), this species inhabits softbottom habitats (i.e., fine sand, silt or mud) in both marine and estuarine environments (Casillas et al. 1998). Both adults and juveniles are demersal (Garrison and Miller 1982). Adults are found from 2 m or less to 1,372 m depth in habitats consisting of mud and sea urchins (*Allocentrotus*) (Kramer et al. 1995; McCain et al. 2005). Their greatest abundance is below 200 to 300 m (Allen and Smith 1988). Juveniles are sublittoral-bathyal at depths of 100 to 700 m and are usually found deeper than 200 m (Hart 1973). Larvae are epipelagic-mesopelagic in both surface and midwaters down to 600 m deep (McCain 2003). Eggs are epipelagic and are found up to 840 km offshore in surface and midwaters from to 50 m to beyond the 200 m isobath where current flows are 10 to 15 cm/sec (Starr et al. 1998). Dover sole are found at water temperatures ranging from 4.0° to 15.5°C: eggs - 8° to 10°C (Casillas et al. 1998) and occur in euhaline waters (MBC 1987).

Life History—Dover sole are migratory with adults and juveniles moving into shallow-water (50 to 225 m) feeding grounds in summer and fall, then migrating offshore into deep waters (300 to 1,000 m) to spawn in late fall (Hunter et al. 1990). This species migrates from onshore to offshore with little coastal north-south movements. Juvenile fish move into deeper water of the oxygen minimum zone (OMZ) with age, and begin seasonal spawning-feeding migrations upon reaching maturity (Henry and Lo 1992; Henry et al. 2001). Larvae are transported offshore and to nursery areas by ocean currents and winds (Hunter et al. 1990).

Dover sole are batch spawners and oviparous with external fertilization (Casillas et al. 1998). Spawning occurs from November to April (peaking between December and February) off Washington State, Oregon, and California in waters 80 to 550 m deep at or near mud bottoms (Hart 1973; Garrison and Miller 1982; Horton 1989). Spawning occurs at temperatures of 4.2° to 6.8°C as well as sub-zero temperatures (MBC 1987; McCain 2003).

Common Prey Species—Dover sole prey upon benthic organisms such as polychaetes, pelecypod and scapopod bivalves, small benthic crustaceans (i.e., pink shrimp), and brittle stars (Hart 1973; Henry and Lo 1992; Henry et al. 2001).

- **English Sole (*Parophyrs vetulus*)**

Distribution—English sole range from Nunivak Island in the Bering Sea and Agattu Island in the Aleutian Islands, to Bahia San Cristobal Bay, central Baja California Sur (Allen and Smith 1988; Love et al. 2005).

Habitat Preference—English sole are very important flatfish in shallow-water, softbottom (i.e., fine sands and mud) marine (i.e., Strait of Georgia) and estuarine environments (e.g., Puget Sound, Hood Canal, Skagit Bay, Grays Harbor; Emmett et al. 1991). Regarded as an inner-shelf mesobenthal species occurring to 55 m (Allen and Smith 1988), it is a member of the shallow sublittoral community in Puget Sound and the intermediate depth Nestucca assemblage off Oregon (McCain et al. 2005). Adults and juveniles are benthic, preferring soft substrates and eelgrass habitats (Garrison and Miller 1982). Adults occur from intertidal zone to 550 m, but are most abundant at depths less than 165 m (MBC 1987). Juveniles occur in intertidal zone at depths up to 150 m and in shallow-water coastal bays and estuarine areas (e.g., Puget Sound <12 m) and protected coastlines (Garrison and Miller 1982; Simenstad 1983). Larvae and eggs are pelagic occurring primarily in waters greater than 200 m deep (McCain 2003). All life stages of the English sole are found at water temperatures ranging from 4° to 18°C: adults/juveniles – less than 18°C, larvae – 8° to 9°C, and eggs – 4° to 12°C (MBC 1987). Adults occur in euhaline waters; whereas juveniles, larvae, and eggs are found in polyhaline salinities of 25 to 28 psu (Garrison and Miller 1982; MBC 1987).

Life History—English sole make limited migrations. Off Washington State and British Columbia, English sole exhibit a northward post-spawning migration in the spring on their way to summer feeding grounds, and a southerly movement in the fall (Garrison and Miller 1982). Tidal currents appear to be the mechanism by which English sole larvae are transported to nearshore nursery areas (i.e., shallow coastal waters and estuaries) along the Pacific coast (Yoklavich 1982). Larvae metamorphose into juveniles in spring and early summer and mature until fall/winter, at which time most emigrate to deeper waters (Gunderson et al. 1990). Early- and late-stage larvae undergo diel vertical migrations (Emmett et al. 1991).

English sole are gonochoristic, oviparous, and iteroparous with external fertilization (Garrison and Miller 1982). Spawning occurs over softbottom mud substrates in shelter waters in channels or bights at depths of 50 to 70 m from winter to early spring depending on the stock (e.g., Eureka, California-Oregon: October to May; Oregon and Puget Sound: January to April peaking in February or March) (Matarese et al. 2003; McCain et al. 2005).

Common Prey Species—English sole preys upon polychaetes, amphipods, mollusks, cumaceans, ophiuroids, and crustaceans (Pearson and Owen 1992; Pearson et al. 2001).

- **Flathead sole (*Hippoglossoides elassodon*)**

Distribution—Flathead sole range from Okhotsk Sea off southwestern Kamchatka and northern Kuril Islands to Gulf of Anadyr, Bearing Sea and Commander-Aleutian chain to Monterey, central California (Miller and Lea 1972; Eschmeyer et al. 1983; Allen and Smith 1988).

Habitat Preference—Flathead sole are mesobenthic inhabiting soft (Eschmeyer et al. 1983), silty or muddy bottoms (Kramer et al. 1995) or mud mixed with gravel or sand (Holladay and Norcross) on the continental shelf in waters from the intertidal zone to as deep as 1,050 m, but usually at depths less than 366 m (Allen and Smith 1988). Adult and juveniles are demersal, whereas eggs and larvae are pelagic (Casillas et al. 1998). Flathead sole are found at water temperatures ranging from 0° to 12°C: adults – 2° to 4°C; juveniles – 5.5° to 10.6°C; and larvae – 6° to 7°C (Paul et al. 1995; Love 1996). This species occurs at the following salinities: adults – 27 to 34 psu, juveniles – 25.0 to 39.6 psu, larvae – 17 to 18 psu, and eggs – 25 to 27 psu (McCain et al. 2005).

Life History—Flathead sole migrate from their wintering grounds on the upper continental slope onto the shelf during the spring and summer where they utilize shallow (<100 m) estuaries, bays, and nearshore areas as nurseries (Holladay and Norcross; McCain 2003). Larvae exhibit diel vertical movements including nocturnal ascent, descent, and diffusion (McCain 2003).

Flathead sole are oviparous and iteroparous, spawning from February to July peaking around April to May, at temperatures ranging from 6° to 8°C and at depths of 73 to 128 m (Love 1996; Matarese et al. 2003; McCain et al. 2005).

Common Prey Species—Flathead sole prey upon mysids, fish (primarily Pacific herring), shrimp, polychaetes, and clams (McCain et al. 2005).

- **Petrale Sole (*Eopsetta jordani*)**

Distribution—Petrale sole range from Aleutian Islands west as far as Unalaska Island and Gulf of Alaska to Islas Coronados, northern Baja California (Mecklenburg et al. 2002). This species is considered rare north and west of southeast Alaska and in the inside waters of British Columbia (Hart 1973; Garrison and Miller 1982; Love et al. 2005).

Habitat Preference—Petrale sole is common on the outer shelf (100 to 150 m) over sand, sandy mud, and occasionally muddy substrates (Starr et al. 1998; McCain 2003) and is an important predator on the continental shelf from British Columbia to central California (McCain et al. 2005). Adults are demersal occurring from the surf line to 550 m depth, with the highest abundance in waters less than 300 m deep (Garrison and Miller 1982; McCain 2003). Juveniles are also demersal (Garrison and Miller 1982) with young juveniles distributed between 18 and 82 m and larger juveniles 25 to 145 m (McCain et al. 2005). Larvae are neritic and epipelagic; whereas eggs are pelagic, both often occurring in the upper 50 m of the water column far offshore (Hart 1973). Larvae have been reported up to 150 km offshore, but off Oregon most are found from 83 to 120 km (Allen and Smith 1988). Petrale sole are found at water temperatures ranging from 4° to 15°C: eggs – 4° to 10°C (Garrison and Miller 1982) and live in polyhaline to euhaline waters: eggs – 25 to 30 psu (McCain et al. 2005).

Life History—Petrale sole migrate seasonally between deep, winter spawning areas to shallow, summer feeding grounds in water 48 to 128 m deep (Garrison and Miller 1982). Few north-south movements along the coast have been observed with a maximum distance of 628 km (Hart 1973). Petrale sole also move into deeper water as they age and increase in size (McCain 2003). Adults may utilize summer feeding grounds in estuaries, while non-migrating subadults overwinter in estuaries (Casillas et al. 1998). Juveniles of offshore stocks often mature within estuaries. Larvae and eggs are transported from offshore spawning locations to nearshore nursery areas by oceanic currents and wind (McCain et al. 2005).

Petrale sole are oviparous with external fertilization and a broadcast spawner (Casillas et al. 1998). Spawning occurs from December to April, peaking in February through March along the continental shelf/slope to depths of 550 m (Garrison and Miller 1982). Nine separate breeding stocks have been identified with all stocks intermingling on summer feeding grounds (Hart 1973). Six of these breeding stocks spawn along the Pacific northwest coast: two off California – Point Delgada and Cape Mendocino; two off Oregon, and two off Washington State (Garrison and Miller 1982).

Common Prey Species—Petrale sole prey upon shrimp and other decapod crustaceans, as well as euphausiids, pelagic fishes (herring, anchovies, hake, rockfish, sand lance), ophiuroids, and juvenile petrale sole (Hart 1973; Thomas 1992, 2001).

- **Rex Sole (*Glyptocephalus zacharis*)**

Distribution—Rex sole range from northern Kuril Islands to Commander Islands in the western Bering Sea to Naravin Canyon in the Aleutian Islands, eastern Bering Sea, and Gulf of Alaska to Cedros Island, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996; Love et al. 2005). This species is the most widely distributed sole on the continental shelf and upper slope off Oregon (McCain 2003). It also occurs in Puget Sound (McCain et al. 2005).

Habitat Preference—Rex sole is a cold-temperate, middle shelf-mesobenthal species that prefers sandy, muddy, and gravelly bottoms and complexes of mud and boulders at depths of 0 to 1,145 m (Kramer et al. 1995). Greatest abundance is at depths from 50 to 450 m (Eschmeyer et al. 1983; Allen and Smith 1988; Love 1996; NMFS et al. 1998). Adults and juveniles are benthic (Stull and Tang 1996) with adults most abundant at 55 to 150 m and juveniles at 150 to 200 m (McCain et al. 2005). Juveniles settle to bottom habitats mainly on the outer continental shelf during the winter and may utilize the outer continental shelf-upper slope region for nursery areas (McCain 2003). Larvae and eggs are pelagic (Stull and Tang 1996). Larvae are widely distributed offshore being most abundant from 46 to 211 km (McCain et al. 2005). Eggs occur in nearshore and offshore waters (Casillas et al. 1998).

Life History— Rex sole move inshore in the summer and make offshore spawning movements in the winter (Love 1996). They also undergo ontogenetic migrations from the shelf to the upper slope habitat (McCain 2003).

Spawning time of the rex sole is variable, often occurring throughout the year (Starr et al. 1998). Rex sole spawn at depths between 100 to 300 m on softbottoms off northern Oregon from January through June peaking from March through April (Matarese et al. 2003; McCain et al. 2005). Spawning coincides with the months of peak average surface and subsurface sea temperatures (Castillo 1995). This species also spawns during the summer off Eureka, California (Quirollo 1992; Quirollo and Dewees 2001).

Common Prey Species—Rex sole prey upon benthic invertebrates (amphipods and polychaetes) as well as euphausiids, cumaceans, and salps (*Oikopleura*; Quirollo 1992; Quirollo and Dewees 2001). In Puget Sound, they prey primarily upon *Capitella* spp. (polychaete; McCain et al. 2005).

- **Rock Sole (*Lepidopsetta polyxystra/L. bilineata*)**

Distribution—Two of the currently recognized species of rock sole occurs along the Pacific coast: northern species (*Lepidopsetta polyxystra*) ranges from the northern coast of Hokkaido, Kuril Islands, and Okhotsk Sea to Gulf of Anadyr and vicinity of St. Lawrence Island, Bearing Sea, and Commander-Aleutian chain to Puget Sound, Washington State and southern species (*L. bilineata*) from Atka Island, Aleutian Islands and southeastern Bering Sea (Slime Bank north of Unimak Island) to Cortes Bank, southern California (Orr and Matarese 2000; Love et al. 2005).

Habitat Preference—Both species prefer sandy or gravel substrata on the coast of the contiguous U.S and steep rock slopes in Puget Sound (Hart 1973; Garrison and Miller 1982; Horton 1989). Northern rock sole occurs at depths from three to five m to 480 to 517 m; whereas the southern rock sole ranges from 13 to 339 m (Orr and Matarese 2000). Adults and juveniles are demersal and found primarily in shallow water bays (e.g., Puget Sound – above 55 m) and over the continental shelf from the intertidal zone to as deep as 732 m, but generally not below 300 m (Hart 1973; Garrison and Miller 1982; Horton 1989). Larvae are pelagic and are found in the upper 30 m of the water column, but sometimes at depths down to 1,000 m (Hart 1973; Horton 1989; Orr and Matarese 2000). Eggs are demersal and adhesive (Horton 1989). Rock sole are found at water temperatures from sub-zero to 18°C: adults – 7° to 10°C, larvae – 6°C, and eggs – minus 0° to 15°C (Garrison and Miller 1982; Horton 1989; Love 1996). Adults inhabit almost exclusively in euhaline waters; whereas juveniles, larvae, and eggs live in polyhaline to euhaline waters (Garrison and Miller 1982; Horton 1989).

Life History—Rock sole is sedentary (Horton 1989) and undergoes seasonal migrations to overwinter and spawn (deep waters: 125 to 275 m, edge of continental slope) and post-spawning, move the summer to feed (shallow shelf waters: 18 to 80 m) (Hart 1973; Horton 1989). Immature rock soles reside in shallow waters in the winter and move to shallower coastal areas in the spring and summer (Orr and Matarese 2000). As rock sole increase in size, they move into deeper waters (Horton 1989). Rock sole larvae exhibit vertical migrations of 5 to 10 m during the

day and up to 30 m at night in response to peak copepod nauplii abundances. Horizontal movement of larvae is facilitated by wind and tidal currents (McCain 2003).

Rock sole are oviparous with external fertilization spawning over a variety of substrates from rocky banks to sand and mud at depths less than 300 m (Horton 1989). Spawning occurs from winter through early spring depending on stock location: Puget Sound - December to April peaking in March and California – February to April (Hart 1973; Garrison and Miller 1982; Horton 1989; Orr and Matarese 2000; Matarese et al. 2003).

Common Prey Species—Rock sole prey upon sedentary foods such as polychaetes, echiuroids, mollusks, echinoderms, benthic fishes, and urochordates (McCain et al. 2005).

- **Sand Sole (*Psettichthys melanostictus*)**

Distribution—Sand sole range from southeastern Bering Sea and Aleutian Islands from Unalaska Island to Port Heiden and Gulf of Alaska to Balboa Pier, Newport Beach, southern California (Garrison and Miller 1982; Mecklenburg et al. 2002; Love et al. 2005).

Habitat Preference—Sand sole are considered an inner shelf-outer shelf species occurring from intertidal zone to 325 m, but are in greatest abundance at depths less than 150 m (Hart 1973; Allen and Smith 1988; McCain et al. 2005). Adult and older juveniles are demersal (Casillas et al. 1998) occurring at depths of 183 m (Kramer et al. 1995). Small juveniles, larvae, and eggs are pelagic (McCain 2003). Small juveniles occur in 5 to 20 m of water in Puget Sound (Garrison and Miller 1982); whereas larvae are generally found in the upper 10 m of the water column and in waters less than 200 m in depth (Garrison and Miller 1982). Eggs generally occur mainly over the shelf (Casillas et al. 1998). In shallow waters along the Pacific coast, sand sole prefer sandy/muddy substrates (Hart 1973). Adults, juveniles, and larvae are found year-round in some estuaries, while spawning adults, larvae and eggs occur in winter-spring in Puget Sound, Bellingham Bay, and East Sound (Hart 1973). Sand sole are found at water temperatures from sub-zero to 16°C: adults – minus 0° to 16°C and larvae/eggs – 4° to 12°C (Garrison and Miller 1982; Horton 1989). All life stages are found in euhaline waters (McCain et al. 2005).

Life History—Sand sole make limited migrations into shallow nearshore waters in early winter to spawn and then move south and offshore in the summer to feed (Casillas et al. 1998). Adults and demersal juveniles tend to move to deeper waters as they age and increase in size (Garrison and Miller 1982), whereas small juveniles and larvae are transported to estuaries and shallow nearshore bays by tidal currents (McCain 2003).

Sand sole are oviparous with external fertilization. Spawning occurs in winter and spring (Hart 1973) over sandy and muddy substrates in water 20 to 30 m deep (Garrison and Miller 1982). In Puget Sound and Bellingham Bay, the spawning season is January through April, peaking in February and March respectively (Hart 1973; Matarese et al. 2003).

Common Prey Species—Sand sole prey mainly on speckled sanddabs (*Citharichthys stigmaeus*), herring, anchovies, crustaceans, mollusks, and worms (Hart 1973; Barry et al. 1996).

- **Starry flounder (*Platichthys stellatus*)**

Distribution—Starry flounder have a very broad geographic distribution around the rim of the north Pacific ocean (Orcutt 1950) ranging from Sea of Japan off Korean Peninsula and Japan to Sea of Okhotsk to Arctic Ocean in East Siberian Sea, Chukchi Sea, Beaufort Sea, and Canada to Bathurst Inlet, Northwest Territories (Mecklenburg et al. 2002). In the northeastern Pacific, they occur from the western Bering Sea and Commander-Aleutian chain to Los Angeles Harbor, southern California. This species is common in Puget Sound Region (Hart 1973; Garrison and Miller 1982; Kramer et al. 1995; McCain et al. 2005).

Habitat Preference—Starry flounder is an important member of the inner continental shelf and shallow sublittoral communities (McCain et al. 2005) ranging from the intertidal zone to depths of about 600 m (Kramer et al. 1995). Adults and juveniles are demersal (Garrison and Miller 1982). Adults prefer sandy to coarse substrate including gravel, whereas juveniles are found on sandy to muddy substrate (Cailliet et al. 2000). Adults along with older juveniles are found from 120 km in the upper reaches of streams to the outer continental shelf at 375 m. Most adults occur in ocean waters less than 150 m (McCain et al. 2005). Adults also occur in estuaries or their freshwater sources year-round in Puget Sound (Garrison and Miller 1982). Juveniles are found in estuaries and the lower reaches of major coastal rivers (Columbia River) (Orcutt 1950; Hart 1973). Larvae and eggs are epipelagic (Garrison and Miller 1982). Larvae are found primarily inshore (within 37 km) and in estuaries (McCain 2003). Eggs occur at or near the surface over water 20 to 70 m deep (Hart 1973; Garrison and Miller 1982). All lifestages typically occur in water temperatures ranging from 0.0° to 21.5°C (Emmett et al. 1991). Adults and larvae are found in euhaline to freshwater, juveniles in mesohaline to freshwater, and eggs polyhaline to euhaline waters (Hart 1973; Garrison and Miller 1982; Simenstad 1983).

Life History—Starry flounder do not migrate extensively (Emmett et al. 1991). They move inshore in late winter-early spring to spawn and offshore to deeper waters in the summer and fall, but these coastal movements are generally less than five km (McCain 2003). Adults and juveniles have been reported to move great distances up major coastal rivers without following any migratory trend. Larvae may be transported long distances by oceanic currents (McCain et al. 2005).

Starry flounder are gonochoristic, oviparous, and iteroparous with external fertilization (Orcutt 1950). Spawning occurs annually in a short time during winter and spring with the exact timing depending on location: California – November to February peaking in December and in Puget Sound – February to April peaking in March (Orcutt 1950; Hart 1973; Garrison and Miller 1982). Most spawning occurs in estuaries or sheltered inshore bays in water less than 45 m at water temperatures of 11°C (Orcutt 1950; Emmett et al. 1991).

Common Prey Species—Starry flounder prey upon amphipods, isopods, decapods, polychaetes, bivalves, echinoderms, and occasionally fish (northern anchovy) (Orcutt 1950; Haugen 1992; Barry et al. 1996; Haugen and Thomas 2001).

- **Sand Flounders (Paralichthyidae)**

  - **Pacific Sanddab (*Citharichthys sordidus*)**

Distribution—Pacific sanddab range from Cabo San Lucas, southern Baja California to Holiday Beach, Kodiak Island, western Gulf of Alaska (Garrison and Miller 1982; Mecklenburg et al. 2002; Love et al. 2005). This species is most abundant along north-central California from Eureka to San Francisco (Rackowski and Pikitch 1989).

Habitat Preference—Pacific sanddab inhabits the inner continental shelf along the western U.S. coast and the shallow sublittoral zone of Puget Sound (Hart 1973; McCain 2003). Adults and juveniles are demersal (Garrison and Miller 1982). Adults inhabit estuaries and coastal waters from the intertidal zone to about 549 m with highest abundance occurring in waters less than 150 m over sand and coarser sediments, low-relief rock bottoms, and occasionally mud (Miller and Lea 1972; Hart 1973; Love 1996). In Puget Sound, adults may be found down to 150 m, but are common in less than 20 m of water (Garrison and Miller 1982). Off Oregon and Washington State, sandab are most abundant between 37 and 90 m (McCain 2003). Juveniles are primarily found in shallow coastal waters, bays, and estuaries over substrates of silty sand (Hart 1973; McCain 2003). Larvae and eggs are pelagic (Garrison and Miller 1982). Larvae may occur as far offshore as 724 km in the upper 200 m of the water column (McCain et al. 2005). Eggs are distributed mainly over the continental shelf (Casillas et al. 1998)). Older fish occur in shallower water and nearer to shore than younger fish at higher latitudes (Rackowski and Pikitch 1989).

Adults are found in high salinity areas correlated with upwellings (Sakuma and Ralston 1995), whereas larvae occur offshore in areas of low salinity (McCain et al. 2005). Eggs are distributed in polyhaline waters at temperatures between 4° to 12°C (Garrison and Miller 1982).

Life History— Pacific sanddab undergo limited migrations and coastal movements are minimal (McCain et al. 2005). Adults are influenced by prey availability, seasonal temperature fluctuations, and substrate type (Rackowski and Pikitch 1989). Larvae are transported by wind and ocean currents (Casillas et al. 1998). Recent reported evidence has suggested that postflexion sanddab larvae make diurnal vertical migrations through the pycnocline with highest catches occurring at night (McCain 2003).

Sanddab are oviparous and iteroparous with eggs fertilized externally (Hart 1973). Spawning occurs from late winter through summer depending on stock and location: California - July through September, peaking in August and Puget Sound – February through spring, peaking in March and April (Hart 1973; Garrison and Miller 1982). Adults spawn near the bottom in bays and the open ocean at low temperatures (Rackowski and Pikitch 1989). Female sanddab may spawn twice per season (Hart 1973; Starr et al. 1998).

Common Prey Species—Pacific sanddab consume shrimp, crab larvae, marine worms, squid, octopus, and northern anchovy (Leos 1992; Allen and Leos 2001).

Rockfish

- **Scorpionfish (Scorpaenidae)**

  - **Aurora Rockfish (*Sebastes aurora*)**

    Distribution—Aurora rockfish range from west of Langara Island, British Columbia to Isla Cedros, central Baja California (Love et al. 2002) and are common from northern Oregon to at least San Diego, southern California (Love et al. 2002).

    Habitat Preference—Aurora rockfish is a deepwater slope species that occupies upper slope habitat (Eschmeyer et al. 1983) ranging in depth from 81 to 893 m (Lauth 2000), with the majority occurring from 300 to 500 m (Allen and Smith 1988; Orr et al. 2000). Adults and juveniles are found in soft and hardbottom habitats on the continental slope/basin (NMFS et al.1998; Love et al. 2002). Larvae are pelagic and range in distance 110 to 170 km from shore (NMFS et al. 1998).

    Life History—Information is lacking on the migrations and movements of the aurora rockfish (McCain et al. 2005).

    Aurora rockfish reproduce from March to May peaking in April off northern and central California and in May off Oregon (Love et al. 2002; McCain 2003). Young are released during late winter through late spring (Casillas et al. 1998).

    Common Prey Species—Information is unavailable on the prey of the aurora rockfish (McCain et al. 2005).

  - **Bank Rockfish (*Sebastes rufus*)**

    Distribution—Bank rockfish range from Queen Charlotte, British Columbia, to central Baja California and Isla Guadalupe, but are most common from Fort Bragg, California southward to at least southern California (Love 1992; Starr et al. 1998; Love et al. 2002; Love et al. 2005).

    Habitat Preference—Bank rockfish occur offshore (Eschmeyer et al. 1983) at depths from 31 to 454 m (Love et al. 2002; Love et al. 2005), with adults preferring depths in excess of 210 m over muddy or sandy bottoms (Miller and Lea 1972; Love et al. 1990). Adults are also found on rocky

reefs, among boulder fields, cobble, mixed mud-rock bottoms, non-rocky shelf, canyons, and along the continental slope/basin (NMFS et al. 1998; Love and Waters 2001). Juveniles are parademersal and pelagic with the parademersal forms probably occupying the shallower parts of the adult range where mixed rock and mud habitats prevail (NMFS et al. 1998). The pelagic forms occur over a wide range depth from 25 to 80 m (Lenarz et al. 1991).

Life History—Information is unavailable on the migrations and movements of the bank rockfish (McCain et al. 2005). Bank rockfish are usually solitary or form aggregations at midwater depths over hardbottoms, over high-relief or on bank edges, and along the ledges of canyons (Love et al. 1990; Love et al. 2002).

Spawning occurs from December to May off northern California peaking in February, and from January to April off Oregon (Love et al. 1990; Love et al. 2002). Off California, this species is a multiple brooder (Love et al. 1990).

Common Prey Species—Bank rockfish prey upon gelatinous planktonic organisms (i.e., tunicates), as well as small fishes and krill (Love 1992).

- **Black Rockfish (*Sebastes melanops*)**

Distribution—Black rockfish range from northern Baja California to the Aleutian Islands (Amchitka Island) and the southern Bering Sea but are most common from San Francisco northward to southeast Alaska (Phillips 1957; Miller and Lea 1972; Hart 1973; Stein and Hassler 1989; Kramer and O'Connell 1995; Mecklenburg et al. 2002). Black rockfish also occur in the Strait of Juan de Fuca (McCain et al. 2005).

Habitat Preference—Black rockfish are found at depths ranging from the surface to 366 m but are most common at depths less than 55 m (Stein and Hassler 1989; Love et al. 2002). Off Oregon, they are most common in waters ranging from 12 to 90 m (ODFW 2002). Adults are semi-pelagic, inhabiting the midwater and surface areas over high-relief rocky reefs as well as in and around kelp beds, boulder fields, pinnacles, and artificial reefs (Bodkin 1988; Love 1996; Starr 1998). Larger benthic juveniles, up to 15 cm, may live in rocky holes (Casillas et al. 1998). Young-of-the-year (e.g., smaller juveniles) are known to recruit to shallow nearshore waters after spending up to five months as pelagic larvae and juveniles in offshore waters (NMFS 2004d). Settlement into nearshore habitats depend on size and location: pelagic, offshore when less than 40 to 50 mm standard length (SL) in the summer; nearshore, on the bottom on sand-rock interface, high-relief rock, or kelp canopy at 40 to 70 mm SL in June, and in estuaries, bays, and tidepools when 35 to 92 mm SL from April to October, often in eelgrass beds (Stein and Hassler 1989; Love 1996; McCain et al. 2005). Larvae are pelagic and have been collected as far as 266 km offshore of the Oregon coast (Love et al. 2002), In shallow water, black rockfish abundances decline in the winter and increase in summer (Stein and Hassler 1989). Densities also decrease with depth during both upwelling and non-upwelling seasons (McCain et al. 2005).

Life History—Off northern Washington State and in the outer Strait of Juan de Fuca, black rockfish exhibit no significant movement. However, they appear to move from the central Washington State coast southward to the Columbia River, but not into Oregon offshore waters. From northern Oregon coast, black rockfish move northward to the Columbia River (Culver 1987).

Black rockfish form mixed-aged and mixed-species (yellowtail, dusky, silvergray, blue, and widow rockfishes), midwater schools near the bottom around kelp forest and high-relief and low-relief rocky terrain, often along steep, dropoffs, and in high-current areas (Hart 1973; Stein and Hassler 1989). In the summer, schools of this species are seen feeding at the surface along the kelp-lined shores of the western Strait of Juan de Fuca (e.g., Duncan Rock) (McCain et al. 2005). In kelp beds, larger adult black rockfish migrate outside the kelp diurnally, returning before dusk; whereas juveniles and small adults remain in the kelp beds remaining closer to the bottom at

night (Stein and Hassler 1989). Black rockfish usually remain in one area (Stein and Hassler 1989).

Black rockfish have internal fertilization and annual mating (Stein and Hassler 1989). Specific mating sites are unknown, but mating may occur in offshore waters (Hart 1973; Stein and Hassler 1989). Parturition occurs from January to May off California, January to March off Oregon, and February to April off British Columbia (Stein and Hassler 1989; Houk 1992a).

Common Prey Species—Black rockfish prey upon invertebrates (i.e., crustaceans, polychaetes, cephalopods, chaetognaths, and jellyfish, but also feed on small fishes, euphausiids, and amphipods during upwelling periods (Houk 1992a; Love 1996; Reilly 2001; McCain 2003).

- **Black-and-Yellow Rockfish (*Sebastes chrysomelas*)**

Distribution—Black-and-yellow rockfish range from Cape Blanco, Oregon to Isla Natividad, central Baja California but are common from Sonoma County, California to near Point Conception, California (Love 1996; Love et al. 2002).

Habitat Preference—Black-and-yellow rockfish are considered a kelp-forest or inshore species that occur from the intertidal zone down to depths of 37 m (Miller and Lea 1972). They are common in waters less than 18 m (Love 1996) within kelp beds and/or high-relief rocky areas (Miller and Lea 1972; ODFW 2002). Adults and older juveniles are demersal (Casillas et al. 1998) with adults spending most of their time sheltering in cracks and crevices within the rocky substratum or perching on the bottom in the open (Cailliet et al. 2000). Young juveniles and larvae are pelagic with young juveniles living in the surface kelp canopy and near drift algae (Casillas et al. 1998). Larvae initially settle out of the water column into the surface and mid-depth portions of the kelp canopies. As they mature into juveniles, they migrate down the kelp stipes to the bottom substrate in sandy areas near low-relief rock formations (Love et al. 2002).

Life History—Black-and-yellow rockfish are largely territorial, sedentary residents with home ranges up to 10 to 12 m^2 (Love et al. 2002). If artificially or naturally displaced (up to one km from their home site), they have the ability to navigate back to their nest (Casillas et al. 1998).

Mating in the black-and-yellow rockfish occurs from late January to early February while parturition occurs from March to May (Casillas et al. 1998).

Common Prey Species—Black-and-yellow rockfish prey upon crustaceans (shrimp, crabs, isopods), mollusks, and other juvenile rockfishes (Love 1996; Lea et al. 1999; ODFW 2002).

- **Blackgill Rockfish (*Sebastes melanostomus*)**

Distribution—Blackgill rockfish range from Queen Charlotte Islands, British Columbia to Punta Abreojos, southern Baja California (Love 1996; Love et al. 2002; Love et al. 2005). They are most abundant in waters off central and southern California (NMFS-NWR 2004c).

Habitat Preference—Blackgill rockfish are transitional species, occupying both midwater and benthic habitats (Love et al. 1990) where they are commonly found nine m above the bottom (Love 1996). They inhabit rocky or hardbottom habitats along steep drop-offs (i.e., edges of submarine canyons and over seamounts) at depths ranging from 230 to 550 m (Eschmeyer et al. 1983; Orr et al. 1998, 2000). Adults live offshore on deep high-relief rock outcrops in areas with extensive caves and crevices from 88 to 768 m (Eschmeyer et al. 1983; Orr et al. 2000). Large juveniles are often found in waters deeper than 180 m (Love 1996). Small pelagic juveniles are carried shoreward at a depth of about 200 m, where they are commonly associated with flat rather than rocky bottoms (Love and Butler 2001). Larvae inhabit the upper mixed layer of the water column, from about 5 to 220 km from shore and are seldom found below 100 m depth.

They transform to pelagic juveniles (at lengths near 16 mm) in midwater over coastal basins (McCain et al. 2005).

Life History—Blackgill rockfish are an aggregating species often associated with bank rockfish (Love 1996).

Blackgill rockfish produce one brood per year, reproducing off central and northern California from January to June (peaking in February) and off Oregon in April (Love et al. 1990; Love 1996; Love et al. 2002).

Common Prey Species—Blackgill rockfish prey upon euphausiids, pelagic tunicates, cephalopods and juvenile rockfishes, hakes, anchovies, and lanternfishes (Love et al. 1990).

- **Blue Rockfish (*Sebastes mystinus*)**

Distribution—Blue rockfish range from Punta San Tomas, northern Baja California to Chatham Strait and Kruzof Island, southeastern Alaska (Miller and Lea 1972; Love et al. 2002; Love et al. 2005). They are most abundant from Eureka, California to the northern Channel Islands, California (NMFS-NWR 2004c).

Habitat Preference—Blue rockfish occur in depth from tidepools to 549 m (Orr et al. 2000) but are usually found over rocky substrates at depths of 25 to 90 m (Houk 1992b; Love et al. 2002). Adults, subadults, and older juveniles are semi-demersal or demersal (McCain 2003). Adults inhabit the midwater and surface areas around high-relief rocky reefs (30 to 91 m), within and around the kelp canopy, and around artificial reefs (Feder et al. 1974; Allen 1985; Bodkin 1988; Love 1996; Starr 1998). Juveniles often appear in massive schools in the kelp canopy and shallow rocky areas by April or May (Feder et al. 1974; Bodkin 1988; Carr 1991; Houk 1992b; Love 1996). Early-stage juveniles and larvae are pelagic (McCain 2003). In the spring, small juveniles remain pelagic for three to five months until they recruit to the kelp canopy, shallow rocky areas, and the nearshore sand-rock interface (Casillas et al. 1998). Larvae live for several months in surface waters (McCain et al. 2005).

Life History—Blue rockfish are not considered a migratory species (Lea et al. 1999), and movements that do occur are most likely related to changes in water temperature or water turbulence (Casillas et al. 1998). Diel movements have been noted, with fish moving slightly off the bottom during the day to feed (Casillas et al. 1998). North of Point Conception, blue rockfish will school with olive and black rockfish (ODFW 2002). Early life history stages are generally found in shallower waters than adults, indicating movement towards deeper water with age (McCain et al. 2005).

Blue rockfish are ovoviviparous (McCain 2003). In southern California, the blue rockfish begins mating in November and continues through early spring producing young twice in a breeding season (Casillas et al. 1998).

Common Prey Species—Blue rockfish prey upon algae, pelagic tunicates, hydroids, jellyfishes, salps, crustaceans, and larval and juvenile fishes (Hart 1973; MacGregor 1983).

- **Bocaccio (*Sebastes paucispinis*)**

Distribution—Bocaccio range from the western Gulf of Alaska south of Shumagin Islands and Alaska Peninsula to Punta Blanca, central Baja California (Miller and Lea 1972; Love et al. 2005) with greatest abundance between Oregon and northern Baja California (Love et al. 2002). This species is rare in Puget Sound (Love et al. 2002).

Habitat Preference—Bocaccio is a middle shelf-mesobenthal species (Allen and Smith 1988) that is most abundant at depths ranging from 50 to 300 m (Orr et al. 2000). Adults and large

juveniles are parademersal occurring over shelf and slope (Garrison and Miller 1982) in association with kelp beds, eelgrass beds, rocky substrate, and artificial structures such as piers and oil platforms at depths of 20 to 475 m (MBC 1987; Love et al. 1990; Sakuma and Ralston 1995; Yoklavich et al. 2000; Love et al. 2005). Adults exhibit two primary habitat preferences: semi-pelagic forming loose schools above rocky areas and solitary benthic non-schooling individuals found around vertical relief, over sand-mud bottoms with little relief, and in areas with mixtures of rocks and boulders, rock ridges, and rocks and boulders among mud (Yoklavich et al. 2000). Juveniles frequently settle over the above habitats as well as rocky areas associated with algae or on to sandy areas with eelgrass or drift algae (Love et al. 2002). Small juveniles and larvae are pelagic occurring in the upper 100 m of the water column, as far as 480 km from shore (MBC 1987). Small juveniles are most abundant from the surface to depths of 18 m (Feder et al. 1974). Young-of-the-year are found in shallow coastal waters over rocky bottoms, associated with algae (Sakuma and Ralston 1995). All life stages are found in water temperatures from 6° to 15°C and salinities from 31 to 34 psu (MBC 1987).

Life History—Bocaccio undergo limited movements (McCain et al. 2005). Adults undergo small vertical movements above rock habitats (Starr et al. 2002), move more than two kilometers per day (km/day) in pursuit of food, and disappear from traditional commercial fishing grounds during winter spawning and reappear in the spring (MBC 1987). Young-of-the year recruit into shallow water during their first year (Hart 1973), then move into deeper water with an increase in size and age (Garrison and Miller 1982). Bocaccio school with widow, yellowtail, vermillion, and speckled rockfishes (Love et al. 2002) and occur in large aggregations under drifting kelp beds and over firm sand-mud bottoms (MBC 1987).

Bocaccio are ovoviviparous (Hart 1973; Garrison and Miller 1982) with a protracted spawning season that lasts more than 10 months (Love et al. 1990). Parturition occurs off northern and central California from November to March (MBC 1987) with the production of two or more broods (Hart 1973; Love et al. 1990) and off British Columbia and Washington State from January to April (MBC 1987).

Common Prey Species—Bocaccio prey upon small fishes (including other species of rockfishes, hake, sablefish, northern anchovy, and lanternfishes) associated with kelp and squid (Sumida and Moser 1984; MBC 1987; Thomas and MacCall 2001).

- **Bronzespotted Rockfish (*Sebastes gilli*)**

Distribution—Bronzespotted rockfish range from Punta Colnett, northern Baja California to Eureka, California (Love et al. 2002; Love et al. 2005).

Habitat Preference—Bronzespotted rockfish are relatively common in deeper waters (200 to 290 m) off central and southern California (Miller and Lea 1972). Adults have been collected at depths of 75 to 413 m in high-relief rocky outcrops (Love et al. 2002); whereas young-of-the-year have been reported from a boulder field at 252 m (Love et al. 2002).

Life History—Information is unavailable on the migrations, movements, and reproduction of the bronzespotted rockfish (McCain et al. 2005).

Common Prey Species—Information is unavailable on the prey of the bronzespotted rockfish (McCain et al. 2005).

- **Brown Rockfish (*Sebastes auriculatus*)**

Distribution—Brown rockfish range from Bahia San Hipolito, central Baja California to Prince William Sound, northern Gulf of Alaska (Miller and Lea 1972; Eschmeyer et al. 1983; Stein and Hassler 1989; Love et al. 2002; Love et al. 2005). They are most common in south and central

Puget Sound, Washington State and from central California to southern California (Love et al. 2002).

Habitat Preference—Brown rockfish inhabit low-profile hardbottom substrates (Lea et al. 1999) from the surf zone to 146 m (Eschmeyer et al. 1983; Love et al. 2005). They are bottom dwellers, most common in waters less than 53 m (Miller and Lea 1972; Love 1996; Love et al. 2002) aggregating in eelgrass beds, near oil platforms and sewer pipes, old tires, and around the sand-rock interfaces and rocky bottoms of artificial and natural reefs (Miller and Lea 1972; Stein and Hassler 1989; Love 1996; Love et al. 1996). Adults are demersal and occupy high-relief portions of the above habitats (Casillas et al. 1998). Juveniles are pelagic occurring over a wide range of depths (50 to 90 m) usually in shallower water than adults (Lenarz et al. 1991; Love 1996). After a three month pelagic stage, young-of-the-year recruit to hard substrates, low-relief (<1 m) reefs, patches of drift algae on the bottom, and walls of submarine canyons off California (Love et al. 2002; NMFS-NWR 2004c). Within the Main Basin in Puget Sound, brown rockfish occur on natural reefs, rock piles, and artificial reefs in water less than 30 m (Miller and Borton 1980). Brown rockfish have a relatively broad range of seasonal temperature variations (10° to 17°C) and a broad salinity tolerance (Stein and Hassler 1989).

Life History—Movements greater than three km are rare for brown rockfish (McCain 2003). This species has a strong homing tendency, maintaining small home ranges on artificial reefs (e.g., Puget Sound: 30 m^2) and large home ranges on low-relief reefs (400 m^2 up to 1,500 m^2) (Love 1996). Subadults migrate from bays to outer coastal waters (50 km) (Love et al. 2002). Juveniles utilize estuaries as nursery grounds (Stein and Hassler 1989) gradually moving into deeper water during the winter as they mature (Love 1996; Palsson 1998). This species may be solitary (ODFW 2002) or live in small aggregations with vermilion, copper, and canary rockfish on deeper rock outcrops or occur with the quillback in Puget Sound (Love et al. 2002).

Brown rockfish are ovoviviparous (Ashcraft and Heisdorf 2001). In Puget Sound, brown rockfish mate once per year in March and April giving birth in June (Hart 1973; Stein and Hassler 1989). Off Oregon, spawning occurs in May and June (Love 1996) and off central and northern California from December to January and May to June, respectively where mating takes place more than once per season (Love 1996; NMFS-NWR 2004c).

Common Prey Species—Brown rockfish prey upon larger fish, shrimp, isopods, polychaetes, crabs and other crustaceans (Carlisle et al. 1964; Quast 1968b; Feder et al. 1974; Stein and Hassler 1989; Love 1996).

- **Canary Rockfish (*Sebastes pinniger*)**

Distribution—Canary rockfish range from Punta Colnett, northern Baja California to the western Gulf of Alaska south of Shelikof Strait (Miller and Lea 1972; Love 1996; Mecklenburg et al. 2002; Love et al. 2005). A major population concentration of canary rockfish occurs between latitude 44°30' and 45°00'N off Oregon (McCain et al. 2005).

Habitat Preference—Canary rockfish are a middle shelf-mesobenthal species (Allen and Smith 1988) that occurs from 18 to 838 m (Hart 1973; Love 1996; Mecklenburg et al. 2002) but primarily inhabiting waters 50 to 250 m deep (Orr et al. 2000). Canary rockfish inhabit deep water as adults (McCain 2003). Adults have two primary habitat preferences: forming loose semi-pelagic schools above rocky areas (i.e., pinnacles and sharp drop-offs, mixtures of mud and boulders) and non-schooling, solitary benthic individuals often associating with yellowtail, widow, bocaccio, vermilion, and silvergray rockfish (Boehlert and Kappenman 1980; Love 1996; Love et al. 2002). Off Heceta Bank, Oregon, canary rockfish are commonly found in boulder and cobble fields in association with rosethorn, sharpchin, yelloweye, and pygmy rockfish (McCain et al. 2005). Juveniles and larvae are pelagic (Boehlert and Kappenman 1980) with juveniles found just beyond the continental shelf and larvae occurring from 13 to 306 km offshore (Casillas et al.

1998). Young-of-the-year can be found in tide pools (Love 1996), associated with artificial reefs and floating algae, and in interfaces between mud and rocks (Cailliet et al. 2000).

Life History—Canary rockfish move into deeper water as they mature and are capable of major latitudinal movements (up to 704 km) (Lea et al. 1999). Juveniles have been reported to be associated with rocky/sandy areas during the day and sand flats at night (Love et al. 2002). Canary rockfish are a densely aggregating fish (Love 1996).

Canary rockfish are ovoviviparous with internal fertilization (Boehlert and Kappenman 1980). Off central and northern California, canary rockfish reproduce from December to March peaking in December and from January to March off Oregon, Washington State, and British Columbia (Hart 1973; Love 1996).

Common Prey Species—Canary rockfish prey upon crustaceans, primarily plankton euphausiids and mysids and occasionally on fish (Phillips 1964; Love 1996; Lea et al. 1999). During spring-summer upwelling periods, euphausiids are the dominant prey (McCain 2003).

- **Chilipepper (*Sebastes goodei*)**

Distribution—Chilipepper range from Magdalena Bay, southern Baja California, to as far north as Pratt and Durgin Seamounts in the Gulf of Alaska; however, they are most commonly found between Cape Mendicino, California, and northern Baja California (Allen and Smith 1988; Love et al. 2002; Mecklenburg et al. 2002; Love et al. 2005).

Habitat Preference—Chilipepper are parademersal (McCain 2003) and a middle-shelf mesobenthal to outer-shelf species occurring mainly at depths between 50 and 250 m (Allen and Smith 1988; Orr et al. 2000). Adults and older juveniles are usually found over the continental shelf and slope to depths of 491 m; whereas small juveniles and larvae occur near the surface (Love et al. 1990; Love et al. 2005). In California, chilipepper are commonly associated with high-relief, rocky areas along cliff drop-offs (Love et al. 1990); on sand and mud bottoms (MBC 1987); and occasionally over flat, hard substrates (Love et al. 1990). Juveniles and larvae are associated with kelp canopies, with juveniles primarily found in 30 to 50 m of water (Love et al. 1990). Young-of-the-year recruit to shallow nearshore waters usually just outside of kelp beds after spending up to five months as pelagic larvae and juveniles in offshore waters (NMFS 2004d). Chillipepper occur in water temperatures of 5° to 25°C and salinities of 32 to 34 psu (MBC 1987).

Life History—Chillipepper is not considered a migratory species; however, movements of up to 2.4 km/day have been recorded with this species swimming as far as 45 m off the bottom during the day to feed (McCain 2003). Adults form large schools over areas with boulders and rock structures (Love et al. 2002).

Chilipepper are ovoviviparous with internal fertilization (McCain 2003). In central and northern California, mating occurs from September to April peaking in December through January (Oda 1992; Love 1996; Ralston and Oda 2001). Chilipepper produce multiple broods in a single season (Love et al. 1990) and school by sex just prior to mating (MBC 1987).

Common Prey Species—Chilipepper prey upon large euphausiids, squid, and small fishes such as anchovy, lanternfishes, and young hake (Hart 1973; Love et al. 1990).

- **China Rockfish (*Sebastes nebulosus*)**

Distribution—China rockfish range from Kodiak Island, western Gulf of Alaska to Redondo Beach (southern California) and offshore of San Nicholas Island (Mecklenburg et al. 2002; McCain et al. 2005). They are abundant from Prince William Sound, Alaska to northern California (Love et al. 2002).

Habitat Preference—China rockfish occurs both inshore and along the open coast at depths from 3 to 128 m but are most commonly found between depths of 18 and 92 m (Hart 1973; Eschmeyer et al. 1983; Love 1996). Sedentary demersal adults and pelagic juveniles are associated with high-energy, high-relief rocky reefs or rubble, often resting on the bottom or hiding in crevices and kelp beds (Love 1996; CDFG 2002b; Love et al. 2002). Juveniles inhabit shallow subtidal waters during summer and early fall (Casillas et al. 1998) and have been observed in the Strait of Georgia, British Columbia in 9 to 18 m of water (Love et al. 2002). Young-of-the-year settle in shallow water after a probably short pelagic stage (NMFS-NWR 2004c).

Life History—China rockfish are territorial and sedentary, traveling less than one m from their home crevices (Eschmeyer et al. 1983; Love 1996; Lea et al. 1999).

Mating of the China rockfish occurs off California from January to June peaking in January (Love et al. 2002).

Common Prey Species—China rockfish prey upon crustaceans (primarily brachyuran crabs), octopus, abalones, chitons, small fishes, snails, nudibranchs, red abalone (*Haliotis rufescens*), and brittle stars (Lea et al. 1999; Love et al. 2002).

- **Copper Rockfish (*Sebastes caurinus*)**

Distribution—Copper rockfish range from the western Gulf of Alaska, east of Kodiak Island to Islas San Benito, central Baja California (Stein and Hassler 1989; Love 1996; Mecklenburg et al. 2002; Love et al. 2005). They are most abundant in Puget Sound throughout the San Juan Islands and the Strait of Juan de Fuca and from Valdez, Alaska to Punta Banda, northern Baja California (NMFS-NWR 2004c).

Habitat Preference—Copper rockfish occur in nearshore waters on natural rocky reefs, boulder fields, artificial reefs, rock piles, and closely associated with reefs (within one m) (Patten 1973) and kelp beds (Lea 2001; Love et al. 2002). Adults are commonly found at depths ranging from the intertidal zone at high tide to 185 m (Eschmeyer et al. 1983; Allen et al. 2002) but are often found in rocky areas and on rock-sand substrates in shallower waters during upwelling periods (Eschmeyer et al. 1983; Stein and Hassler 1989). They are usually found in waters shallower than 20 m in British Columbia and less than 23 m in Puget Sound, but occupy deeper waters in the southern part of their range (ODFW 2002). Small juveniles and larvae are pelagic for several months to a year and are frequently associated with waters containing surface-forming kelp before settling in shallow water (Stein and Hassler 1989; Carr 1991; Love 1996). Older young-of-the-year occur with drift algae near the bottom, in and around sand and low rock formations (Carr 1991).

Life History— Copper rockfish are relatively resident animals showing little movement once they have settled to the bottom; however, movement of up to 1.6 km has been noted (Miller and Geibel 1973; Lea et al. 1999). Their home ranges are relatively small (<10 m^2) over high-relief areas and large (to 4,000 m^2) over low-relief areas (Love et al. 2002).

Copper rockfish mate once per year and move inshore to release their young (Love et al. 2002). Parturition occurs from April to June in Puget Sound and from February to April south of British Columbia (Love 1996). Copper rockfish may utilize bays as nursery areas (Stein and Hassler 1989).

Common Prey Species—Copper rockfish prey upon demersal crustaceans (cancrid crabs [*Cancer* sp.], kelp crabs, shrimp), cephalopods (*Loligo* sp. and octopus), and fishes such as young-of-the-year rockfishes, cusk eels, eelpouts, and sculpins (Carlisle et al. 1964; Stein and Hassler 1989; Love 1996; Lea et al. 1999; Lea 2001).

- **Cowcod (*Sebastes levis*)**

  Distribution—Cowcod range from Ranger Bank and Guadalupe Island, Baja California to Mendocino County, California and may infrequently occur as far north as Newport, Oregon (Love et al. 2002), but their preferred habitat is located in the SCB (Barnes 2001).

  Habitat Preference—Cowcod is a parademersal species occurring in water depths of 40 to 491 m (Love et al. 2005). Adults are commonly found at depths of 72 to 491 m (Orr et al. 1998, 2000) over high-relief rocky areas, in association with large white sea anemones (Casillas et al. 1998), submarine canyons, under ledges, and in crevices of isolated rock outcrops surrounded by mud (Yoklavich et al. 2000). Juveniles occur in waters 40 to 100 m over sandy and clay (low-relief) bottoms and near oil platforms (Love et al. 2002; Butler et al. 2003; Love et al. 2005). Larvae are almost exclusively found in southern California adjacent to the northern Channel Islands at depths less than 200 m (MacGregor 1983; Moser et al. 2000), but may occur 320 km offshore over the continental shelf from northern California to northern Baja California (Love et al. 2002).

  Life History—Cowcod is not migratory but may move to some extent to follow food (McCain 2003). They are generally solitary, but occasionally aggregate (Love et al. 1990).

  Cowcod are ovoviviparous with large females producing up to three broods per season (Love et al. 1990). In the central and northern California, a single brood is produced from December to February peaking in December (Love et al. 2002).

  Common Prey Species—Cowcod prey upon fish, octopus, and squid (McCain 2003).

- **Darkblotched Rockfish (*Sebastes crameri*)**

  Distribution—Darkblotched rockfish range from Santa Catalina Island, southern California to an area southeast of Zhemchug Canyon in the eastern Bering Sea (Miller and Lea 1972) and Tanaga Island in the Aleutian Islands (Allen and Smith 1988). Distinct population groups have been found off Oregon coast between latitude 44°30’ and 45°20’N. They also occur in the Strait of Juan de Fuca and Haro Strait in British Columbia (McCain et al. 2005).

  Habitat Preference—Darkblotched rockfish is an outer shelf/upper slope species occurring off Oregon, Washington State, and British Columbia over softbottoms (Eschmeyer et al. 1983) or mud near cobble or boulders (Love et al. 2002). Adults occur at depths of 25 to 915 m but are most common between 50 and 400 m (Allen and Smith 1988). Benthic juveniles are found at depths of 50 to 200 m (Lenarz et al. 1991; Love et al. 2002). Larvae and pelagic juveniles are found 83 to 93 km offshore in water 900 to 1,300 m deep (McCain 2003). Off central California, young darkblotched rockfish recruit to soft substrate and low-relief (<1 m) reefs (McCain et al. 2005).

  Life History—Darkblotched rockfish migrate to deeper waters with increasing size and age and make limited season movements after recruitment to adult stock (McCain 2003). This species co-occurs with an assemblage of slope rockfish: Pacific ocean perch, and splitnose, yellowmouth, and sharpchin rockfishes (McCain et al. 2005).

  Darkblotched rockfish are ovoviviparous with fertilization and parturition occurring from December to March off Oregon and California, and primarily in February off Oregon and Washington State (Hart 1973; Nichol and Pikitch 1994).

  Common Prey Species—Darkblotched rockfish prey upon macroplanktonic organisms, primarily euphausiids, but also occasionally on amphipods, small salps and octopus, and infrequently on small fish (McCain 2003).

- **Dusky Rockfish (*Sebastes variabilis*)**

  Distribution—Dusky rockfish range from Hokkaido, Japan to eastern Kamchatka in the Bering Sea and along the Aleutian Islands to the central coast of Oregon (Orr and Blackburn 2004; Love et al. 2005).

  Habitat Preference—Dusky rockfish are an off-bottom to midwater species that occurs at depths of 6 to 675 m (Love et al. 2005), but are most commonly found at depths of 100 to 300 m in boulder-rubble substrate (Love et al. 2002) or in areas with extensive sponge beds (NMFS et al. 1998). Juveniles inhabit shallow water areas over rocks and among algae (McCain et al. 2005). They remain above boulder-rubble substrata in the summer, and hide within the substratum's crevices during the winter (Love et al. 2002).

  Life History—Dusky rockfish have been observed in aggregations with other rockfish (northern rockfish [*Sebastes polyspinis*] and Pacific ocean perch) over rocky outcroppings (Love et al. 2002).

  Dusky rockfish spawns in northwestern Gulf of Alaska in May and June (NMFS et al. 1998).

  Common Prey Species—Dusky rockfish prey upon primarily on euphausiids as well as larvae, cephalopods, shrimp, and hermit crabs (NMFS et al. 1998).

- **Flag Rockfish (*Sebastes rubrivinctus*)**

  Distribution—Flag rockfish range from Heceta Bank, Oregon to off Arrecife Sacramento, central Baja California (Miller and Lea 1972; Love 1996; Love et al. 2002; Love et al. 2005).

  Habitat Preference—Flag rockfish occur at depths from 15 to 549 m (Miller and Lea 1972; Love 1996; Orr et al. 2000; Love et al. 2005), but are most common between 30 and 183 m (Orr et al. 2000). Adults are solitary, bottom-dwelling reef fish over boulders and other high-relief rock substrata and are often found among large white sea anemones and in submarine canyons (CDFG 2002b). Pelagic juveniles are commonly found near the water surface in areas with drifting algae mats and plant debris, often many kilometers from shore (Love et al. 2002) and maybe associated with rocky reefs (CDFG 2002b).

  Life History—Information is unavailable on the migrations and movements of the flag rockfish (McCain et al. 2005).

  Flag rockfish reproduce from July to August off northern California and from April to May off Oregon (Kendall and Lenarz 1987).

  Common Prey Species—Flag rockfish prey upon pelagic red crabs, hermit crabs, shrimp, fishes, calanoid copepods, krill, gammarid amphipods, and octopus (Love 1996; Love et al. 2002).

- **Gopher Rockfish (*Sebastes carnatus*)**

  Distribution—Gopher rockfish range from Cape Blanco, Oregon, to Punta San Roque, southern Baja California (Miller and Lea 1972; Love et al. 2002; Love et al. 2005), but are most common from Sonoma County, California to Arrecife Sacramento, central Baja California (NMFS-NWR 2004c).

  Habitat Preference—Gopher rockfish are a shallow-water benthic rockfish that inhabits rocky reefs, kelp beds, as well as sandy areas near reefs (Eschmeyer et al. 1983; Love 1996). They are commonly found in water depths between 12 and 37 m (Love 1996; Orr et al. 2000) but range from intertidal zone to about 86 m (Love et al. 2002). Adults and large juveniles are benthic, whereas small juveniles and larvae are pelagic before settling in shallow water (Casillas et al.

1998). Large juveniles become demersal, preferring low-relief rocks or sand bottoms closely associated with drift algae and the giant kelp (*Macrocystis pyrifera*) (Carr 1991).

Life History—Gopher rockfish are known to move from one to two km in pursuit of better habitats (Lea et al. 1999; McCain 2003). They are largely territorial with home ranges of up to 10 to 12 m^2 (Love et al. 2002). Gopher rockfish spend the day in rocky shelters and at night on the bottom in the open (McCain et al. 2005).

Gopher rockfish are ovoviviparous with eggs carried for one to two months before larvae are released (McCain 2003). Gonadal development begins in late November, mating in late January and early February, and reproduction from March through May (Casillas et al. 1998).

Common Prey Species—Gopher rockfish prey upon crustaceans (*Cancer* sp., crabs, caridean shrimp, anomurans), juvenile sculpins and rockfishes, polychaetes, brittle stars, and mollusks (Larson 1980; Love 1996; Lea et al. 1999; ODFW 2002).

- **Grass Rockfish (*Sebastes rastrelliger*)**

Distribution—Grass rockfish range from Playa Maria Bay, central Baja California to Westport, Washington State (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005), but are most common south of southern Oregon to about Bahia San Quintin, northern Baja California (Miller and Lea 1972; Love et al. 2002; NMFS-NWR 2004c).

Habitat Preference—Grass rockfish is a shallow-water rockfish that is common in nearshore rocky areas, rocky bottom tidepools, along jetties, and in vegetation (kelp and eelgrass) (Miller and Lea 1972; Eschmeyer et al. 1983). They are commonly found from the intertidal zone to 46 m depth but frequently less than 15 m (Miller and Lea 1972; Eschmeyer et al. 1983; Orr et al. 2000). Adults are found hiding in crevices around reef structures (Carlisle et al. 1964; Turner et al. 1969; Feder et al. 1974; Allen 1985; Love 1996; Love and Johnson 1998). Juveniles are most common in tidepools (Love 1996). Young-of-the-year settle to hard substrates in shallow water during the spring and summer after a short pelagic stage (Love 1996; Lea et al. 1999).

Life History—Grass rockfish are considered sedentary and residential moving less than one m from their home range (Casillas et al. 1998).

Grass rockfish have internal fertilization (McCain 2003). Parturition occurs in winter from January to March, with greatest larval abundance occurring in January (Love et al. 2002).

Common Prey Species—Grass rockfish prey upon crustaceans, juvenile fishes (surfperches, midshipmen, white croaker [*Genyonemus lineatus*]), crabs, pistol shrimp, cephalopods, and gastropods (Love 1996; Lea et al. 1999).

- **Greenblotched Rockfish (*Sebastes rosenblatti*)**

Distribution—Greenblotched rockfish range from Ranger Bank, central Baja California to Point Delgada, northern California, but are most common southward from central California (Miller and Lea 1972; Love et al. 2002).

Habitat Preference—Greenblotched rockfish are a deep-dwelling species that occupy a depth range of 55 to 491 m (Miller and Lea 1972; Love et al. 2002). Adults and juveniles are demersal with adults preferring depths of 61 to 396 m (Orr et al. 2000). Adults and large juveniles utilize high-relief rocks, caves, crevices and occasionally mixtures of mud and rock, boulders, or cobble (Love et al. 1990; Love et al. 2002). Larvae are pelagic (Love et al. 1990).

Life History—Information is unavailable on the migrations and movements of the greenblotched rockfish (McCain et al. 2005). Greenblotched rockfish are semi-solitary usually found singly or occasionally in very small groups (Love et al. 2002).

Greenblotched rockfish are viviparous (Love 1996) producing multiple broods (two or more times per season) from December to July, with peak mating occurring in April (Love et al. 1990). Smaller mature females most likely have single broods (Love et al. 1990).

Common Prey Species—Greenblotched rockfish prey upon planktonic organisms, such as euphausiids, pelagic tunicates as well as small fishes (hake, anchovies, lanternfishes), and squid (McCain 2003).

- **Greenspotted Rockfish (*Sebastes chlorostictus*)**

Distribution—Greenspotted rockfish range from Barkley Canyon, southern Vancouver Island to southern Baja California but are abundant as far north as Monterey Bay, California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005).

Habitat Preference—Greenspotted rockfish are common, benthic inhabitants found in waters 30 to 379 m deep (Miller and Lea 1972; Love et al. 2005) on or near the bottom, and often in caves and crevices (McCain et al. 2005). They also utilize various habitat types (e.g., cobble-mud, pebble-mud, boulder-mud, rock-mud, and rock ridge) associated with submarine canyons (Yoklavich et al. 2000). Adults prefer waters depths of 49 to 201 m over high-relief rocky reefs (Love et al. 1990; Love et al. 2002) but are also common on softbottoms, such as sand or mud (Eschmeyer et al. 1983). Juveniles occur at depths between 30 to 89 m (Love et al. 1990) and are often associated with rock outcrops (Love et al. 2002), softbottom habitats (CDFG 2002b), and oil platforms (Love et al. 2002). Solitary greenspotted rockfish are commonly found in association with large sea anemones and under ledges and crevices of isolated rock outcrops (Yoklavich et al. 2000).

Life History—Greenspotted rockfish are sedentary and do not undergo extensive seasonal migrations or movements, rarely moving more than a three km from their habit (Love 1996). Greenspotted rockfish commonly occur with greenblotched, flag, canary, and half-banded rockfishes (Love et al. 2002).

Greenspotted rockfish are viviparous producing multiple broods (two or more times per season). Smaller mature females are single brooders and male rockfish may mate more than once per season (Love et al. 1990). Reproduction occurs off Oregon in April and off northern and central California from April through September, peaking in May (Love 1996; Love et al. 2002).

Common Prey Species—Greenspotted rockfish prey upon planktonic euphausiids, tunicates, small fishes (juvenile rockfishes and hake, lanternfishes, and anchovies), and squid (Love et al. 1990).

- **Greenstriped Rockfish (*Sebastes elongatus*)**

Distribution—Greenstriped rockfish range from Cedros Island, central Baja California to Chirikof Island in the western Gulf of Alaska; but are most common between British Columbia and Punta Colnett in northern Baja California (Hart 1973; Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005).

Habitat Preference—Greenstriped rockfish are a deep-water, parademersal species inhabiting waters from 12 to 1,145 m deep (Hart 1973; Love et al. 2005), but commonly encountered at depths from 100 to 250 m (Love et al. 1990; Orr et al. 2000; Johnson et al. 2001). Adults are widely distributed on rocky (boulder, cobble, pebble) and softbottoms (mud) habitats (Eschmeyer et al. 1983; Love et al. 1990; McCain et al. 2005), associated with both high-relief and low-relief

reefs (Love et al. 1990), and may co-occur with the greenspotted rockfish, demosponges, and brittle stars on deep reefs (McCain 2003). Juveniles have also been observed at oil platforms and artificial reefs (Cailliet et al. 2000). Young-of-the-year settle to the bottom in water deeper than 40 m at the interface between fine sand and clay but can also be found within sand-cobble patches and along sand-mud bottoms that surround rock outcrops (Love et al. 2002).

Life History—Greenstriped rockfish are primarily sedentary (McCain 2003).

Greenstriped rockfish are viviparous and multiple brooders mating two or more times per season (Love et al. 1990). This species reproduces off the northern and central California from May to July, peaking in May and off Oregon, Washington State, and British Columbia in late spring and early summer (Hart 1973; Love et al. 1990).

Common Prey Species—Greenstriped rockfish prey upon various planktonic organisms, such as euphausiids, calanoid copepods, and pelagic tunicates as well as small fishes (hake, anchovies, lanternfishes), shrimp, and squid (Love et al. 2002; McCain 2003).

- **Harlequin rockfish (*Sebastes variegates*)**

Distribution—Harlequin rockfish range from southwest of Newport, Oregon to the southeastern Bering Sea and the Aleutian Islands at Bowers Bank (Hart 1973; Love et al. 2002; Mecklenburg et al. 2002; Love et al. 2005).

Habitat Preference—Harlequin rockfish inhabit the inner shelf-mesobenthal (outer shelf) zone at depths from 6 to 588 m (Allen and Smith 1988; Love et al. 2005). Adults are found over high-relief substrata (including seamounts) at depths ranging from 100 to 350 m and as shallow as 49 m (Love 1996; Orr et al. 2000; Love et al. 2002). Juveniles occur in shallow waters to a depth of 6 m (Love et al. 2002).

Life History—Harlequin rockfish are a sedentary benthic species that occur singly or in small aggregations usually either on the bottom or within a few meters of rocks (Love et al. 2002).

Information is unavailable on the reproduction of the harlequin rockfish (McCain et al. 2005).

Common Prey Species—Information is unavailable on the prey of the harlequin rockfish (McCain et al. 2005).

- **Olive Rockfish (*Sebastes serranoides*)**

Distribution—Olive rockfish range from southern Oregon to Islas San Benito in central Baja California (Miller and Lea 1972; Love et al. 2002). They are abundant from the Channels Islands off Santa Barbara northward to Cape Mendocino in northern California (Eschmeyer et al. 1983; Love 1996).

Habitat Preference—Olive rockfish occur at depths ranging from surface/intertidal waters to 172 m (Eschmeyer et al. 1983), but are most common in waters less than 30 m deep (Love 1996). Adults occupy midwater, living over hard, high-relief areas such as reefs, wrecks, oil platforms, pipes (Love 1996) and clear-water areas of dense kelp (Love et al. 2002). They are distributed evenly over all rocky substrata, preferring low-rock substratum (Carr 1991). Older juveniles tend to aggregate near the bottom along the outer edge of the kelp bed and disperse over adjacent kelp beds at night (McCain 2003). Newly settled individuals form aggregations at mid-depths along the shoreward margins of kelp beds (McCain et al. 2005). Young-of-the-year are found hovering off the bottom around kelp beds, drifting kelp mats, oil platforms, surfgrass, artificial reefs, and other structures at depths as shallow as three m (Carlisle et al. 1964; DeMartini 1981; Carr 1991; Love 1996; Cailliet et al. 2000; Love 2001). Young-of-the-year also aggregate in areas of reduced water movement where drift algae accumulate; whereas other juveniles recruit to both

kelp-only and rock-only substrate in the lower third of the water column (Carr 1991). Larval olive rockfish are planktonic (Casillas et al. 1998).

Life History—Olive rockfish are sedentary (Love 1996), spending their entire life near the same reef (Watters 1992). Lea et al. (1999) reported movements of less than 1.8 km. During the day, olive rockfish are found in midwaters around kelp, descending to the bottom at night (Love 1996). Movement patterns are limited by the presence or absence of kelp beds (Casillas et al. 1998). This species forms small to moderate-sized aggregations and may be found singly in schools of blue or yellowtail rockfishes (Love et al. 2002; ODFW 2002).

Olive rockfish reproduce once per season (January to March, peaking in January or February) extruding fully developed larvae (Carr 1991; Love 1996; Love et al. 2002).

Common Prey Species—Olive rockfish prey upon fishes (rockfishes, blacksmith (*Chromis punctipinnis*), anchovy, topsmelt (*Atherinops affinis*), pipefish), cephalopods, isopods, krill, and polychaete worms (Quast 1968a; Feder et al. 1974; Bodkin 1988; Watters 1992; Love 1996; Lea et al. 1999; Love 2001).

- **Pacific ocean perch (*Sebastes alutus*)**

Distribution—Pacific ocean perch range from southern Japan and Sea of Okhotsk to Navarin Canyon in the Bering Sea and from the Commander and Aleutian Islands to Punta Blanca, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005) but are common from Oregon northward (Eschmeyer et al. 1983).

Habitat Preference—Pacific ocean perch inhabit the edge of the upper continental slope (Archibald et al. 1983; Dark and Wilkins 1994), occurring at depths of 25 to 825 m, but are common from depths of 55 to 350 m (Orr et al. 2000). The majority of the population occurs in patchy, localized aggregations over the smooth bottom of the continental slope (NMFS et al. 1998). Adults and subadults are benthopelagic (McCain 2003). Adults are generally found below 122 m depth (Eschmeyer et al. 1983) associated with gravel, rocky or boulder substrates found along gullies, submarine canyons, pinnacles, seamounts, and submarine depressions of the upper continental slope (McCain 2003). Juveniles and larvae are pelagic (Casillas et al. 1998). Juveniles are epipelagic and can remain pelagic for two to three years (if carried offshore by currents). Those juveniles carried into shallow waters become demersal and inhabit waters shallower than 250 m (McCain 2003). Juveniles are confined to shallow portions of their bathymetric range (depths as shallow as 37 m) over hardbottom habitats of the shelf break (Casillas et al. 1998). Larval stages initially occur at mesopelagic depths over the continental slope, later rising to epipelagic depths (McCain et al. 2005). All life stages occur in euhaline waters with water temperatures of 2.5° to 6.5°C (Casillas et al. 1998), although adults off British Columbia to Oregon preferred temperatures ranging from 5° to 8°C (McCain et al. 2005).

Life History—Migrations and movement patterns of the Pacific ocean perch are related to summer feeding and winter spawning (NMFS et al. 1998). Pacific ocean perch winter and spawn in deeper water (>275 m) moving to feeding grounds in shallower water (180 to 220 m) in the summer (June to August) (Archibald et al. 1983). In the northeast Pacific, juveniles make seasonal depth migrations (McCain 2003). Adults form large schools, including for spawning, that are 30 m wide to 80 m deep, and as much as 1,300 m long (McCain et al. 2005). Juveniles form ball-shaped schools near the surface (Casillas et al. 1998).

Pacific ocean perch are viviparous with internal fertilization. Reproduction takes place among seamounts and other steep areas that are associated with circulation patterns from September to October off British Columbia and Washington State (McCain 2003). Actual parturition takes place months after mating, primarily from January to April off Washington State (Casillas et al. 1998) with a few fish releasing larvae in August and October (Love et al. 2002). Females are reported to

release larvae at dusk, 20 to 30 m off the bottom in depths of 360 to 400 m, with larvae rising to midwater depths of 215 to 275 m (Love et al. 2002).

Common Prey Species—Pacific ocean perch prey upon euphausiids, calanoid copepods, mysids, shrimp, and fishes (flatfishes, lanternfishes, smelts) (Love 1996; McCain et al. 2005).

- **Pink Rockfish (*Sebastes eos*)**

Distribution—Pink rockfish range from central Oregon to southern Baja California and Isla Guadalupe, central Baja California (Love et al. 2002; Love et al. 2005).

Habitat Preference—Pink rockfish occur in deep waters, ranging from 45 to 366 m (Miller and Lea 1972). Adults are found in boulder fields, resting on softbottom sediments (Love et al. 2002), or near rocky bottoms on the shelf, slope, and in canyons (CDFG 2002b). Juveniles inhabit softbottom sediments (CDFG 2002b).

Life History—Information is unavailable on the migrations, movements, and reproduction of the pink rockfish (McCain et al. 2005).

Common Prey Species—Information is unavailable on the prey of the pink rockfish (McCain et al. 2005).

- **Quillback rockfish (*Sebastes maliger*)**

Distribution—Quillback rockfish range from Anacapa Passage, southern California to Kodiak Island in the Gulf of Alaska (Miller and Lea 1972; Love et al. 2005). They are common in the Strait of Georgia, British Columbia, San Juan Islands in Puget Sound, and from southeastern Alaska to northern California (Hart 1973; Love 1996; Love et al. 2002).

Habitat Preference—Quillback rockfish are a common, shallow-water benthic species that occur from 5 to 275 m (Hart 1973; Love 1996), but are found mainly at depths from 9 to 147 m (Orr et al. 2000). This species is a solitary reef-dweller living in or close to the bottom among rocks in crevices and holes, on coarse sand or pebbles next to reefs in areas with flat-bladed kelp (Love 1996). In Puget Sound, quillback rockfish occupy a wide variety of habitats having the highest abundance on shallow (2 to 20 m) reefs (Love et al. 2002, ODFW 2002). Adults occur in deeper waters (140 m) associated with high-relief substrata (McCain 2003). Pelagic juveniles (young-of-the-year) settle at 18 to 25 mm total length (TL) in shallow waters along the shores within a variety of habitats (drifting aggregates of benthic macrophytes, established bull kelp (*Nereocysis luetkeana*) beds, natural rock configurations, and artificial reefs) (Osorio and Klingbell 2001; McCain et al. 2005). Larvae are planktonic occurring in estuaries and waters over the continental shelf (Casillas et al. 1998).

Life History—Quillback rockfish are residential, with movements less than 9.6 km (Miller and Geibel 1973; Lea et al. 1999). They have also demonstrated homing ability and specific diurnal movement patterns (Matthews et al. 1987). Quillbacks move from artificial reefs to low-relief reefs during the summer and return to artificial reefs in the fall and winter when kelp disappears from the low-relief reefs (McCain 2003). In Puget Sound, quillbacks living over high-relief rocky reef have very limited home ranges (within 30 m^2), while those living over low-relief rocky reefs roam a greater distance (400 to 1,500 m^2) (Love et al. 2002).

Quillbacks are viviparous. Over their geographic range, this species spawns from April to July with a peak early in the season (Love 1996). In Puget Sound, mating occurs in March and parturition in May (McCain et al. 2005).

Common Prey Species—Quillback rockfish prey upon crustaceans (shrimp and various crabs), small fishes including rockfishes and flatfishes, bivalves, polychaetes, and fish eggs (Love 1996;

ODFW 2002). In Puget Sound, this species preys upon brachyuran crabs, gammarid amphipods, euphausiids, and calanoid copepods (McCain et al. 2005).

- **Redbanded Rockfish (*Sebastes babcocki*)**

Distribution—Redbanded rockfish range from the Bering Sea (Zhemchug Canyon) and Aleutian Islands (Amchitka Island) to San Diego, southern California (Miller and Lea 1972; Hart 1973; Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005). They are most abundant from the Yakutat region of the northeast Gulf of Alaska to Oregon and fairly common into central California (Love et al. 2002).

Habitat Preference—Redbanded rockfish occurs in waters as shallow as 49 m and as deep as 1,145 m (Love et al. 2005) but are commonly found between depths of 150 to 400 m (Allen and Smith 1988; Orr et al. 2000). Adults and juveniles typically occur over soft substrates (Eschmeyer et al. 1983; CDFG 2002b). However, they have also been associated with hardbottom substrata, generally in crevices between boulders and are occasionally observed over mixtures of mud, cobblestones, and pebbles (Love et al. 2002).

Life History—Information is unavailable on the migrations and movements of the redbanded rockfish (McCain et al. 2005).

Redbandeds are viviparous (Love 1996). Off Oregon, parturition occurs from March to September (Love et al. 2002) and off British Columbia in April (Hart 1973).

Common Prey Species—Information is unavailable on the prey of the redbanded rockfish (McCain et al. 2005).

- **Redstripe Rockfish (*Sebastes proriger*)**

Distribution—Redstripe rockfish range from southern Baja California to Pribilof Canyon, southeastern Bering Sea and Amchitka Island, Aleutian Islands (Hart 1973; Allen and Smith 1988; Love et al. 2002; Love et al. 2005). This species is relatively uncommon in Puget Sound (Garrison and Miller 1982) but is most abundant from southeast Alaska to central Oregon (NMFS-NWR 2004c).

Habitat Preference—Redstripe rockfish inhabit the outer shelf and upper continental slope (Allen and Smith 1988) in water depths between 12 and 442 m (greatest depth frequency between 150 and 275 m) (Allen and Smith 1988). Adults are semi-demersal (Garrison and Miller 1982) occurring at the transition zone between mud and rock habitats (Cailliet et al. 2000). Juveniles and larvae are pelagic to semi-demersal (Casillas et al. 1998). Both adults and juveniles are found slightly off the bottom (~1 m) over both high-relief and low-relief rocky areas (CDFG 2002b).

Life History—Redstripe rockfish are sedentary, or occur in small groups and in schools exhibiting little (short distance) or no movement from a home habitat or range (Mathews et al. 1996). Off British Columbia, there is some evidence that redstripe rockfish form dense near-bottom schools by day that rise off the bottom and disperse at night (Love et al. 2002).

Redstripe rockfish are ovoviviparous (Garrison and Miller 1982). Off northern and central California, larvae are released July through September and between April and July off Oregon (Casillas et al. 1998). In Puget Sound, larvae are released during July (Garrison and Miller 1982).

Common Prey Species—Redstriped rockfish prey upon krill, small fish (anchovies, herring, other rockfishes), and squid (Love et al. 2002; McCain 2003).

- **Rosethorn Rockfish (*Sebastes helvomaculatus*)**

  Distribution—Rosethorn rockfish range from Banco Range, central Baja California, to the western Gulf of Alaska east of Sitkinak Island (Phillips 1957; Hart 1973; Love et al. 2005). They also occur in Puget Sound (McCain et al. 2005).

  Habitat Preference—Rosethorn rockfish most commonly occur in water depths of 59 to 1,145 m (Johnson et al. 2003) but range from waters 25 to 549 m deep (Phillips 1957; Hart 1973; Love et al. 2002). Adults inhabit muddy areas adjacent to boulders, cobble, or rock, in rocky areas without mud, or in association with sea lilies (Love et al. 2002). Off Heceta Bank on the central Oregon coast, adults were found in habitats consisting of boulders, cobble, demosponges, and brittle stars (McCain et al. 2005). Juveniles are found on both hard and soft substrates (CDFG 2002b).

  Life History—Information is unavailable on the migrations and movements of the rosethorn rockfish (McCain et al. 2005). Rosethorns are solitary rarely rising more than a meter from the bottom (Love et al. 2002).

  Rosethorn rockfish are viviparous (Love 1996). Parturition occurs during May and June in northern and central California (Casillas et al. 1998), and primarily in June from Oregon to British Columbia (McCain 2003).

  Common Prey Species—Rosethorn rockfish prey upon euphausiids, crustaceans (gammarid amphipods), and fishes (Love at al. 2002; McCain et al. 2005).

- **Rosy Rockfish (*Sebastes rosaceus*)**

  Distribution—Rosy rockfish range from Strait of Juan de Fuca near Puget Sound, Washington to Bahia Tortugas in southern Baja California (Miller and Lea 1972; Love et al. 2002). This species has also been observed near the Cobb Seamount off Washington State (Orr et al. 1998, 2000).

  Habitat Preference—Rosy rockfish are solitary, bottom-dwelling rockfish that occur at depths of 7 to 263 m (Love et al. 2002). Adults inhabit hard, high-relief and low-relief areas among rocks and sand between 30 and 46 m (Love 1996, Orr et al. 2000; Love et al. 2002). Juveniles are found from 30 to 61 m (Love 1996) and recruit to rocky areas (Love et al. 2002).

  Life History—Information is unavailable on the migrations and movements of the rosy rockfish (McCain et al. 2005). This species occurs in small groups often rising a few meters above the bottom (Love et al. 2002).

  Rosy rockfish are multiple brooders. Reproduction occurs from central California northward from April to July, peaking in June (Love et al. 1990).

  Common Prey Species—Rosy rockfish prey upon benthic crustaceans (shrimp, crabs, gammarid amphipods, krill, salps, and young-of-the-year rockfishes (Love 1996; Love et al. 2002).

- **Rougheye Rockfish (*Sebastes aleutianus*)**

  Distribution—Rougheye rockfish range from the Commander and Aleutian Islands to San Diego, southern California (Hart 1973; Eschmeyer et al. 1983). They are also found in Pacific waters off northern Hokkaido, Japan and Kuril Islands to Navarin Canyon in the Bering Sea (Allen and Smith 1988). This species is abundant from the Bering Sea and Gulf of Alaska to central Oregon (Love et al. 2002).

  Habitat Preference—Rougheye rockfish commonly occur at water depths of 50 to 450 m, but can occur as shallow as 25 m to as deep as 900 m (Allen and Smith 1988; Mecklenburg et al.

2002). This species is common in offshore waters, but rare in nearshore waters (Hart 1973). Adults are demersal (Eschmeyer et al. 1983) commonly observed over steeply sloped bottoms (Casillas et al. 1998). Off California, young rougheye rockfish recruit to soft substrates, frequent boulders, and rocky slopes greater than 20° (McCain 2003). Rougheyes have been found in water between minus 0.3° to 4.9°C (Love et al. 2002).

Life History—Information is unavailable on the migrations and movements of the rougheye rockfish (McCain et al. 2005). Small juveniles may sometimes be found in schools, whereas larger fish are either solitary or in small groups (Love et al. 1998). Fishes in the northwest Pacific may aggregate more in the fall-winter months (November to December) than May through October (Love et al. 2002).

Rougheye rockfish larvae are released during May off Oregon (McCain 2003) and from February to June off British Columbia (Love et al. 2002).

Common Prey Species—Rougheye rockfish prey upon crustaceans (pandalid shrimps, gammarid amphipods, mysids, and crabs) and fishes (Love et al. 2002).

- **Sharpchin Rockfish (*Sebastes zacentrus*)**

Distribution—Sharpchin rockfish range from San Diego, southern California to Attu Island in the Aleutian Islands, Alaska (Allen and Smith 1988; Love et al. 2005). More specifically, it has been reported that their occurrence is from San Clemente Island, southern California (32.8°N 117.4°W) to Resurrection Bay, Alaska (60.0°N 149.4°W) in the north, and Petrel Bank near the Aleutian Island chain (52.3°N 179.8°'W) to the west (McCain 2003). This species is most abundant from the Gulf of Alaska to northern California (NMFS-NWR 2004c) and off Heceta Bank, central Oregon (Love et al. 2002).

Habitat Preference—Sharpchin rockfish is an outer shelf-mesobenthal species that is commonly found at water depths from 25 to 610 to 660 m (Allen and Smith 1988). This species occurs over softbottoms (Eschmeyer et al. 1983) but prefers mud and cobble or mud and boulder substrates, and are associated with boulder and cobble fields (Casillas et al. 1998). Off central Oregon on Heceta Bank, adults inhabit areas consisting of boulders, cobble, demosponges, and brittle stars (*Ophiacantha*) (McCain et al. 2005). Pelagic juveniles occur 9 to 148 km offshore and larvae 46 to 148 km offshore over 270 to 2,800 m deep water (McCain et al. 2005).

Life History—Information is unavailable on the migrations and movements of the sharpchin rockfish (McCain et al. 2005). Sharpchin rockfish occur in small schools as well as singly on or near the seafloor (Love et al. 2002).

Sharpchin rockfish undergo parturition off northern and central California from May through June and off Oregon from March through July (Casillas et al. 1998).

Common Prey Species—Sharpchin rockfish prey upon euphausiids, shrimps, gammarid amphipods, copepods, and small fishes (Love et al. 2002; McCain 2003).

- **Shortbelly Rockfish (*Sebastes jordani*)**

Distribution—Shortbelly rockfish range from southern Baja California to La Perouse Bank, southern British Columbia (Eschmeyer et al. 1983; Love et al. 2005). Large concentrations occur off the Columbia River at the Oregon-Washington State border (Love et al. 2002).

Habitat Preference—Shortbelly rockfish are a midshelf-mesobenthal and cold-temperate species inhabiting waters from 91 to 491 m deep (Allen and Smith 1988) on the continental shelf (Chess et al. 1988) and upperslope (Stull and Tang 1996). Adults are parademersal occurring in waters ranging from 150 to 200 m from central California to southern Vancouver Island (Casillas et al.

1998; Love et al. 2002). Adult habitats are wide ranging (Eschmeyer et al. 1983) occurring in midwater and away from underwater objects (i.e., reefs or kelp) (Casillas et al. 1998), over smooth bottom habitats near the shelf break and sharp dropoffs (McCain 2003), and along ledges of submarine canyons (Ralston et al. 2003). Juveniles are pelagic for three to five months before recruiting to kelp beds, outer margins of kelp beds, and deep rock outcrops (Love et al. 2002). Off California, young-of-the-year have been observed in the surf line (Lenarz 1992) and are known to inhabit soft substrate and low-relief (<1 m) reefs (Casillas et al. 1998). Larvae occur up to 278 km offshore but are more common closer to shore within 19 km of land (MacGregor 1986).

Life History—Shortbelly rockfish are an active schooling species that is found near the bottom in dense aggregations during the day, but are distributed in the mid-water column at night (Chess et al. 1988). During the summer, shortbelly rockfish tend to move into deeper waters and to the north as they grow but do not make long return migrations to the south in the winter to reproduce (Casillas et al. 1998). Off central California, shortbelly rockfish larvae make diurnal vertical migrations, where the larvae tend to stay within or above the pycnocline at all times (Casillas et al. 1998). During intense upwelling from May to June, small shortbelly rockfish stay in deep waters, presumably to avoid advection to shore (Lenarz et al. 1991).

Shortbelly rockfish are viviparous, bearing advanced yolk-sac larvae at the time of parturition (Casillas et al. 1998). They reproduce off central and northern California from January to April and off Oregon from November to May, both peaking in February (Lenarz 1992; Love 1996; Starr et al. 1998; Love et al. 2002).

Common Prey Species—Shortbelly rockfish prey upon various life stages of euphausiids and calanoid copepods (Chess et al. 1988; Lenarz et al. 1991; Lenarz and Pearson 2001).

- **Shortraker rockfish (*Sebastes borealis*)**

Distribution—Shortraker rockfish range from off northern Hokkaido, Japan to Kamchatka Peninsula in the western Bering Sea (Eschmeyer et al. 1983; Allen and Smith 1988; Krieger 1992; Krieger and Ito 1999) to Navarin Canyon and Aleutian Islands south to Point Conception, California (Allen and Smith 1988).

Habitat Preference—Shortraker rockfish are an offshore, demersal species (Krieger 1992) that inhabits the middle shelf to the mesobenthal slope from 25 to 1,200 m, but commonly occurs from 50 to 650 m (Allen and Smith 1988) or 100 to 600 m (Orr et al. 2000). This species is common over hard, steeply-sloped bottoms (3° to 12°), fine-grained substrata of silt or pebbles, and currents of 0.1 to 0.4 kilometers per hour (km/hr) (Krieger 1992; Krieger and Ito 1999).

Life History—Shortraker rockfish may perform seasonal vertical migrations with depth range expanding during the months of June through November and decreasing from spring to autumn (Love et al. 2002). Migration may also occur in response to food availability with larger individuals undergoing greater movements than smaller individuals (McCain et al. 2005).

Female shortraker rockfish have fully developed embryos from March through July, releasing larvae from summer through fall at depths between 300 and 500 m (Love et al. 2002). Off British Columbia, larvae are released in April (McCain 2003).

Common Prey Species—Shortraker rockfish prey upon shrimp, squids, octopus, mysids, bathylagids, myctophids, and mollusks (Yang and Nelson 2000; Love et al. 2002).

- **Silvergray Rockfish (*Sebastes brevispinis*)**

Distribution—Silvergray rockfish range from Bahia de Sebastian Vizcaino, central Baja California to the southeastern Bering Sea (Hart 1973; Allen and Smith 1988; Love et al. 2005) but are most common between the central Gulf of Alaska and Oregon (Love et al. 2002).

Habitat Preference—Silvergray rockfish are common in open coastal regions generally inhabiting the outer shelf-mesobenthal zone (Allen and Smith 1988) at depths of 100 to 300 m with a range from the surface to 441 m (Allen and Smith 1988; Love et al. 2002). Adults and subadults are found on a variety of rocky-bottom habitats (Love et al. 2002). Young silvergray rockfish inhabit shallow embayments and associated kelp beds (Love et al. 2002).

Life History—Information is unavailable on the migrations and movements of the silvergray rockfish (McCain et al. 2005). Silvergray rockfish form loose aggregations with black, canary, dusky, Puget Sound rockfish (*Sebastes emphaeus*), and yellowtail rockfish or occur as solitary individuals resting on the bottom (Love et al. 2002).

Silvergray rockfish release young between April and August off Oregon, Washington State, and southeast Alaska (Hart 1973; Love et al. 2002).

Common Prey Species—Information is unavailable on the prey of silvergray rockfish (McCain et al. 2005).

- **Speckled Rockfish (*Sebastes ovalis*)**

Distribution—Speckled rockfish range from northern Washington State to Arrecife Sacramento, central Baja California (Love et al. 2002; Love et al. 2005) and are common from central California southward (Love 1996).

Habitat Preference—Speckled rockfish occur in midwater depths from 30 to 366 m (Miller and Lea 1972) over rocks (Love et al. 1990; Love 1996), near the bottom of reefs (Love 1996), among boulders, and to a lesser degree among cobble (Love et al. 2002). Adults are parademersal and usually occur over rocky substrates between 76 and 152 m deep (Love 1996; Casillas et al. 1998). Juveniles can be found as deep as 142 m (Love et al. 2002) but commonly occur from depths of 30 to 89 m (Love et al. 1990; Love 1996). Off California, young rockfish recruit to hard substrate, boulders, and high-relief (>1 m) reefs often in association with macrophytes and crinoids at depths from 95 to 142 m (Love et al. 2002).

Life History—Speckled rockfish is an aggregating species (Love et al. 1990) that probably moves from reef to reef (Love 1996). This species often forms mixed groups with bocaccio, squarespot, and subadult or small adult widow and pygmy rockfish (Love et al. 2002).

Speckled rockfish produce multiple broods (two or more times per season) releasing larvae in May off central and northern California (Love et al. 1990).

Common Prey Species—Speckled rockfish prey upon plankton (krill, copepods) and occasionally eat small fish (Love 1996).

- **Splitnose Rockfish (*Sebastes diploproa*)**

Distribution—Splitnose rockfish range from Sanak Islands, western Gulf of Alaska to Cedros Islands, central Baja California (Miller and Lea 1972; Allen and Smith 1988; Love et al. 2005). They are most abundant from British Columbia to southern California (NMFS-NWR 2004c).

Habitat Preference—Splitnose rockfish inhabit the outer shelf-mesobenthal zone being common at water depths of 150 to 450 m with extremes of 80 to 894 m (Allen and Smith 1988). Adult and juveniles are demersal occurring in non-rocky shelf, continental slope and basin habitats consisting of mud near isolated rock, cobble, and boulder fields (NMFS et al. 1998; Starr et al. 1998), and occasionally in submarine canyons (CDFG 2002b). Prejuveniles and larvae are pelagic (Casillas et al. 1998). Pelagic prejuveniles recruit to soft substrate and low-relief (<1 m) habitat after a transitory midwater residence (Love et al. 2002). Young occur in shallow water at

the surface under drifting kelp (bull kelp) (Eschmeyer et al. 1983), algae (*Fucus* spp. - dominant), and seagrasses (eelgrass) (McCain 2003).

Life History—Splitnose rockfish form schools that are occasionally found as high as 100 m up in the water column (Love et al. 2002). Emigration of juvenile splitnose rockfish from surface waters occurs in May and June (Casillas et al. 1998). Small benthic juveniles appear in July and August with peaks of abundance in November and December (McCain 2003). This temporal discrepancy between disappearance from the surface and peak benthic appearance suggests that migrant juveniles may occupy an intermediate habitat of 200 to 250 m between emigration and settlement (Casillas et al. 1998).

Splitnose rockfish are ovoviviparous, reproducing and releasing larvae throughout the year (Love et al. 2002). Peak reproductive/parturition season for this species decreases incrementally northward from mid-May to June off Oregon, June to July off Washington State, and July and October to December off British Columbia (Casillas et al. 1998; Love et al. 2002).

Common Prey Species—Splitnose rockfish prey upon midwater plankton, primarily euphausiids, copepods, sergestid shrimp, and amphipods (McCain 2003; NMFS-NWR 2004c).

- **Squarespot Rockfish (*Sebastes hopkinsi*)**

Distribution—Squarespot rockfish range from northern Baja California and Guadalupe Island, central Baja California to the southern Oregon coast (Love 1996; Casillas et al. 1998; Love et al. 2005).

Habitat Preference—Squarespot rockfish are a dwarf (maximum 29 cm TL), midwater species occurring in water depths of 18 to 305 m, but most commonly between 30 and 150 m (Miller and Lea 1972; Love et al. 2002). Adults are parademersal (Casillas et al. 1998) occurring over high rocky outcrops (boulder fields) and in areas with flat, hard, fractured substrata and cobblestones at depths from 18 to 183 m (Love et al. 1990; Love 1996; Love et al. 2002). Juveniles are pelagic for three to four months (Love et al. 2002). Young recruit in water greater than 30 m (Love et al. 1990) and settle out over nearshore rocky areas as shallow as 27 m (Love et al. 2002).

Life History—Squarespot rockfish tend to form large aggregations of thousands of individuals (Love 1996). This species sometimes schools with pygmy, speckled, and juvenile widow rockfishes (Love et al. 2002).

Squarespot rockfish are multiple brooders with reproduction occurring from February and March off central California (Love 1996).

Common Prey Species—Squarespot rockfish prey upon plankton primarily copepods, krill, arrow worms, and crab larvae (Love 1996; Love et al. 2002).

- **Stripetail Rockfish (*Sebastes saxicola*)**

Distribution—Stripetail rockfish range from Punta Rompiente, southern Baja California to Yakutat Bay, eastern Gulf of Alaska (Miller and Lea 1972; Hart 1973; Love et al. 2002, 2005). They are most commonly found between British Columbia and southern California (Love et al. 2002).

Habitat Preference—Stripetail rockfish inhabit the outer shelf-outer slope (Stull and Tang 1996) occurring in waters from 25 to 547 m, but most commonly between 100 and 350 m depth (Allen and Smith 1988; Orr et al. 2000). Most adults are demersal, associated with mud bottoms or substrate containing mud and scattered small rocks, although some adults are parademersal near these habitats (Love et al. 2002). Pelagic juveniles are found over a relatively narrow depth range of 50 to 60 m (Lenarz et al. 1991), before recruiting to benthic habitats at depths of 60 to

100 m (Johnson et al. 2001). Juvenile habitat consists of sandy substrate in association with macrophytes (kelp beds) (Love et al. 1994) and low-relief rocks and sedimentary outcrops bounded by mud and sand (Love et al. 2002).

Life History—Adult stripetail rockfish are probably nocturnally active; whereas juvenile rockfish are diurnally active (McCain et al. 2005). Once this species is recruited to shallower depths, it gradually moves to depths commonly used by the adults (Johnson et al. 2001). Adults are most often found on or very near the seafloor (Love et al. 2002).

Stripetail rockfish produce one brood per season. Young are released in northern and central California, from November through March peaking in January, off Oregon in January and February, and off British Columbia in February (Hart 1973; Love 1996; Casillas et al. 1998).

Common Prey Species—Stripetail rockfish prey upon euphausiids and copepods (Stull and Tang 1996).

- **Tiger Rockfish (*Sebastes nigrocinctus*)**

Distribution—Tiger rockfish range from Tanner and Cortes Banks, southern California to Unalaska Island, Aleutian Islands (Love et al. 2002; Love et al. 2005). They are most common between southeast Alaska and northern California including north Puget Sound, Washington State and the Strait of Georgia, British Columbia (Love et al. 2002).

Habitat Preference—Tiger rockfish commonly occur at water depths of 55 to 274 m (Orr et al. 2000) and have a reported range from 17 to 298 m (Johnson et al. 2003). In the northeastern Strait of Georgia, tiger rockfish are found in waters ranging from 21 to 140 m; and in Puget Sound in less than 30 m (McCain et al. 2005). Tiger rockfish are often associated with "wall" habitat (McCain 2003), in caves along undersea cliffs, or on the sea floor, generally in high-relief areas with strong currents (Johnson et al. 2003). Adults are semi-demersal to demersal (Garrison and Miller 1982). Juveniles are pelagic, commonly found near the surface and often associated with drifting algal mats and plant debris (Love et al. 2002).

Life History—Tiger rockfish are solitary and territorial (Hart 1973), defending a home crevice in the reef (ODFW 2002) and have been reported to make short storm-related movements (Love et al. 2002). Aggregations have been observed off southeast Alaska (Love et al. 2002).

Tiger rockfish are ovoviviparous (McCain et al. 2005). This species mating season peaks in May and June in Puget Sound (Casillas et al. 1998) and in April and May in southeast Alaska (Love 1996; Love et al. 2002).

Common Prey Species—Tiger rockfish prey upon crustaceans (caridean shrimp, rock crab, gammarid amphipods) and small fishes like herring and juvenile rockfish (Love et al. 2002; McCain 2003).

- **Vermillion Rockfish (*Sebastes miniatus*)**

Distribution—Vermilion rockfish range from Zaikof Bay, Montague Island, Prince William Sound, Alaska to Islas San Benito, central Baja California, Mexico (Love 1996; Love et al. 2005). They are most abundant from northern California to northern Baja California (Love et al. 2002).

Habitat Preference—Vermilion rockfish are found from 12 to 439 m and are most common between 50 and 150 m (Love et al. 2002; Love et al. 2005). This species commonly occurs over rocks, along drop-offs, and over hardbottom (Love 1996). Adults and juveniles are benthopelagic (MBC 1987)). Adults occur on or near the bottom in areas with structural diversity (i.e., high-relief rocky reefs, drilling platforms, etc.) and kelp beds (Love 1996; Cailliet et al. 2000; Love et al. 2002). Juveniles are secretive and often take refuge in dense algal (Ventresca 2001) and/or kelp

beds in shallow water 6 to 27 m deep (Cailliet et al. 2000). Larvae are pelagic and remain near the surface for three to four months before settling to soft or hardbottom substrate (Ventresca 1992) in waters between 5 and 30 m (Love et al. 1990). Young-of-the-year recruit to soft/hard substrata such as low-relief (<1 m) structural habitats surrounded by sand (i.e., rocky strata, worm tubes, eelgrass, and pilings) (Carr 1991; Love et al. 2002). All life stages occur in euhaline waters with salinities of 32 to 34 psu and temperatures of 6° to 20°C (MBC 1987).

Life History—Vermilion rockfish have strong site fidelity moving very little from its primary habitat type (Lea et al. 1999). It is thought that movements off reefs (two km) may be associated with following schools of prey (i.e., squid) (McCain 2003). This species is usually found aggregating near or slightly above the bottom over high-relief or artificial structures (MBC 1987).

Vermilion rockfish are ovoviviparous with internal fertilization and single broods (Love et al. 1990). Peak spawning months are September, December, and April to June off central and northern California (Ventresca 2001; Love et al. 2002).

Common Prey Species—Vermilion rockfish prey upon small fishes (northern anchovy, blue lanternfish [*Tarletonbeania crenularis*], midshipmen, rockfishes, sculpins, flatfishes), octopus, squids, pyrosomes, pelagic red crab (*Pleuroncodes planipes*), and krill (Phillips 1964; Love 1996; ODFW 2002).

- **Widow Rockfish (*Sebastes entomelas*)**

Distribution—Widow rockfish range from Albatross Bank, western Gulf of Alaska to Todos Santos Bay, northern Baja California (Miller and Lea 1972; Eschmeyer et al. 1983). They are most abundant from British Columbia to northern California (Love et al. 2002) and most common off southern Washington State and northern Oregon (MBC 1987).

Habitat Preference—Widow rockfish are common in water depths of 100 to 350 m (Love et al. 1994) over hardbottom high-relief and low-relief substrata such as rocky banks, seamounts, ridges near canyons, headlands, and muddy bottoms near rocks along the continental shelf (Squire and Smith 1977; Yoklavich et al. 2000; McCain 2003). All life stages are pelagic, with adults and older juveniles often associated with benthic habitats (Casillas et al. 1998). Adults are sublittoral to bathyal from near surface to 800 m (Eschmeyer et al. 1983; Orr et al. 1998, 2000; Love et al. 2002; Mecklenburg et al. 2002). Large juveniles occur near the bottom and inshore over depths of 9 to 37 m (Eschmeyer et al. 1983) over hard, rocky substrate but are found as deep as 140 m (Love et al. 2002). Small juveniles and larvae are neritic and epipelagic, occurring from near surface waters to 20 m depths and nearshore to 300 km offshore (McCain 2003). Young-of-the-year recruit to nearshore areas containing soft substrata and low-relief (<1 m) in association with kelp and other algae (Love et al. 2002). All life stages occur in euhaline (31 to 34 psu) waters in water temperatures of 6° to 15°C (Eschmeyer et al. 1983; MBC 1987).

Life History—Widow rockfish can be solitary, but are more often found in large schools exhibiting a range of diel behaviors (Love et al. 2002). Adults form dense, irregular, mid-water and semi-demersal schools deeper than 100 m at night and disperse in mid-water during the day (Eschmeyer et al. 1983). Similarly, juveniles inhabit rocky areas containing macroalgae during the night and the water column during the day (Love et al. 2002). Large concentrations of widow rockfishes occur off headlands (e.g., Cape Blanco, Oregon and Cape Mendocino, California) whose area characteristics include extended points of land, offshore canyons, and current circulation eddies inshore of main currents (McCain et al. 2005). These oceanographic characteristics appear to be associated with widow rockfishes during their reproductive cycle (McCain 2003). In addition, aggregations have been reported around offshore seamounts such as Cobb seamount off Oregon and Bowie seamount off British Columbia (Love et al. 2002; McCain et al. 2005).

Widow rockfish are ovoviviparous, have internal fertilization, and brood their eggs until released as larvae (Casillas et al. 1998). Reproduction occurs from December through April off central and northern California (peaking in February, respectively), January to March off Oregon, and January to April off British Columbia (Hart 1973; Love et al. 2002).

Common Prey Species—Widow rockfish prey upon small pelagic crustaceans (hyperiid and gammarid amphipods), euphausiids, midwater fishes (northern anchovy, juvenile Pacific hake, lanternfishes), salps (including pyrosomes), caridean shrimp, sergestid shrimp, and small squids (Hart 1973; Eschmeyer et al. 1983; Ralston and Lenarz 2001; Love et al. 2002).

- **Yelloweye Rockfish (*Sebastes ruberrimus*)**

Distribution—Yelloweye rockfish range from south of Umnak Island, Aleutian Islands to Ensenada, northern Baja California; they are common from central California northward to the southeastern Gulf of Alaska (Phillips 1957; Miller and Lea 1972; Hart 1973; Eschmeyer et al. 1983; Mecklenburg et al. 2002). This species is considered rare in Puget Sound (Love et al. 2002).

Habitat Preference—Yelloweye rockfish are a middle-shelf, mesobenthal species (Allen and Smith 1988) that is commonly found at depths from 91 to 180 m (Love et al. 2002) but occur in waters ranging from 15 to 549 m (Orr et al. 1998, 2000). Adults are benthic, commonly found either on or over reefs, in submarine canyons, around steep cliffs, offshore rugged pinnacles, and cobble, continuous rock, broken rock, caves, large cracks, overhangs, and boulder habitats (Eschmeyer et al. 1983; O'Connell and Funk 1987; Love 1996; Casillas et al. 1998; CDFG 2002b; McCain 2003). Young-of-the-year are found in areas of high structural relief at depths greater than 15 m (Love et al. 2002), on sponge beds in low-relief areas (Casillas et al. 1998), and on vertical walls (Love et al. 2002).

Life History—Yelloweye rockfish are solitary, found either on or just over reefs (Love 1996), however, aggregations of 30 or more adults have been noted on the Bowie Seamount, off British Columbia (Love et al. 2002). This species does not undergo diel movements (McCain et al. 2005).

Yelloweye rockfish are ovoviviparous and a spring/summer spawner releasing young from March to July off California, in June off Washington State, and April to September (peaking in May and June) off British Columbia (Love et al. 2002).

Common Prey Species—Yelloweye rockfish prey upon fish (rockfish, cods, sand lances, herrings, lumpsuckers), crustaceans (caridean shrimp, lithodid crab), green sea urchin, and gastropods (Love 1996; McCain 2003). Off Oregon, this species preys upon cancroid crabs, cottids, righteye flounders, rockfish, and pandalid shrimp (McCain et al. 2005).

- **Yellowmouth rockfish (*Sebastes reedi*)**

Distribution—Yellowmouth rockfish range from Sitka, southeastern Gulf of Alaska to near San Francisco, northern California; but occur most commonly between southeast Alaska and Oregon (Love et al. 2002; Love et al. 2005).

Habitat Preference—Yellowmouth rockfish occupy a depth range from 141 to 366 m, usually 180 to 275 m over rocky shelf on the continental slope/basin (Eschmeyer et al. 1983; NMFS et al. 1998; Love et al. 2005). Pelagic juveniles are collected off Oregon (Love et al. 2002).

Life History—Information is unavailable on migrations and movements of the yellowmouth rockfish (McCain et al. 2005). Adults have been reported to aggregate in midwater over high-relief rocks (Love et al. 2002).

Off Oregon, yellowmouth rockfish release their young from February through June (Kendall and Lenarz 1987).

Common Prey Species—Information is unavailable on the prey of the yellowmouth rockfish (McCain et al. 2005).

- **Yellowtail Rockfish (*Sebastes flavidus*)**

Distribution—Yellowtail rockfish range from eastern Aleutian Islands south of Unalaska Island, Alaska to Isla San Martin, northern Baja California (Miller and Lea 1972; Love 1996; Love et al. 2002; Love et al. 2005). Their abundance center is from southeast Alaska to central California with the highest concentrations occurring off Washington State and Oregon in Astoria Canyon near the mouth of the Columbia River (Ralston 2001; Love et al. 2002). Yellowtail rockfish are more abundant in northern than central Puget Sound (McCain 2003).

Habitat Preference—Yellowtail rockfish, a middle–shelf mesobenthal species, commonly occurs at water depths between 50 and 250 m with an overall depth range from the surface to 549 m (Allen and Smith 1988; Orr et al. 1998, 2000; Love et al. 2002). This species is part of the shelf rockfish assemblage that includes Pacific ocean perch, bocaccio, chilipepper, and canary, silvergray, black, and widow rockfishes (Love 1996). From Washington State to northern California, a canary-yellowtail-silvergray assemblage characterizes the area from Cape Flattery, Washington State to Cape Blanco, Oregon and a yellowtail-stripetail assemblage from Cape Blanco to Cape Mendocino region in 91 to 181 m water zone (McCain et al. 2005).

Adults are semi-pelagic or pelagic (Love 1996) occurring along steep walls and cliffs, above rocky reefs (Hart 1973; Casillas et al. 1998), over mud substrates with cobble, boulder, and rock ridges, and in sand habitats (Love 1996). Off Heceta Bank (Oregon), they inhabit ridges and boulders, vase sponges, and brittle stars (McCain et al. 2005). Pelagic juveniles occur from 24 to 266 km offshore, whereas benthic juveniles are found nearshore in 20 to 37 m (Casillas et al. 1998), usually in rocky areas with giant or bull kelp (Love et al. 2002).

Life History—Yellowtail rockfish form large mid-water schools (>1,000 fish), singly or in association with black, copper, dusky, Puget Sound, silvergray, and widow rockfishes in northern waters and with canary and vermilion rockfish off California (Ralston 2001; Love et al. 2002). Adults exhibit strong site fidelity and homing abilities (Love 1996). Stanley et al. (1999) and others have reported that yellowtail rockfish exhibit diurnal vertical migrations in behavior associated with feeding on vertically migrating prey. Young-of-the-year commonly school with olive rockfish in nearshore kelp forests (Lea et al. 1999). This species is capable of making long distance movements from 158 to 1,000 km (Starr et al. 1998; Lea et al. 1999).

Yellowtail rockfish are viviparous (McCain 2003). Along the west coast, months of larval release occur from January to July off northern/central California with February or March peaks, February off Oregon, and January to April in British Columbia waters (Love et al. 2002).

Common Prey Species—Yellowtail rockfish prey upon fish (small hake, Pacific herring, smelt, anchovies, lanternfish), squid, mysids and other planktonic organisms (euphausiids, salps, pyrosomes) (Love 1996; McCain 2003).

Thornyhead

- **Longspine Thornyhead (*Sebastolobus altrivelis*)**

Distribution—Longspine thornyhead range from Cabo San Lucas, southern Baja California to Shumagin Islands, western Gulf of Alaska (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996; Love et al. 2005) but are abundant from southern California northward (Love 1996).

Habitat Preference—Longspine thornyhead are found in relatively deep water ranging from 201 to 1,756 m (Orr et al. 2000; Love et al. 2002), but most typically between 600 and 1,000 m in the OMZ (Eschmeyer et al. 1983; Wakefield and Smith 1990; Love et al. 2002). They inhabit softbottoms, preferably sand or muddy areas (Eschmeyer et al. 1983; Love 1996) associated with rocks and sponges (Love et al. 2002), or on seamounts (Casillas et al. 1998). Longspine thornyheads spend their entire benthic adult and large juvenile and part of their pelagic larval phases in the OMZ (McCain 2003). Adults and juveniles are demersal and occupy the sediment surface at depths from 400 to 1,400 m (Casillas et al. 1998). Small juveniles and larvae are pelagic for 18 to 20 months before utilizing benthic habitats (McCain 2003). Juveniles settle on the continental slope at midwater depths, approximately 600 to 1,200 m (Casillas et al. 1998). Longspine thornyhead larvae have been collected up to 560 km off the California coast, but mostly more than 32 km offshore (Cross 1987).

Life History—Longspine thornyhead neither schools, aggregates, nor exhibits any ontogenetic migration pattern (McCain 2003). However, Wakefield and Smith (1990) reported that this species displays ontogenetic migration when the eggs from the bathyal bottom rise to the surface and juveniles return to the bottom.

Longspine thornyhead are oviparous and multiple spawners, spawning two to four batches per seasons (Wakefield and Smith 1990; Love 1996). Off California, longspine thornyhead spawn from about January to May and off Oregon, during March and April continuing into May (Love et al. 2002; Pearson and Gunderson 2003). This species is also a determined spawner in that all of the eggs spawned are developed at the same time and released at one spawning event (Love et al. 2002). Spawning occurs at depths of 600 to 1,000 m (Wakefield and Smith 1990), with gelatinous egg masses that are released and float into the surface waters, from March to May (Wakefield and Smith 1990). The egg masses undergo rapid development to a feeding larval stage. Approximately 90% of the spawning populations reside in “a stratum bounded by the 500 and 1,100 m isobaths” (Wakefield and Smith 1990).

Common Prey Species—Longspine thornyhead prey upon fish fragments, crustaceans, bivalves, and polychaetes (Love 1996).

- **Shortspine Thornyhead (*Sebastolobus alascanus*)**

Distribution—Shortspine thornyhead range from Seas of Okhotsk and Japan to Bering Sea off Kamchatka (Love et al. 2005) and to Navarin Canyon and Aleutian Islands to Boca de Santo Domingo, southern Baja California (Casillas et al. 1998; Love 1996; Mecklenburg et al. 2002). They are most abundant off central California to the northern Kuril Islands (NMFS-NWR 2004c).

Habitat Preference—Shortspine thornyhead inhabit areas over the continental shelf and slope (Wakefield and Smith 1990) forming a deep-water assemblage, along with Pacific ocean perch and darkblotched, splitnose, redbanded, and rougheye rockfishes (Casillas et al. 1998). Although they can occur at depths as shallow as 17 m (Love et al. 2002) and as deep as 1,524 m (Orr et al. 1998, 2000), shortspine thornyhead are commonly found between depths of 100 and 850 m (Casillas et al. 1998). Adults are demersal and are most often found over mud bottoms, near cobblestones, pebbles, sponges, and sea urchins (e.g., Heceta Bank) (Love et al. 2002). Juveniles occupy shallower waters than adults (Love 1996) at depths between 100 and 600 m (Jacobson et al. 2001) over muddy bottoms near rocks (Love et al. 2002). They spend 14 to 15 months in midwater before transforming to a benthic stage (Owen and Jacobson 1992). Recently settled and adult individuals are more abundant at the deep end of their range than the shallow end, while mid-sized individuals are more abundant at the shallow end (McCain 2003). Cross (1987) suggested that juveniles recruit to the bottom regardless of depth. Larvae are pelagic for 12 to 15 months and have been collected up to 560 km off the California coast (Cross 1987; McCain 2003).

Life History— Early life history stages of the shortspine thornyhead are likely widely transported, primarily via the Alaskan Gyre system and the California Current (Stepien et al. 2000) and possibly transported northward by the California Counter Current (McCain 2003). During January to June, juveniles undergo ontogenetic migration settling onto the continental shelf and then move into deeper water as they become adults (Casillas et al. 1998). Ontogenetic migration transports particulate organic carbon from the bottom to the surface by the eggs and particulate organic matter is moved from the surface back down to the bottom as recruiting juveniles (Wakefield and Smith 1990).

Shortspine thornyhead are thought to be oviparous and single spawners in OMZ at depths between 600 to 1,000 m (Love 1996). Spawned bi-lobed, gelatinous hollow egg masses rise to the surface between December and May off the west coast to develop and hatch (Wakefield and Smith 1990; Pearson and Gunderson 2003). Larvae are much more common north of Point Conception, California (Love 1996).

Common Prey Species—Shortspine thornyhead prey upon small crustaceans (shrimp, crabs, amphipods), worms, and fishes including shortspine and longspine thornyheads (Owen and Jacobson 1992; Barnes et al. 2001).

Roundfish

- **Sculpins (Cottidae)**

  - **Cabezon (*Scorpaenichthys marmoratus*)**

Distribution—Cabezon range from southeast Alaska near Sitka to Punta Abreojos, central Baja California (O'Connell 1953; Miller and Lea 1972; Hart 1973). They are abundant from Washington State to southern California (Love 1996). Northern and southern substocks exist off California (Cope and Punt 2005).

Habitat Preference—Cabezon is abundant year round in estuarine and subtidal areas and to mid-depths (110 m) along the continental shelf (Miller and Lea 1972; Love 1996). They are found intertidally or in shallow, subtidal areas in the vicinity of kelp beds, jetties, isolated rocky reefs or pinnacles, and in shallow tide pools (Wilson-Vandenberg 1992). Rocky bottoms and cobble substrates are utilized most frequently along with eelgrass beds and occasionally sandy bottoms (O'Connell 1953). Off California, cabezon are found in moderate to high abundance in the waters along the inner shelf (CDFG 2002b); whereas they only infrequently occur at depths over 50 m off Washington State and Oregon (McCain et al. 2005). Cabezon is a member of a nearshore assemblage of 19 fishes including several *Sebastes* species that are included in California's nearshore FMP (CDFG 2002b).

Adults and large juveniles are demersal (O'Connell 1953), residing primarily in shallow water bays and estuarine areas (Hart 1973). Adults tend to move to deeper waters (>9 m) with increased size (O'Connell 1953). Small juveniles and larvae are pelagic and planktivorous with neustonic planktivorous larvae being carried offshore (>322 km) by oceanic currents (O'Connell 1953). In California, juveniles first appear in kelp canopies, tidepools, and other shallow rocky habitats, such as breakwaters from April to June (O'Connell 1953; Quast 1968b). Larvae and eggs are found in estuaries from winter through spring (Casillas et al. 1998).

Life History—Cabezon are not known to make any significant migrations and are considered to be sedentary (Miller and Geibel 1973). They are known to move inshore with a flood tide and retreat offshore on an ebb tide to feed (O'Connell 1953; Miller and Geibel 1973). Cabezon spend most of their time sitting in holes on reefs, in pools, or on kelp blades beneath the canopy but do not actively swim (Wilson-Vandenberg 1992).

Spawning is protracted with a seasonal progression that begins off California in winter and proceeds northward to Washington State by spring (O'Connell 1953). Off California, spawning takes place from late October to March, peaking in January and February, while in Puget Sound, spawning season begins in November and extends into September, peaking in March and April (Wilson-Vandenberg and Hardy 2001; NMFS 2004c). Egg masses are fertilized externally. Cabezon spawn more than once per year but absolute fecundity is not known. It has been reported that cabezon spawn their eggs on subtidal, algae-free rocky surfaces in estuaries, which can be horizontal or vertical in orientation (Wilson-Vandenberg 1992). Cabezon spawn in the recesses of natural and man-made objects with males exhibit nest-guarding behavior (Garrison and Miller 1982).

Common Prey Species—Cabezon prey upon crabs, small lobsters, mollusks (abalone, squid, octopus), small fish (including rockfishes), and fish eggs (Quast 1968b; Love 1996).

- **Greenlings (Hexagrammidae)**

  - **Kelp Greenling (*Hexagrammos decagrammus*)**

Distribution—Kelp greenling range from Attu Island, Aleutian Islands and Gulf of Alaska coasts (Mecklenburg et al. 2002) to La Jolla, southern California (Hart 1973; Kendall and Vinter 1984; Love 1996), but are common north of Morro Bay, central California (Mecklenburg et al. 2002).

Habitat Preference—Kelp greenling are abundant in coastal waters and inland seas (i.e., Puget Sound, Washington) (Hart 1973) from the intertidal zone to 130 m (Love et al. 2005). They inhabit rocky reefs of shallow nearshore areas near dense algae or kelp beds (Hart 1973; Kendall and Vinter 1984; Love 1996). Adults, spawning adults, and large juveniles are demersal (Casillas et al. 1998). Adults are not commonly found below 20 m (Love 1996), although they may range down to depths of 52 m (Howard 1992). In Puget Sound, females are most abundant between 7 and 12 m with males preferring water three m deep (Garrison and Miller 1982). Juveniles are commonly associated with rocky reefs and macroalgae (CDFG 2002b). Small juveniles and larvae are pelagic occurring in the upper 45 m of the water column in spring and summer (Kendall and Vinter 1984). They have been reported up to 965 km offshore from northern California northward (Casillas et al. 1998). Eggs are demersal and found subtidally (Garrison and Miller 1982). Adults, spawning adults, large juveniles, and eggs prefer water temperatures between 9° and 13°C and favorable salinities of 27.5 to 29.9 psu (Patten 1980).

Life History—Kelp greenling are not a migratory species. Most adults inhabit depths of 13 m or less all year round, which inhibits their migration (McCain et al. 2005). However, newly hatched larval migration may take up to a year when they move out of estuaries or shallow nearshore areas and into open waters (Garrison and Miller 1982).

Kelp greenling are oviparous with external fertilization (Casillas et al. 1998). Spawning occurs in Puget Sound in the fall peaking in October and November, and in California in late fall to early winter (Garrison and Miller 1982; Howard and Silberberg 2001).

Common Prey Species—Kelp greenling prey upon ascidians, shrimp, crabs, worms, octopus, brittle stars, snails, and small fishes (Howard 1992; Love 1996; Howard and Silberberg 2001).

  - **Lingcod (*Opdiodon elongatus*)**

Distribution—Lingcod range from Punta San Carlos, northern Baja California to Shumagin Islands, southeastern Gulf of Alaska (Love et al. 2005). Highest densities occur from Point Conception, California to Cape Spencer, Alaska (Miller and Lea 1972, Mecklenburg et al. 2002) with their center of abundance off British Columbia (Starr et al. 1998; Adams and Starr 2001).

Habitat Preference—Lingcod occupy the estuarine-mesobenthal zone occurring from the intertidal zone to 475 m, but most commonly are found between 100 and 150 m over a wide range of substrates (Allen and Smith 1988). Adults, spawning adults, and eggs are common in Puget Sound, Hood Canal, and Skagit Bay in Washington State and Humboldt Bay in northern California. Juveniles are common in most large estuaries between Puget Sound and San Pedro Bay, California. Larvae are common in most Washington State estuaries as well as Coos Bay, Oregon and throughout San Francisco Bay in central California (Emmett et al. 1991).

Adults, older juveniles, young larvae, and eggs are demersal (Allen and Smith 1988; Shaw and Hassler 1989). Two main habitats are preferred by adults: slopes of submerged banks (e.g., Heceta Bank) 10 to 70 m below the surface with seaweed, kelp, and eelgrass beds that form feeding grounds for small prey fish, and channels with swift currents that flow around rocky reefs that concentrate plankton and plankton-feeding fish (Shaw and Hassler 1989; Emmett et al. 1991; Love 1996). Older larvae and very young juveniles are epipelagic, primarily found in the upper three m of the water column (Adams and Hardwick 1992) in waters greater than 150 m deep. Off California, pelagic juveniles occur in the upper 35 m of surface waters (Casillas et al. 1998) and prefer sandy and rocky substrates in subtidal zones and estuaries (Hart 1973; Shaw and Hassler 1989; Emmett et al. 1991; CDFG 2002b). Larvae and eggs occur in nearshore areas from winter through late spring. Egg masses are found in rocky reefs/ledges where they are wedged in rock crevices or under overhanging boulders allowing water currents of 3.5 killometers per hour (km/hr) or greater to maintain their interstitial oxygen levels (Hart 1973; Miller and Geibel 1973; Adams and Hardwick 1992). All life history stages occur in polyhaline to euhaline waters (18 to 30+ psu) that have temperatures between 5° to 15°C, although juveniles may also be found in mesohaline waters (5 to 18 psu) (Simenstad 1983; Shaw and Hassler 1989; Emmett et al. 1991).

Life History—Lingcod are considered a relatively sedentary species, living their whole lives associated with a single rock reef, possibly out of fidelity to a prime spawning or feeding area (Allen and Smith 1988; Shaw and Hassler 1989). Migrations greater than 100 km have been reported but were typically undertaken by sexually immature fish (Smith et al. 1990). Larvae are carried by tidal currents into rearing areas within estuaries undergoing metamorphosis in early summer, while juveniles rear until winter before moving to deeper waters (Miller and Geibel 1973) Mature females live in deeper water than males and move from deep water to shallow water in the winter to spawn (Hart 1973; Casillas et al. 1998).

Lingcod are oviparous, iteroparous, and gonochoristic with external fertilization (Shaw and Hassler 1989; Emmett et al. 1991). Spawning takes place from December through April in waters 3 to 10 m below mean lower low water (MLLW) (lowest tide) over rocky reefs in areas of swift current (Adams and Hardwick 1992). For the Humboldt Bay, California stock, peak spawning is January through February; Yaquina Bay, Oregon stock, late January to early March; and Washington State's Puget Sound, Hood Canal, and Skagit Bay stocks, February to March (Garrison and Miller 1982; McCain et al. 2005). Eggs masses are laid in rock crevices or on rocky reefs (Hart 1973). Males guard the nest until hatching, usually about six weeks (Shaw and Hassler 1989).

Common Prey Species—Lingcod prey upon demersal fishes (spiny dogfish, Pacific herring, walleye pollock (*Theregra chalcogramma*), rockfishes, greenlings, small lingcods, and Pacific sand lance, squids, octopus, and crabs (Hart 1973; Miller and Geibel 1973; Garrison and Miller 1982; Shaw and Hassler 1989).

- **Cods (Gadidae)**

  - **Pacific Cod (*Gadus macrocephalus*)**

Distribution—Pacific cod range from Yellow Sea off Manchuria, China, east to the Bering Sea, Aleutian Islands, and Gulf of Alaska, and south to Santa Monica, southern California (Miller and Lea 1972; Hart 1973; Allen and Smith 1988; Love 1996).

Pacific cod in Puget Sound are generally categorized into three components: (1) North Sound: located in U.S. waters north of Deception Pass, including the San Juan Islands, Strait of Georgia, and Bellingham Bay; (2) West Sound: located west of Admiralty Inlet and Whidbey Island and in the U.S. section of the Strait of Juan de Fuca, including Port Townsend; and (3) South Sound: located south of Admiralty Inlet (Stout et al. 2001).

Habitat Preference—Pacific cod, a member of the inner shelf-mesobenthal community, is found near surface to a depth of 875 m (Allen and Smith 1988), with the vast majority occurring between 50 and 300 m depths (Hart 1973; Allen and Smith 1988; Love 1996). Pacific cods are inhabitants of shallow, softbottom habitats in marine and estuarine environments (Garrison and Miller 1982). All life stages occur in the various bays in Puget Sound and the Strait of Juan de Fuca near Vancouver Island (Garrison and Miller 1982).

Adults and large juveniles are parademersal preferring mud, sand, and clay, as well as coarse sand and gravel substrates (Garrison and Miller 1982). Small juveniles and larvae are pelagic (McCain 2003). Small juveniles usually settle between 60 and 150 m depth, gradually moving into deeper water with increased age; whereas larvae are found in the upper 45 m of the water column with the highest abundance occurring between 15 and 30 m (Casillas et al. 1998). Larvae and eggs are found over the continental shelf between Washington State and central California from winter through summer (McCain 2003). Adults are found in marine waters, whereas juveniles occur in polyhaline to euhaline waters (McCain et al. 2005). Eggs are demersal, adhesive, and occur sublittorally in polyhaline to euhaline waters at temperatures between 1° and 10°C (Hart 1973).

Life History—Typically not considered a migratory species, Pacific cod have been known to move more than 1,000 km (Casillas et al. 1998). Genetic analysis indicates two spawning stocks exist in North America: a seasonal bathymetric movement from deep spawning areas of the outer shelf and upper slope in fall and winter to shallow middle-upper shelf feeding grounds in the spring (Hart 1973; Casillas et al. 1998). Larvae may be transported by tidal currents to nursery areas (Casillas et al. 1998). There is also some evidence to suggest that the fish move into deeper water with age (Hart 1973), although adults are not found exclusively in deeper water (McCain 2003).

Pacific cod are oviparous with external fertilization (Hart 1973). Spawning typically occurs at depths between 40 to 265 m from late fall to early spring in Puget Sound (Garrison and Miller 1982) and in winter through spring in the Gulf of Alaska and the Bering Sea (McCain 2003). No spawning occurs below 0°C or above 10° to 13°C, speculating that eggs may experience high mortality or decreased development (Casillas et al. 1998).

Common Prey Species—Pacific cod prey upon various organisms depending on its size: shrimp, mysids, and amphipods (2 to 40 cm), crabs and amphipods (40 to 50 cm), Pacific sand lance (50 to 70 cm), and walleye pollock (70+ cm) (Allen and Smith 1988; McCain 2003).

- **Morid Cods (Moridae)**

  - **Pacific Flatnose (*Antimora microlepis*)**

Distribution—Pacific flatnose (formerly known as finescale codling) (Nelson et al. 2004) range from off southern Japan to Sea of Okhotsk, to Bering Sea and Gulf of Alaska, and south to Gulf of California (Allen and Smith 1988).

Habitat Preference—Pacific flatnose are mesobenthal-bathybenthal over the continental slope with a reported depth range of 175 to 3,048 m (Allen and Smith 1988). This species has been caught at depths up to 1,275 m, most often on the bathybenthal slope between 800 and 850 m (Allen and Smith 1988).

Life History—Information is unavailable on the migrations and movements of the Pacific flatnose (McCain 2003).

Sexes apparently segregate by depth with males occurring in shallower waters and females in deeper waters (McCain et al. 2005)

Common Prey Species—Pacific flatnose prey upon benthic macrofauna, especially crustaceans, squid, and fish (McCain et al. 2005).

- **Grenadiers (Macrouridae)**

  - **Pacific Grenadier (*Coryphaenoides acroplepis*)**

Distribution—Pacific grenadiers (formerly known as Pacific rattail) (Eschmeyer et al. 1983) range from the Sea of Okhotsk off Japan to the southern Bering Sea and Aleutian Islands to Isla Guadalupe, central Baja California (Hart 1973; Mecklenburg et al. 2002).

Habitat Preference—Grenadiers are among the most abundant fish of the continental slope and abyssal waters worldwide (Matsui and Kato 1990). They are benthopelagic and bathypelagic species that have been reported as shallow as 35 and 155 m and as deep as 2,825 m (Love et al. 2005), These species commonly occur between 600 and 2,500 m off Oregon and Washington State in the northeast Pacific Ocean on sandy bottoms of the abyssal plain (Hart 1973; Mecklenburg et al. 2002). Specific habitat associations are unavailable for any life history stage of the Pacific grenadier (McCain et al. 2005).

Life History—Migrations have not been documented and it is assumed that the Pacific grenadier is a relatively sedentary species (McCain 2003). Older larvae and juveniles occur deeper suggesting a movement with increasing size, whereas larval stages have been captured in the water column at depths less than 200 m (Casillas et al. 1998).

Pacific grenadiers are oviparous with external fertilization (Casillas et al. 1998). In more northern areas, ripe females have been collected in September, October, and April implying the possibility of two spawning seasons per year (Iwamoto 1992; McCain et al. 2005). Off southern California, spawning occurs mostly from late winter to early spring, although spent females are found throughout the year (Iwamoto 1992). Spawning depth is unavailable on the Pacific grenadier (Iwamoto 1992).

Common Prey Species—Pacific grenadier prey upon cephalopods, other demersal fishes (i.e., other macrourids), and sinking food particles of dead nekton (Iwamoto 1992; McCain 2003).

- **Merlucciid Hakes (Merlucciidae)**

  - **Pacific Hake (*Merluccius productus*)**

Distribution—Pacific hake or Pacific whiting, of the coastal stock, range from Attu Island in the western Gulf of Alaska to Magdalena Bay, southern Baja California (Mecklenburg et al. 2002) but are most abundant in the CCS between Baja California and British Columbia (Hart 1973; Love 1996). In addition to the coastal stock, there are three much smaller stocks with reduced ranges: Puget Sound, Washington State; Strait of Georgia, British Columbia; and a dwarf stock limited to waters off Baja California (Bailey et al. 1982).

Habitat Preference—Coastal stock of Pacific hake inhabits the continental slope and shelf within the CCS (Quirollo 1992; Mecklenburg et al. 2002). Currently, the coastal stock utilizes three habitats: (1) a narrow 30,000 square kilometers (km^2) feeding habitat near the shelf break of British Columbia, Washington State, Oregon and California populated six to eight months per year; (2) a broad 300,000 km^2 open-sea area of California and Baja California populated by

spawning adults in the winter and embryos and larvae for four to six months a year; and (3) a continental shelf area of unknown size off California and Baja California, where juveniles brood (P.E. Smith 1995).

Adults, juveniles, larvae, and eggs are pelagic (MBC 1987) ranging in depths from 12 to 1,400 m (Love et al. 2005). Adults are epipelagic-mesopelagic (Sumida and Moser 1980) occurring as deep as 920 m with highest densities between 50 and 500 m and as far offshore as 400 km (Hart 1973; Bailey et al. 1982; Dark and Wilkins 1994; Dorn 1995). Juveniles reside in shallow coastal waters, bays, and estuaries at depths less than 200 m (Bailey et al. 1982; P.E. Smith 1995); are less abundant in upwelled nearshore coastal waters compared to non-upwelled water (Sakuma and Ralston 1995); and have their highest densities in submarine canyons at depths of 150 to 200 m (McCain 2003). Larvae of 8 to 12 mm are found at 100 to 300 m, whereas those greater than 12 mm occur primarily below 200 m (Bailey et al. 1982). Abundance and distribution of hake larvae are strongly influenced by prevailing currents (Horne and Smith 1997) and aggregate near the base of the thermocline or mixed layer of low-salinity water on top on well-mixed marine waters (McCain 2003). The majority of eggs occur at depths ranging between 50 to 150 m (i.e., early-stage eggs: 75 to 150 m and later-stage eggs: 50 to 100 m) (Moser et al. 1997). All life stages are found in water with salinities of 29.3 to 33.6 psu and temperatures from 9° to 17°C (Garrison and Miller 1982; MBC 1987).

Life History—Pacific hake are highly migratory moving between the nearshore shelf, shelf break, and slope (McCain et al. 2005). In April, the coastal stocks undertake extensive annual migrations from offshore spawning areas in Baja California (Saunders and McFarlane 1997), moving inshore, following food supply and Davidson Current to summer feeding grounds off northern California, Oregon, and Washington State, and Vancouver Island, British Columbia (Quirollo 1992). By late summer or fall, Pacific hake move offshore from their feeding grounds and undergo a southern migration to their spawning grounds utilizing the southward flowing California Current (Bailey et al. 1982; Dorn 1995; P.E. Smith 1995). Stocks in the Strait of Georgia and Puget Sound undergo similar migration patterns, but on a greatly reduced scale (McCain et al. 2005).

During the summer, Pacific hake form extensive midwater aggregations (22 km long x 14 km wide) near the continental shelf break, with highest densities located over bottom depths of 200 to 300 m (Quirollo 1992). Pacific hakes school at depth during the day, then move to the surface and disband at night for feeding (Sumida and Moser 1984).

Pacific hake are oviparous, pelagic spawners with external fertilization, spawning at least once per season (Casillas et al. 1998). The coastal stock (Magdalena Bay, Baja California to Cape Mendocino, California) spawns from December through March, peaking in late January (P.E. Smith 1995). Spawning aggregations begin a month prior to gamete release, with spawning occurring at depths between 130 and 500 m (Bailey et al. 1982; P.E. Smith 1995).

The interior Pacific hake stocks spawn and live their entire lives within Puget Sound (Quirollo 1992). Spawning in the Strait of Georgia occurs from March through May, peaking in late April, and in Puget Sound, from February through April, peaking in March (McCain et al. 2005). In both areas, spawning occurs in locations proximate to major sources of freshwater inflow near the Frazier River in the Strait of Georgia and near the Skagit and Snohomish rivers in Port Susan (McCain et al. 2005).

Common Prey Species—Pacific hake prey upon euphausiids, amphipods, squid, pandalid shrimp, smelt, crabs, and occasionally on Pacific hake and pelagic schooling fish (eulachon and herring) (Bailey et al. 1982; Dark and Wilkins 1994). The diet of the Pacific hake varies with latitude (i.e., northern anchovy and rockfish in central California and Pacific herring off Vancouver Island, British Columbia, Washington State, and Oregon) and season (i.e., euphausiids off Oregon and Washington State in the summer compared to fish and shrimp in the autumn, and fish in the spring compared with a dominance of cannibalized Pacific hake in the autumn off California) (Buckley and Livingston 1997).

- **Sablefish (Anoplopomatidae)**

  - **Sablefish (*Anoplopoma fimbria*)**

    Distribution—Sablefish range from off central Honshu, Japan, to Aleutian Islands and Bower Banks to Bering Sea, south of St Lawrence Island, Alaska, and southeast to Cedros Island, central Baja California. This species is uncommon south of Point Conception, California, and most abundant in the Gulf of Alaska (Hart 1973; McFarlane and Beamish 1983a, 1983b; MBC 1987; Love 1996).

    There are at least three genetically distinct stocks: (1) south of Monterey Bay characterized by slower growth rates and smaller average size; (2) northern California to Washington State that is characterized by moderate growth rates and sizes; and (3) off British Columbia and Gulf of Alaska characterized by fast growth rates and larger sizes. Only the northern California to Washington State stock occurs within the Pacific Northwest OPAREA and Puget Sound Study Area (Schirripa and Colbert 2005).

    Habitat Preference—Sablefish is an inner shelf-bathybenthal species that is found over soft substrates in deep marine waters (Love 1996). Adults and larger juveniles are benthopelagic (Hart 1973). Adults occur as deep as 2,740 m but are most abundant at depths between 200 and 1,200 m; whereas juveniles are rarely found at depths less than 200 m (Mason et al. 1983; Love 1996; Jacobson et al. 2001). Adults and large juveniles form schools over sand and mud (McFarlane and Beamish 1983a), occur on hard-packed mud and clay bottoms in the vicinity of submarine canyons (MBC 1987), and are associated with seamounts (e.g., Heceta Bank) consisting of mud and sea urchins (*Allocentrotus*) (McCain 2003). Small juveniles, larvae, and eggs are pelagic (Hart 1973). Small juveniles inhabit the upper 100 m of the water column (MBC 1987) and newly hatched larvae and eggs usually occur deeper than 300 m (Hart 1973). Small juveniles and larvae are found up to 370 km offshore, often near drifting kelp (McCain 2003). The distribution of larvae in the water column is strongly influenced by the onset of upwelling conditions (McFarlane et al. 1997). All life stages occur in euhaline waters at temperatures of 2.9° to 21.0°C: adults/large juveniles - 2.9° to 6.5°C; small juveniles - 11.7° to 16.5°C; larvae - 5.6° to 16.5°C; and eggs - 3.8° to 6.5°C (Mason et al. 1983; MBC 1987).

    Life History—Sablefish are a non-migratory species, although some individuals have been recorded moving up to 2,735 km to mid-ocean seamounts (Love 1996). Sexually mature adults do not undergo any spawning migration (Hart 1973; Mason et al. 1983; McFarlane and Beamish 1983a). Small juveniles descend to the bottom during the fall and remain in relatively shallow water for about a year before moving into deeper water (MBC 1987). Sablefish seem to have a deeper, lower limit to their distribution off the west coast as compared with their distribution off Alaska (McCain 2003). Hart (1973) recognized localized movement from shallow summer waters to deeper waters in the winter.

    Sablefish are batch spawners and oviparous with external fertilization (Love 1996; Casillas et al. 1998). Spawning occurs annually in waters deeper than 300 m along the continental slope (Hart 1973) from late fall through winter but varies with latitude (Monterey Bay in central California: November to February and Canadian Pacific coast: January through April, peaking in February) (Mason et al. 1983; MBC 1987). The peak spawning biomass of sablefish is located within the deep waters of the OMZ (Casillas et al. 1998). The ontogenetic movement of sablefish into deep water to spawn is more strongly correlated with age than with size (Schirripa and Colbert 2005).

    Common Prey Species—Sablefish prey upon fishes (i.e., rockfishes, northern anchovy, Pacific herring, shrimp, crabs, and octopus, but their predominant prey organism is euphausiids (Hart 1973; McFarlane and Beamish 1983a; McCain 2003).

Skates, Sharks, and Chimaeras

- **Skates (Rajidae)**

  - **Big Skate (*Raja binoculata*)**

    Distribution—Big skate range from Bering Sea and Aleutian Islands, at least as far west as Unalaska Island, to eastern Gulf of Alaska south to Cabo Falsa, southern Baja California, and Gulf of California (Love et al. 2005). They are uncommon south of Point Conception, California but relatively abundant in northern and central California (Roedel and Ripley 1950; Allen and Smith 1988; Ebert 2003; NMFS-NWR 2004c; FLMNH[9]).

    Habitat Preference—Big skate occupies inner and outer shelf areas (Allen and Smith 1988) at depths up to 800 m. They inhabit inner shelf waters as shallow as two m or less in bays but are found most frequently on the outer shelf in waters 50 to 200 m deep (Allen and Smith 1988). Big skates have also been associated with silty sediment or with sediment consisting of a mixture of mud, sand, gravel, and cobble as well as in habitats (e.g., Heceta Bank) consisting of mud and sea urchins (*Allocentrotus*; McCain et al. 2005). Juveniles are associated with softbottom sediments (CDFG 2002b).

    Life History—Information is unavailable on the migrations and movements of the big skate (McCain et al. 2005).

    Big skates are oviparous with fertilized internal eggs that are deposited on the bottom to hatch and develop (Casillas et al. 1998). Eggs are covered with a thick leathery membrane (case) and can measure up to 30 cm in length (Eschmeyer et al. 1983). Egg cases are laid year round or possibly seasonal, containing up to seven eggs per case with an average of three to four (Eschmeyer et al. 1983; McCain 2003).

    Common Prey Species—Big skates prey upon crustaceans, small benthic fishes, polychaete worms, and mollusks (Hart 1973; Eschmeyer et al. 1983; Ebert 2003).

  - **California Skate (*Raja inornata*)**

    Distribution—California skate range from the Strait of Juan de Fuca, Canada to Cedros Island, central Baja California and the Gulf of California (Roedel and Ripley 1950; Ebert 2003). This species is common off most of the California coast (Roedel and Ripley 1950).

    Habitat Preference—California skate occur inshore and in shallow bays (13 m) (Eschmeyer et al. 1983). This species has been caught as deep as 1,600 m (Eschmeyer et al. 1983) but typically inhabits a depth range of 17 to 671 m (Ebert 2003). Adults and juveniles inhabit inshore soft muddy bottoms sediments (Roedel and Ripley 1950; CDFG 2002b) and habitats (e.g., Heceta Bank) consisting of mud and sea urchins (*Allocentrotus*) (McCain et al. 2005).

    Life History—Information is unavailable on the migrations and movements of the California skate (McCain et al. 2005).

    California skates are oviparous, have internal fertilization, and deposit their eggs on the bottom to develop and hatch (Casillas et al. 1998). Eggs are encased in a distinctive smooth-surfaced leathery case with horns (Roedel and Ripley 1950; Eschmeyer et al. 1983). Upon hatching, the young are fully developed, although they do have a yolk sac that is gradually absorbed (Casillas et al. 1998).

    Common Prey Species—California skate feeds on shrimp and other invertebrates such as polychaete worms (Ebert 2003).

- **Longnose Skate (*Raja rhina*)**

  Distribution—Longnose skate range from southeastern Bering Sea to just below Punta San Juanico, southern Baja California and the Gulf of California (Allen and Smith 1988; Ebert 2003).

  Habitat Preference—Longnose skate is one of the more common skates (Roedel and Ripley 1950) occurring on the bottom of the inner and outer shelf areas from 9 to 1,069 m depths (Ebert 2003). It is most commonly found at depths ranging from 100 to 150 m (Allen and Smith 1988). Adults and juveniles are typically associated with softbottom sediments and with combinations of mud and cobble near high-relief structures (CDFG 2002b; Ebert 2003).

  Life History—Information is unavailable on the migrations and movements of the longnose skate (McCain et al. 2005).

  Longnose skates are oviparous with internal fertilization depositing their eggs on the bottom to develop and hatch.[7] Eggs are laid in an enclosed rough, leathery shell with a loose covering of fibers and short horns (Eschmeyer et al. 1983). The egg cases generally contain one egg per case (Roedel and Ripley 1950; Hart 1973). The young are fully developed when the eggs hatch, although they do contain a yolk sac that is gradually absorbed (Casillas et al. 1998).

  Common Prey Species—Longnose skates less than 60 cm prey upon crustaceans and those greater than 60 cm prey upon bony fishes (Ebert 2003).

♦ **Requiem Sharks (Carcharhinidae)**

- **Leopard Shark (*Triakis semifasciata*)**

  Distribution—Leopard shark range from southern Oregon to Mazatlan, Mexico, including the Gulf of California (Eschmeyer et al. 1983; Ebert 2003; FLMNH[9]). This species is most abundant in northern California bays and estuaries and along southern California beaches (Ebert 2003).

  Habitat Preference—Leopard shark is a coastal species that is common in enclosed, muddy bays and sloughs (northern California) as well as flat, sandy areas, mud flats, sandy and muddy bottoms strewn with rocks near rocky reefs, and kelp beds (southern California) from the surf zone to 156 m (Eschmeyer et al. 1983; Compagno 1984b; Emmett et al. 1991; Smith 2001; Love et al. 2005). This species also inhabits littoral waters (Castro 1983; Eschmeyer et al. 1983; Compagno 1984b; Emmett et al. 1991), areas around jetties and piers (Emmett et al. 1991), and congregates around warm water outfalls of power plants (Smith 2001). Leopard sharks are most common on or near the bottom in waters less than 20 m deep but have been collected in waters greater than 91 m (Emmett et al. 1991). Estuaries (Monterey Bay) (Emmett et al. 1991; Starr et al. 1998) and shallow coastal waters (Smith 2001) are used as pupping and feeding/rearing grounds. Neonate pups occur in and just beyond the surf zone in Santa Monica Bay (Smith 2001) and near eel grass beds in other bays (i.e., San Francisco and Humboldt bays; Ebert 2003). This species occurs in polyhaline to euhaline waters (NMFS-NWR 2004c).

  Life History—Leopard shark often enters shallow bays and intertidal flats during high tides, retreating on ebb tides. Unlike other nocturnal sharks, this species is active during the day, (Eschmeyer et al. 1983; Emmett et al. 1991). They may form large nomadic schools composed of single sexes or size cohorts that may be mixed with gray (*Mustelus californicus*) or brown (*M. henlei*) smoothhounds, sevengill sharks (*Notorynchus cepedianus*), bat rays, or spiny dogfish (Castro 1983; Compagno 1984b; Emmett et al. 1991; Love 1996; Ebert 2003; FLMNH9).

  Leopard sharks are gonochoristic, ovoviviparous, and iteroparous (Emmett et al. 1991). Internal fertilization and embryogenesis occur within the female; there is no yolk-sac placenta (Castro 1983; Emmett et al. 1991). This species has a gestation period lasting 10 to 12 months (Castro 1983; Emmett et al. 1991). Mating occurs soon after the females give birth, primarily in April and

May. Females give birth to 7 to 36 pups (Smith 2001) from March to August (Compagno 1984b; Love 1996).

Common Prey Species—Leopard shark prey upon cancrid crabs, clam siphons, fishes, polychaetes, echiuroid worm (*Urechis caupo*), and fish eggs (i.e., herring, topsmelt, jacksmelt (*Atherinopsis californiensis*), and midshipmen) (Compagno 1984b; Love 1996).

- **Soupfin Shark (*Galeorhinus zyopterus*)**

Distribution—Soupfin shark range from northern British Columbia to Gulf of California and Ecuador to Chile (Roedel and Ripley 1950; Hart 1973; Compagno 1984b).

Habitat Preference—Soupfin shark is an abundant coastal-pelagic species of temperate continental and insular waters that is often associated with bottom habitats (Compagno 1984b) such as bays and muddy shallows (Eschmeyer et al. 1983). Soupfin sharks often occur at depths as shallow as two m but are also found in submarine canyons up to 1,100 m deep (Compagno 1984b).

Male and female soupfin sharks segregate by sex (Casillas et al. 1998), with adult males favoring deep waters and females, shallow waters (Compagno 1984b). The proportion of males is greater in northern waters off California with females occurring mostly in southern California waters and a mixture of sexes in central California waters (Roedel and Ripley 1950; Castro 1983; Eschmeyer et al. 1983; Ebert 2003). Young soupfin sharks are abundant in southern California waters, probably as a result of the larger female population in the area (Casillas et al. 1998).

Life History—Soupfin shark forms dense schools exhibiting a coastwide movement, migrating north in the summer and southward in the winter (Castro 1983). This species has extensive movements, without recognizable patterns, of up to 56 km/day, with sustained speeds of 16 km/day for 1,600 km (Hart 1973; Eschmeyer et al. 1983; Compagno 1984b).

Soupfins are ovoviviparous with mating occurring during the spring (Ebert 2003). After a gestation period of approximately one year, females move into bays to bear their live young in litters ranging in size from 6 to 52 pups (Roedel and Ripley 1950; Hart 1973; Castro 1983; Eschmeyer et al. 1983; Compagno 1984b) averaging 35 pups (Ebert 2003). The primary nursery grounds are south of the Pacific Northwest OPAREA and Puget Sound Study Area in inshore areas south of Point Conception. In central California, San Francisco and Tomales bays are utilized to a certain extent as pupping grounds (Compagno 1984b).

Common Prey Species—Soupfin shark prey upon herrings, sardines and other clupeids, anchovies, salmon, smelt, hake, cod, lingcod, midshipmen, flying squid (*Ommastrephes bartrami*), mackerel and small tuna, barracuda (*Sphyraena argentea*), croakers, wrasses, opaleye (*Girella nigricans*), surfperches, damselfishes, gobies, kelp fish, halibut and other flatfishes, rockfishes and scorpionfish, sculpins, sablefish, cephalopods, marine snails, crab, shrimp, annelid worms, echinoderms and uncommonly on other chondrichthyians such as ratfish, sharks, and small stingrays and skates (Compagno 1984b; Ebert 2003).

♦ **Dogfish Sharks (Squalidae)**

- **Spiny Dogfish (*Squalus acanthias*)**

Distribution—Spiny dogfish are found in temperate and subarctic latitudes in both the northern and southern hemispheres. In the northern and central Pacific Ocean, they range from Yellow Sea off China to Bering Sea and southeastern Chukchi Sea, Alaska to Gulf of California (Castro 1983; Eschmeyer et al. 1983; Allen and Smith 1988; Mecklenburg et al. 2002; FLMNH[9]). This species is common in inlands seas (i.e., San Francisco Bay and Puget Sound) (Castro 1983;

Allen and Smith 1988) and in shallow bays from Alaska to central California (Eschmeyer et al. 1983).

Habitat Preference—Spiny dogfish is an inner shelf-mesobenthal species that occurs from the surface and intertidal areas at depths ranging from intertidal zone to 1,244 m and perhaps as deep as 1,446 m (Love et al. 2005) but is commonly found in waters less than 350 m (Castro 1983; Allen and Smith 1988). Adults and subadults are mostly sublittoral-bathyal (Ebert 2003). Adults occur at depths less than 350 m; whereas subadults are found on muddy bottoms, when not found in the water column less than 200 m depth (Casillas et al. 1998). Small juveniles (<10 years old) are pelagic occurring at depths less than 100 m (Ebert 2003). All life stages occur in euhaline waters at temperature ranges of 7° to 15°C (Ebert 2003; McCain et al. 2005).

Life History—Seasonal migrations of offshore populations of spiny dogfish sharks result from a desire to stay within their preferred temperature range (Castro 1983). Schooling occurs with inshore populations and with migratory offshore populations (Eschmeyer et al. 1983). The schools, numbering in the hundreds, exhibit north-south coastal movements and onshore-offshore movements (Castro 1983). These schools tend to divide up according to size and sex, although young males and females tend to stay together (Casillas et al. 1998). Spiny dogfish also make diel migrations from near bottom habitats during the day to near surface habitats at night (McCain 2003).

Spiny dogfish are viviparous and have internal fertilization (Castro 1983; Eschmeyer et al. 1983; Ebert 2003) with males and females mating annually on the ocean bottom between September and January (Casillas et al. 1998). The spiny dogfish's gestation period lasts 18 to 24 months, one of the longest of any aquatic vertebrate (Nammack et al. 1985). Adult females move inshore to shallow waters during the spring to release their young in the midwater zone over depths of 165 to 300 m with the litter size ranging from 2 to 20 pups (Ebert 2003).

Common Prey Species—Spiny dogfish prey primarily upon fish (i.e., Pacific sand lance, herring, smelts, cods, capelin, hake, and ratfish) and invertebrates (i.e., shrimp, crabs, worms, krill, squid, octopus, jellyfish, and sea cucumbers) (Castro 1983; Ebert 2003; McCain et al. 2005).

- **Shortnose Chimaeras (Chimaeridae)**

  - **Spotted Ratfish (*Hydrolagus colliei*)**

Distribution—Spotted ratfish (formerly known as ratfish) (NMFS 2004h) range from the western Gulf of Alaska to near Punta Prieta, southern Baja California and northern Gulf of California (Miller and Lea 1972; Allen and Smith 1988; Mecklenburg et al. 2002).

Habitat Preference—Spotted ratfish is a middle-shelf-mesobenthal species that is found from the intertidal zone to 971 m but occurs most frequently between depths of 100 and 150 m (Allen and Smith 1988). This species is a deepwater fish that prefers low-relief rocky bottoms, exposed gravel and cobble, and mud and sea urchins (*Allocentrotus*) as a habitat (e.g., Heceta Bank) (McCain et al. 2005). All free-swimming life history stages are demersal and share essentially the same habitat with no partitioning by age or size (Casillas et al. 1998). Spotted ratfish inhabit larger estuaries for feeding and mating throughout its range, especially from early winter to late spring (Love 1996). They are more common in shallow waters (intertidal/subtidal) to the north (bays and sounds) and in deeper waters (>30 m) to the south (southern California) (Love 1996; Ebert 2003). All life stages occur in waters temperature of 7.2° to 8.9°C (Ebert 2003).

Life History—Spotted ratfish occur singly, in small groups or in large aggregations (Love 1996). They make significant seasonal and diel migrations (Love 1996). In the winter, they move into shallow nearshore waters and estuaries, for feeding and pre-spawn mate selection (Casillas et al. 1998). In Puget Sound and other estuaries, spotted ratfish move from deep water by day to shallower water at night, which is undertaken mostly by smaller fish. This type of diel migration

suggests that deep water is the preferred feeding ground for young spotted ratfish or a means of predator avoidance (Casillas et al. 1998).

Spotted ratfish are oviparous with internal fertilization (Love 1996). Mating occurs at all times throughout the year but seems to peak from late summer to early fall. Spotted ratfish, regardless of size or age, produce only two egg cases per year (Kato 1992). Eggs are attached by the mother to rocks or placed upright in the sand (Hart 1973). In the summer and fall, ratfish move offshore into deep waters to deposit egg cases (Casillas et al. 1998).

Common Prey Species—Spotted ratfish prey upon isospondylous (herring-like) fishes, mollusks, squid, nudibranchs, opistobranchs, annelids, and small crustaceans such gammarid amphipods (Hart 1973; Allen and Smith 1988; Love 1996; Ebert 2003).

4.4.4 Highly Migratory Species

As a group, HMS are managed by the PFMC under the supervision of the NMFS-Southwest Region (SWR) (NMFS 2004h). The U.S. west coast HMS are composed of 13 species of which seven species (**Table 4-2**) occur within the Pacific Northwest OPAREA and Puget Sound Study Area. One species, skipjack tuna (*Katsuwonus pelamis*) is not included because its range extends to about the 40°N latitude which would place this species just below the southern extension of the Pacific Northwest OPAREA and Puget Sound Study Area (PFMC 2003c). Fishes under the FMP for HMS with EFH designation include oceanic sharks, tuna, billfish and swordfish, and other species (dorado - *Coryphaena hippurus*), which are distributed over wide areas of the open ocean, neritic waters of the continental shelf, and coastal waters (PFMC 2003c). In addition to the EFH species, great white shark (*Carcharodon carcharias*), basking shark (*Cetorhinus maximus*), megamouth shark (*Megachasma pelagio*), Pacific halibut (*Hippoglossus stenolepis*), and Pacific salmon species (*Oncorhynchus* spp.) are designated for prohibited status under the HMS FMP (NMFS 2004g). For help in the identification of the HMS refer to Collette and Nauen (1983), Compagno (1984a; 1984b), Nakamura (1985), Compagno and Niem (1998), Compagno (2002), Pacific Shark Research Center[29], and Froese and Pauly[7].

HMS are not correlated with the areas or features that typify most fish habitat (bottom substrate or submerged vegetation) but rather are associated with physiographic and hydrographic features, such as ocean fronts, current boundaries, the continental shelf margin, or seamounts. These characteristics, along with the fact that these fishes generally occur in the open ocean and frequent nearshore waters, complicate the identification process of HMS habitat. These species exhibit both horizontal and vertical movements, as well as traveling great distances inshore, offshore, and for seasonal migrations. The distributions of the various life stages of these highly mobile species are also constrained by temperature, salinity, and oxygen concentrations. The majority of the resulting habitat parameters are dynamic, changing both spatially and temporally, and make habitat characterization for highly migratory fish species difficult except in a broad context (PFMC 2003c).

EFH species are discussed in the following subsection and listed in **Table 4-2**. The status, distribution, habitat preference (substrate, depth, temperature, and salinity), life history (migration, movements, and spawning), common prey species, and EFH designations of the individual HMS are presented for each species (PFMC 2003c). Currently there are no existing HAPC in the PFMC region for HMS (Moncada et al. 2004).

Sharks

Sharks are highly mobile predators that rely on their non-visual senses (i.e., electroreception), have a slow metabolism, grow and mature slowly, and produce small numbers of young. These factors make them extremely susceptible to commercial exploitation and environmental degradation precipitating rapid stock declines or collapses from which recovery may take decades (Helfman et al. 1999; Musick 1999). The PFMC manages five species of Pacific sharks to protect them from overfishing and finning; the practice of removing the fins from a shark's body and dumping the remainder of the fish back into the water (Allen 1999; NMFS 2002a; PFMC 2003c).

Four shark species found in the Pacific Northwest OPAREA and Puget Sound Study Area have EFH described for their three lifestages (neonate/early juvenile, late juvenile/subadult, and adult) by the PFMC (2003c). All four species presented in this section are pelagic sharks. Pelagic sharks occupy large portions of the marine environment that include epipelagic, mesopelagic, oceanic, and neritic zones. Pelagic sharks, such as the threshers (Alopiidae), mackerels (Lamnidae - makos), and requiem (Carcharhinidae – blue) are widely distributed over the upper oceanic zones and are capable of traveling over entire ocean basins (PFMC 2003c).

- **Thresher Sharks (Alopiidae)**

  - **Common Thresher Shark (*Alopias vulpinus*)**

    Status—Common thresher shark is not managed internationally and there are no quotas. The common thresher shark is considered data deficient by the IUCN Red List due to the lack of adequate information necessary to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.[8] The FAO lists this species as category 4 (exploited species) due to the low reproductive potential of the species and the fact that it is a target of many intensive fisheries throughout the world (Castro et al. 1999). This species is not overfished, nor is overfishing occurring (PFMC 2003c; NMFS 2005k).

    Distribution—Common thresher shark is circumglobal occurring in temperate and warm oceans, penetrating into tropical waters. It is found in the Atlantic Ocean, Mediterranean Sea, Indian Ocean, and central and western Pacific. In the eastern Pacific, this species ranges from southeastern Alaska and Goose Bay, British Columbia to Chile but may include the Gulf of California (Eschmeyer et al. 1983; Compagno 1984b, 2002).

    Habitat Preference—Common thresher sharks are most abundant over continental and insular shelves in neritic and oceanic waters out to 161 km (Compagno 1984b, 2002). Adult and juveniles are epipelagic with adults occurring from the surface to depths of 366 m or more (Ebert 2003) and juveniles preferring open coast and semi-enclosed bays (Eschmeyer et al. 1983) with high concentrations of schooling prey. This species is often associated with areas of high biological productivity and the presence of strong frontal zones that separate regions of upwelling and adjacent waters, as well as areas with strong horizontal and vertical mixing of surface and subsurface waters (NMFS-NWR 2004c). These effects create habitats conducive to the production and maintenance of schooling pelagic prey (PFMC 2003c). Common thresher sharks occur in waters with salinities of 32 to 36 psu and temperatures of 14° to 29°C (MBC 1987).

    Life History—Common thresher sharks undergo active transboundary seasonal north-south migration from San Diego/Baja California-Mexico to Oregon and Washington State following warm water masses and schools of prey (Ebert 2003; PFMC 2003c). In early spring, adults remain in offshore southern California waters (366 to 549 m) from one to two months during which time pupping occurs followed by the pups moving to inshore nursery areas (PFMC 2003c). Adults, mostly males, move as far north as Vancouver Island in late summer and early fall (Ebert 2003). Subadults tend to remain in the SCB, which is an important nursery area, rarely venturing further north than Cape Mendocino, California (Ebert 2003) except during warm-water years where they are found by the Columbia River mouth and as far as 48°N (PFMC 2003c). In fall, subadults are thought to move south again, arriving in the Channel Islands area of the SCB. Little is known about the presumed southward migration of large adults, which do not appear along the coast until spring (PFMC 2003c).

    Reproduction in the common thresher shark is ovoviviparous and oophagous with a normal brood size of two to four pups per litter (Bedford 1992; Smith and Aseltine-Neilson 2001). Mating presumably takes place in mid-summer (July to August) along the U.S. west coast EEZ, with a gestation period of about nine months, with parturition occurring most likely in the spring months (March to June) off California (PFMC 2003c).

Common Prey Species—Common thresher shark prey upon anchovy (*Engraulis* and *Anchoa* spp.) Pacific sardine, herring (Clupeidae), mackerel (*Scomber* spp.), shortbelly rockfish, Pacific hake, lancetfish (*Alepisaurus* spp.), lanternfishes (Myctophidae), Pacific salmon (*Oncorhynchus* spp.), market squid, octopus, pelagic red crab, shrimp, and seabirds (Hart 1973; Preti et al. 2001; FLMNH[9]).

EFH Designations—(PFMC 2003c; **Figure E-5**)

- Neonate/early juveniles (<102 cm fork length [FL])—EFH includes epipelagic, neritic, and oceanic waters off beaches, in shallow bays, and in near surface waters from the U.S./Mexico EEZ border north to Santa Cruz (37°N latitude). These habitats are primarily over bottom depths of 11 to 732 m, particularly in water less than 183 m deep and to a lesser extent further offshore between 366 and 549 m.
- Late juveniles/subadults (>101 cm FL and <167 cm FL)—EFH consists of the epipelagic, neritic, and oceanic waters off beaches and open-coast bays, as well as offshore in near-surface waters. These waters range from the U.S./Mexico EEZ border north to off Pigeon Point, California (37°N10' latitude), from the 11 to 2,560 m isobaths.
- Adults (>166 cm FL)—EFH is located in the epipelagic, neritic, and oceanic waters off beaches and open-coast bays in near-surface waters. Within the Pacific Northwest OPAREA, these waters range from the U.S./Mexico EEZ border north (seasonally) to Cape Flattery, Washington State from the 73 m isobath westward to about 127°30'W longitude north of the Mendocino Escarpment and from the 73 to 3,475 m isobath south of the Mendocino Escarpment.

- **Bigeye Thresher Shark (*Alopias superciliosus*)**

Status—Bigeye thresher shark is not managed internationally and there are no quotas. This species is thought to be more vulnerable to overfishing than the common thresher shark but little is known of the bigeye thresher shark's abundance and stock structure (PFMC 2003c; NMFS 2005k)**.** The FAO lists this species as category 3 (exploited species) due to its slow growth, limited reproductive potential, and the fact that it is caught in large numbers in numerous tuna and swordfish fisheries throughout its range (Castro et al. 1999).

Distribution—Bigeye thresher is circumglobal in tropical and temperate seas. It occurs in the Atlantic Ocean, western Mediterranean Sea, western Indian Ocean, and central and western Pacific. In the eastern Pacific, this species ranges from Vancouver, British Columbia, south to the Gulf of California and Islas Galapagos and possibly off Peru and northern Chile; usually south of 45°N latitude (Compagno 1984b, 2002; PFMC 2003c).

Habitat Preference—Bigeye thresher sharks are found in oceanic and neritic waters over continental and insular shelves, occasionally in shallow areas (Compagno 1984b). This species is an epipelagic and mesopelagic shark in depths ranging from surface down to an recorded maximum depth of 723 m (Nakano et al. 2003). This species occurs in deeper (200 to 550 m) and cooler (6° to 11°C) waters during the day, shifting upwards to the mixed layer (at about 50 to 130 m) and warmer water temperatures (15° to 26°C) at night (PFMC 2003c). Bigeye threshers can reportedly stay in cooler water for longer periods of time than other pelagic sharks (PFMC 2003c). The population off California and Oregon appears to be predominately adult males. Immature females occur primarily south of Monterey Bay in the SCB. Juveniles off the west coast appear to associate with a broader range of SST (15° to 25°C) than adult males (15° to 19°C) (PFMC 2003c). Bigeye thresher sharks are frequently caught off southern California from August to November, peaking in September (Hanan et al. 1993; Ebert 2003).

Life History—Data are unavailable on long-term movements and migrations of the bigeye thresher shark (PFMC 2003c). In the eastern Pacific off Central and South America, recent studies on this species suggest diel vertical migration for night feeding in the area of the thermocline and adjustment to water temperatures ranging from 6° to 26°C (PFMC 2003c).

Reproduction in the bigeye thresher shark is ovoviviparous and oophagous with a normal brood size of one to four pups, usually one per litter (Compagno 2002; Ebert 2003). A probable period of gestation has been estimated at 12 months (PFMC 2003c).

Common Prey Species—Bigeye thresher sharks prey upon bottom fishes (Pacific hake) and pelagic fishes such as longnose lancetfish (*Alepisaurus ferox*), herring (Clupeidae), mackerel (*Scomber* spp.), small billfishes (Istiophoridae), and king-of-the-salmon (*Trachipterus altivelis*), squids (Teuthoidea), and crustaceans (Compagno 2002; Ebert 2003; PFMC 2003c; FLMNH[9]).

EFH Designations—(PFMC 2003c; **Figure E-6**)

- Neonate/early juveniles (~90 to 115 cm FL, 0 to 2 and 3 year old)—These size classes are not known to occur in the U.S. west coast EEZ.
- Late juveniles/subadults (>115 cm FL and <155 cm FL males and <189 cm females)—EFH consists of coastal and oceanic waters in the epipelagic and mesopelagic zones from the U.S./Mexico border north to 37°N latitude of Davenport, California. This early life history stage occurs south of 34°N latitude from the 183 to 3,658 m isobath and north of 34°N latitude from the 1,463 to 4,023 m isobath.
- Adults (>154 cm FL males and >188 FL females)—EFH is located within the Pacific Northwest OPAREA in coastal and oceanic waters in the epipelagic and mesopelagic zones from the U.S./Mexico border north seasonally to 45°N latitude off Cascade Head, Oregon. In southern California, this life stage is found south of 34°N latitude, from the 183 to 3,658 m isobath and north of 34°N latitude from the 1,463 m isobath toward the outer EEZ boundary.

- **Mackerel Sharks (Lamnidae)**

  - **Shortfin Mako Shark (*Isurus oxyrhinchus*)**

Status—Shortfin mako is not managed internationally and there are no quotas. Significant effects of exploitation have not been shown, and the local stock is not currently considered overfished, nor is overfishing occurring (PFMC 2003c; NMFS 2005k). Information is unavailable on the population structure of the shortfin mako in the eastern North Pacific (Ebert 2003). The FAO lists this species as category 4 (exploited species), as it has shown historical declines due to swordfish and tuna bycatch operations (Castro et al. 1999). The IUCN red list of threatened species lists the shortfin mako as a lower risk but near threatened. [8]

Distribution—Shortfin mako is circumglobal occurring in warm-temperate and tropical seas. In the eastern Pacific, it ranges found from Chile and Islas Galapagos, northward to British Columbia, occurring most commonly off southern California (Hanan et al. 1993; Holts and Bedford 1993; Ebert 2003).

Habitat Preference—Shortfin mako shark, an offshore littoral and epipelagic species, is known to occur in the water column from the surface to depths of at least 500 m or more (Compagno 2002; PFMC 2003c). This species is endothermic and thus able to maintain higher temperatures than the surrounding waters in their body musculature, brains, eyes, and viscera with countercurrent vascular heat exchangers (Compagno 2002). Adults are less common on the outer banks of the SCB around the Channel Islands during late summer (Ebert 2003). Juveniles are abundant in the summer months off southern California near the surface above the thermocline in the mixed layer utilizing these offshore continental waters as a nursery area (Holts and Bedford 1993) for at least two years (Cailliet and Bedford 1983). Off California, shortfin makos are associated with SSTs ranging from 15° to 25°C (PFMC 2003c).

Life History—Shortfin mako is highly migratory (Ebert 2003). In the extreme northern and southern part of its range, this species has a tendency to follow movements of warm water masses poleward in the summer at temperatures ranging from 17.2° to 22.2°C (Compagno 2002) then retreating when temperature cools (Ebert 2003).

Water column preference of adult fish is unknown except from one study that tracked one adult in the Atlantic Ocean, noting large vertical movements between the surface and 450 m during the day, with small excursions down to the thermocline at night (PFMC 2003c).

Reproduction in the shortfin mako shark is ovoviviparous and oophagous with a normal brood size of 4 to 25 and possibly 30 pups (average 10 to 18 pups) in a litter (Love 1996; Compagno 2002). This species has a three-year reproductive cycle, which includes a 15- to 18- month gestation period, a late winter to mid-spring pupping season, followed by an 18-month resting period before females become fertile again (Mollet et al. 2000; Ebert 2003). The SCB is an important pupping and nursery area (Taylor and Bedford 2001; Ebert 2003).

Common Prey Species—Shortfin mako sharks prey upon mackerel, tuna, bonito, anchovies, herring, lancetfishes, rockfish, lingcod, yellowtail jacket (*Seriola lalandi*), seabass, swordfish, juvenile blue, requiem, and hammerhead sharks, cephalopods, dolphins, and sea turtles (Strasburg 1958; Taylor and Bedford 2001; Compagno 2002; Ebert 2003; FLMNH[9]).

EFH Designation—(PFMC 2003c; **Figure E-7**)

- Neonate/early juveniles (<101 cm FL)—EFH is located in oceanic and epipelagic waters of the U.S. west coast from the 183 to 3,658 m isobath (and possibly beyond), from the Mexico border to Point Pinos, California (especially the SCB from the 1,829 to 3,658 m isobaths from Monterey Bay north to Cape Mendocino) and within the Pacific Northwest OPAREA from the 1,829 m isobath out to the EEZ boundary north of Cape Mendocino to 46°30'N latitude. This early life history stage occupies northerly habitats during warm water years.
- Late juveniles/subadults (>100 cm FL and <180 cm FL males and <249 cm females)—EFH is identified as oceanic and epipelagic waters from the U.S./Mexico EEZ border north to 46°30'N latitude from the 100 m isobath out to the EEZ boundary north to San Francisco (38°N latitude) and within the Pacific Northwest OPAREA from the 1,829 m isobath out to the EEZ boundary north of San Francisco.
- Adults (>179 cm FL males and <248 cm FL females. Most adults within the U.S. west coast EEZ are males)—EFH consists of epipelagic oceanic waters from the U.S./Mexico EEZ border north to 46°30'N latitude extending from the 732 m isobath out to the EEZ boundary south of Point Conception, California and within the Pacific Northwest OPAREA from the 1,829 m isobath out to the EEZ boundary and beyond, north of Point Conception

♦ **Requiem Sharks (Carcharhinidae)**

- **Blue Shark (*Prionace glauca*)**

Status—Blue shark is not actively managed internationally and there are no quotas. Recent studies indicate that the species, which may comprise a single stock, is abundant and healthy in spite of being incidentally fished by high-seas, longline fleets for over 50 years (PFMC 2003c). This species is not undergoing overfishing, nor is it consider overfished on the west coast (PFMC 2003c; NMFS 2005k; FLMNH[9]). The FAO lists this species as category 3 (exploited) species because it is caught in significant numbers in the bycatch of numerous longline fisheries (Castro et al. 1999). The IUCN red list of threatened species lists the blue shark as a lower risk but near threatened.[8]

Distribution—Blue shark is primarily circumglobal in its distribution occurring in temperate and tropical waters from 60°N to 50°S latitude (Compagno 1984a). In the eastern Pacific, this species ranges from Kodiak Island, western Gulf of Alaska to Chile including Gulf of California and Islas Galapagos, being abundant in offshore and coastal waters of the western U.S. and Mexico (Compagno 1984a; Holts 1992).

Habitat Preference—Blue shark is an oceanic-epipelagic and fringe-littoral species occurring from the surface to about 350 m (Holts et al. 2001). Considered an offshore species, it sometimes

occurs near the coast at night often where the continental shelf narrows or is cut by submarine canyons close to shore (Compagno 1984a; Ebert 2003). In the Pacific, blue sharks are present in greatest abundance between 20°N to 50°N with females more abundant at higher latitudes than males (PFMC 2003c). Within the U.S. west coast EEZ, this species is common and one of the most frequently encountered sharks along the entire California coast (Ebert 2003). Juveniles are abundant off California, especially in the SCB (major birthing/nursery area) and Monterey Bay from May to October (Sciarrotta and Nelson 1977; Hanan et al. 1993; Holts et al. 2001). Strasburg (1958) found that north of 30°N latitude, blue sharks preferred shallower depths (<85 m). Off California, this species spends the majority of its time in water depths ranging from 16.0 to 25.9 m (Klimley et al. 2002).

Blue sharks are tolerant of a relatively wide range of water temperatures. According to Compagno (1984a) and Eschmeyer et al. (1983), this species apparently prefers relatively cool water at 7° to 16°C but can tolerate water of 21°C or warmer. SSTs associated with blue shark drift catches off the U.S. west coast ranged from 12° to 25°C (Sciarrotta and Nelson 1977) and off California from 10° to 15°C (Klimley et al. 2002).

Life History—In the north Pacific, seasonal migrations occur between latitudes 20°N and 50°N, with northward movements extending into the Gulf of Alaska as waters warm during the summer months, and southward movements occurring during the winter months (Strasburg 1958). Along the west coast, mature females are thought to start their northward journey in early spring as warm water moves northward, while juveniles of both sexes follow closely; large males start later and tend to stay further offshore (Holts 1992; Hanan et al. 1993). Nakano (1994) has proposed a migration model for the blue shark in the north Pacific, where birth occurs in early summer in nursery areas located at 35° to 45°N, with one to five year old females moving north of these latitudes and two to four year old males moving south. Upon reaching maturity, this species apparently migrates to the subtropics and tropics to join a reproductively active population (PFMC 2003c). Within the U.S. west coast EEZ, a larger nursery area extends from 31° to 47°N (PFMC 2003c). This species is known to undertake extensive trans-oceanic migrations, sometimes moving over 6,678 km (Kohler et al. 1998; Ebert 2003).

Diel movements of blue sharks off southern California indicate that adults increase their activity at night and make shallower dives during the day. This cyclical diving behavior is thought to serve as a hunting, orientation, and/or thermo-regulatory function (Holts et al. 2001). Blue sharks appear to aggregate in loose schools (Holts et al. 2001).

Blue shark is viviparous with 4 to 135 young per litter (average 20 to 40) and a gestation period lasting 9 to 12 months (Compagno 1984a; Ebert 2003). Reproduction for blue sharks has been reported as seasonal in most areas, with birth often occurring in spring or summer (Nakano 1994; PFMC 2003c). Off California, mating reportedly occurs from late spring to early winter, and parturition takes place in early spring (Hanan et al. 1993). The nursery habitat may extend northward from the SCB to off the Columbia River and primarily offshore of the 183 m isobath (PFMC 2003c).

Common Prey Species—Blue sharks prey upon relatively small bony fishes such as Pacific herring, sardines, northern anchovy, blacksmith (*Chromis punctipinnis*), salmon, lancetfishes, flying fishes, pipefishes, hake, rock cod, jack mackerel, tunas, sea bass, flatfishes, and spiny dogfish and invertebrates including squid (Histioteuthid and market squid), red crab, and euphasuiid swarms (*T. spinifera*) (Compagno 1984a; Love 1996; Ebert 2003; PFMC 2003c; FLMNH[9]).

EFH Designations—(PFMC 2003c; **Figure E-8**)

- <u>Neonate/early juveniles (<83 cm FL)</u>—EFH is located in epipelagic, oceanic waters from the U.S./Mexico border north to the U.S./Canada border from the 1,829 m isobath seaward to the

outer boundary of the EEZ and beyond; extending inshore to the 183 m isobath south of 34°N' latitude.

- Late juveniles/subadults (>82 cm FL and <167 cm FL males and <153 cm females)—EFH is identified as epipelagic, oceanic waters from the U.S./Mexico EEZ border north to 37°N latitude (off Santa Cruz, California) from the 183 m isobath seaward to the outer boundary of the EEZ and beyond; and within the Pacific Northwest OPAREA north to the U.S./Canada border from 1,829 m isobath seaward to the EEZ outer boundary.
- Adults (>166 cm FL males and <152 cm FL females)—EFH consists of epipelagic, oceanic waters from the U.S./Mexico EEZ border north to the U.S./Canada border from the 1,829 m isobath seaward to the outer boundary of the EEZ and beyond in the Pacific Northwest OPAREA; extending inshore to the 366 m isobath south of 37°N latitude off Santa Cruz.

Tuna

The family Scombridae, the mackerels, tunas, and bonitos, includes some of the world's most popular food and sport fishes. Within this family, members of the genus *Thunnus* are unique in possessing a high metabolic rate and vascular heat exchange allowing thermo-regulation and endothermy. They are predaceous, swift-swimming, and powerful fishes that occur in tropical and temperate waters. Two of the five EFH designated tuna species occur in the Pacific Northwest OPAREA (PFMC 2003c).

- **Albacore Tuna (*Thunnus alalunga*)**

Status—Albacore tuna stock is healthy and it is not known if it is overfished, or if is overfishing occurring (PFMC 2003c). No quotas are being considered and no regional harvest guidelines have been recommended at the present time (NMFS 2005k). The albacore tuna is listed as data deficient by the IUCN red list of threatened species, due to the lack of adequate information necessary to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status. [8]

Distribution—Albacore tuna are circumglobal in tropical and subtropical oceanic regions between latitudes 40° to 58°N and 25° to 43°S occurring in the Atlantic, Pacific, and Indian oceans and in the Mediterranean Sea (Collette and Nauen 1983). In the northeastern Pacific, they range from northern and eastern Gulf of Alaska to Chile including Islas Galapagos and entrance to Gulf of California (Squire and Smith 1977; Collette and Nauen 1983; Eschmeyer et al. 1983; Mecklenburg et al. 2002). Albacore tuna are generally distributed in a band centered at 35°N in the Kuroshio Current off Japan, the North Pacific Transition Zone (NPTZ), and the California Current (IATTC 2001).

Habitat Preference— All life stages of the albacore tuna are pelagic with temperature being the most influential factor in determining their distribution (Collette and Nauen 1983). Adults and subadults occur as deep as 600 m, but primarily from 27 to 180 m; whereas small juveniles, larvae, and eggs are found from the surface to 50 m (primarily 20 to 30 m) (Collette and Nauen 1983). Depth distribution of deep-swimming adults is dependent upon vertical thermal structure and dissolved oxygen levels greater than 60%. Juveniles are often found near oceanic fronts or in regions of temperature discontinuities (PFMC 2003c). Deep-swimming adults occur in waters between 13.5° to 25.2°C, while the 15.6° to 19.4°C SST isotherms appear to delimit the habitat of juveniles (PFMC 2003c). While very young juveniles and larvae are not known to occur within the U.S. Pacific coast EEZ, sizable concentrations of juveniles (<85 cm FL) and adults (>85 cm FL) occur from Cedros Island, Baja California to Oregon in the area of the Columbia River Plume and from 80 to 482 km offshore (MBC 1987). Albacore tuna are found in euhaline waters with salinities of 32.7 to 38.8 psu and at temperatures of 9° to 30°C: adults – 13.5° to 25.2°C; juveniles - 13.9° to 22.2°C; larvae - 24° to 27°C; and eggs - 24° to 30°C (Hart 1973; Collette and Nauen 1983; MBC 1987).

Life History—Albacore tuna have a complex migration pattern, with the north and south Pacific stocks having similar patterns. Most migrations are undertaken by subadults (two to four years

old). A given year class migrates west to east in a band between 30° to 45°N, leaving the northwest Pacific in springtime. Albacore move into the eastern portion of the NPTZ 1,000 to 1,500 km offshore waters off North America by early summer. When surface waters warm, they migrate into coastal waters by mid-summer off Baja California and California. This onshore migration continues throughout the summer months extending northward during late summer then westward in the fall entering into subtropical waters to reproduce (Kimura et al. 1997; Moyle and Cech 2000). Migrations may also be influenced by large-scale climate events that affect the Kuroshio Current regime off Japan. Albacore tuna may migrate more intensely to the eastern Pacific when the Kuroshio Current takes a large meandering path (Kimura et al. 1997).

Similar size albacore travel together in school groups (young: small, loose, and broadly scattered and old: compact), which collectively can be up 320 to 480 km wide (MBC 1987; Crone 2001). In North American waters, albacore tuna are generally associated with coastal frontal boundaries and tend to aggregate in the vicinity of local upwelling fronts (MBC 1987; Laurs and Dotson 1992).

Spawning does not occur in the Pacific Northwest OPAREA, instead taking place in the North Pacific between latitudes 10° and 30°N from Japan to Hawaii between April and July in oceanic waters (MBC 1987). Albacore tuna is oviparous with eggs released in two batches per year (Collette and Nauen 1983).

Common Prey Species—Albacore tuna prey upon small fishes (northern anchovies, Pacific saury (*Cololabis saira*), rockfish spp., myctophids, barracudina (*Magnisudis atlanica*), squids, (e.g., opalescent inshore, armhook (*Gonatus anonychus*), boreoatlantic armhook (*G. fabracil*), and clubhook (*Onychoteuthis* spp.), and crustaceans (sergestid shrimp, pelagic red crab, amphipods (*Phronima sedentaria*), euphausiids (*E. pacifica*) (Hart 1973; Collette and Nauen 1983; Bernard et al. 1985; PFMC 2003c).

EFH Designations—(PFMC 2003c; **Figure E-9**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.
- Juveniles (<85 cm FL)/Adults (>84 cm FL)—EFH is identified in the Pacific Northwest OPAREA as oceanic, epipelagic waters generally beyond the 183 m isobath, from the U.S./Mexico border north to the U.S./Canada border, and westward to the outer edge of the EEZ boundary.

- **Northern Bluefin Tuna (*Thunnus orientalis*)**

Status—Evidence for overfishing or for persisting decline in the stock of northern bluefin tuna is lacking (NMFS 2005g). The bluefin tuna is treated as a vulnerable species due to the fact that this species is the least productive and has the most restricted spawning conditions among tunas.[8] Its population status is also considered problematic because no indices reliably reflect overall stock abundance. No regional harvest guidelines are recommended in view of the stock being primarily western Pacific, the lack of international agreement on stock status relative to maximum sustainable yield (MSY), and the west coast fishery not directly affecting the spawning stock (PFMC 2003c).

Distribution—Northern bluefin tuna originates in the western Pacific, especially west of 180° and the Hawaiian Islands. Their distribution ranges from southward to off New Zealand, eastern Australia, and New Guinea, and westward to Japan, East China Sea, and Philippines. In the eastern Pacific, this species is found from about 20°N and 42°N, sometimes extending northward in warm-water years to 48°N and beyond (Bayliff 2001). Within the U.S. west coast EEZ, the northern bluefin tuna occurs from the below U.S./Mexico border (tip of Baja California) (Love et al. 2005) to Point Conception, California and intermittently north to the U.S./Canada border and beyond (Shelikof Strait, Gulf of Alaska) (Mecklenburg et al. 2002) when SST are above normal (Bayliff 1993).

Habitat Preference—Northern bluefin tuna occur in oceanic, epipelagic waters usually beyond the 183 to 732 m isobath out to the EEZ boundary, but occasionally inhabit inshore waters (Collette and Nauen 1983). Research suggests that the most suitable habitat off Baja California and along the U.S. west coast exists from May through October, when the bluefin tuna's preferred SSTs (17° and 23°C) tend to prevail in those areas (PFMC 2003c). There appears to be no consistently utilized habitat within the U.S. west coast EEZ for adult fish over 150 cm FL, although some of these large fish have been caught in the SCB in the vicinity of the Channel Islands (Bayliff 1993). In addition to the preferred temperature range defined by SSTs, northern bluefin tuna can also be found associated with the following habitat features: California Current in the eastern Pacific and the NPTZ, North Pacific Subarctic Boundary, and Kuroshio Current off Japan (Bayliff 1993).

Life History—Research suggests that the northern bluefin tuna's migratory path is within the North Pacific Subarctic-Subtropical Transition Zone. Recent studies have documented the migration of juveniles from the western Pacific to the eastern Pacific. Tagged individuals off Japan made the trans-Pacific migration in about two months, then resided in the eastern Pacific for about eight months before being recaptured (Itoh et al. 2003a). Off the west coast, Domeier et al. (2005) reported a seasonal movement pattern of young northern bluefin tuna spending winter and spring off central Baja California, moving northward to Oregon from summer through fall, then returning southward into Mexican waters by winter where they remained until the following spring.

Northern bluefin tuna (40 to 80 kilograms [kg]) school by size with other tunas such as albacore, yellowfin (*T.albacares*), bigeye (*T. obesus*), skipjack, frigate tuna (*Auxis rochei*), eastern Pacific bonito (*Sarda chiliensis*) and yellowtail (Collette and Nauen 1983). Itoh et al. (2003b) reported a diurnal and seasonal change in swimming depth and vertical swimming behavior at dawn and dusk.

The majority of northern bluefin tuna spawn in the northwest Pacific ocean in area from the Philippines past Taiwan to Okinawa from April to June. Small numbers also spawn off southern Honshu in the Pacific ocean in July and in the Sea of Japan in August (Bayliff 2001; Itoh et al. 2003a). This species is oviparous producing as many as 10 million eggs per year (Love 1996).

Common Prey Species—Northern bluefin tuna prey upon northern anchovy, herring, sanddabs, white croakers, pompanos, mackerel, Pacific saury, squid, Pacific hake, and other tuna (Collette and Nauen 1983; Bayliff 1993; Love 1996; FLMNH[9]).

EFH Designations—(PFMC 2003c; **Figure E-10**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.
- Juveniles (<150 cm FL and 60 kg)—EFH is identified in the Pacific Northwest OPAREA as oceanic, epipelagic waters beyond the 183 m isobath from the U.S./Mexico EEZ border north to the U.S./Canada border, and westward to the outer edge of the EEZ boundary. The northerly migration extension appears dependent on position of the North Pacific Subarctic Boundary.
- Adults (>150 cm FL and 60 kg)—No regular habitat within the U.S. west coast EEZ exists, although large fish are occasionally caught in the vicinity of the Channel Islands off southern California but rarely off central California.

Billfish

The family Istiophoridae (marlins and sailfish) consists of gamefish that have a prolonged snout and upper jaw that forms a sword. Billfish are exceptional foodfish and are regarded as excellent and exciting targets by sport fishermen (Nakamura 1985). One species of billfish (broadbill swordfish) has EFH designated within the Pacific Northwest OPAREA (PFMC 2003c).

Swordfish

- **Broadbill Swordfish (*Xiphias gladius*)**

Status—Recent studies indicate that the EPO broadbill swordfish population is healthy and currently no regional harvest guideline is recommended (PFMC 2003c). The swordfish is listed as data deficient by the IUCN red list of threatened species, due to the lack of adequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.[8]

Distribution—Broadbill swordfish are circumglobal in distribution occurring in all tropical, subtropical, and temperate seas ranging from around 50°N to 50°S (Nakamura 1985; PFMC 2003c). In the eastern Pacific, this species ranges from south of Vancouver Island, British Columbia to Valdivia, Chile including southernmost part of Gulf of California and Islas Galapagos (Palko et al. 1981; Love et al. 2005). Broadbill swordfish are most abundant off northwestern Mexico (south of Baja California), common off California but uncommon north of Point Conception, California (Miller and Lea 1972; Squire and Smith 1977; Palko et al. 1981).

Habitat Preference—All life stages of the swordfish are pelagic (Palko et al. 1981; Nakamura 1985). Adults and subadults occur from the surface to 2,878 m (Nakamura 1985; Love et al. 2005). Small juveniles, larvae, and eggs are epipelagic with small juveniles occurring in the upper 29 m, larvae from 1 to 15 m, and eggs from the surface to 75 m (MBC 1987). Adults and juveniles are most abundant near current boundaries, frontal zones, submarine escarpments, and boundary zones, where sharp gradients of temperature and salinity exist, and areas of high productivity where forage species (i.e., squid) are abundant (Palko et al. 1981).This association with cephalopod prey, concentrated near frontal boundaries, appears significant in determining their distribution in the north Pacific (PFMC 2003c).

Broadbill swordfish adults and juveniles can tolerate a wide range of water temperature ranging from 5° to 27°C but are normally found in areas with SSTs above 13°C (Nakamura 1985). Larvae occur in water temperatures of 22.4° to 30.7°C and eggs at 22.4° to 30.7°C (Palko et al. 1981). Most large-sized fish are female, which appear to be more common in cooler waters. According to Palko et al. (1981) few males tend to occur in waters below 18°C and make up the majority of warm water landings. Research suggests that adult swordfish spend 75% of their time in or just below the upper mixed layer, at depths of 10 to 50 m in water temperatures around 14°C, and make excursions to approximately 300 m depths in water temperatures close to 8°C (PFMC 2003c). Adults are found over a broad range of salinities (6 to 39 psu), whereas earlier life history stages occur only in euhaline water with salinities of 33.8 to 37.4 psu (MBC 1987).

Dewees (1992) states that like adults, juveniles tend to concentrate along productive thermal boundaries, between cold, upwelled water and warm water masses where they feed on fishes and squids. In the Pacific, juvenile swordfish are restricted to areas of upwelling and high productivity and do not move far during the first year of life. Young swordfish originate in tropical and subtropical regions and migrate to higher latitudes as they increase in size (PFMC 2003c).

Life History—Little is known about migration in Pacific swordfish, although limited tagging data support a general west-to-east movement from Hawai'i toward continental North America (PFMC 2003c). This species does not migrate long distances, although individuals occasionally wander more than 1,000 km. In general, they move into temperate waters during the summer to feed and return to warmer waters to over-winter and spawn (Palko et al. 1981). Adults, juveniles, and larvae undertake diel vertical migration from deeper depths (up to 600 m) during the daytime (related to feeding or to light) and moving into the mixed surface layer (upper 200 m) at night for feeding (Palko et al. 1981; Holts 2001).

Research suggests that swordfish do not seem to have a discrete spawning ground or spawning season (PFMC 2003c). Larvae and juveniles tend to occur in warmer tropical and subtropical

regions. No egg and larval habitats have been reported for the U.S. west coast EEZ, although larvae have been reported as far north as 35°N latitude in late summer (Grall and de Sylva 1983). Spawning occurs throughout the year in equatorial waters but is progressively restricted to spring-summer at higher latitudes. In the eastern Pacific, the distribution narrows, probably because of lower water temperatures associated with the Peru Current and upwelling in that region (PFMC 2003c). Swordfish are oviparous and are believed to spawn inshore from the surface to 75 m (MBC 1987). There is some evidence for pairing of spawning adults, as this species apparently does not school (Palko et al. 1981). Peak spawning occurs in the north Pacific between May and August, from December to January in the south Pacific, and from March to July in the central Pacific (Palko et al. 1981). It is probable that some degree of spawning occurs throughout the year in tropical waters between 20°N and 20°S, due to the distribution of larvae associated with SSTs between 24° and 29°C (PFMC 2003c).

Common Prey Species—Swordfish prey upon squid and pelagic fishes including dorado, barracuda, flying fish, clupeids, sauries, Pacific hake, gadids, jack mackerel, shortbelly rockfish, and small scombrids (Squire and Smith 1977; Palko et al. 1981; Nakamura 1985; FLMNH[9]).

EFH Designations—(PFMC 2003b; **Figure E-11**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.
- Juveniles-males (males <102 EFL or 118 cm JFL; females <144 cm EFL or <163 JFL)—EFH is identified as oceanic, epipelagic, and mesopelagic waters from the U.S./Mexico EEZ border north to 41°N latitude; in the SCB primarily south of the Santa Barbara Channel Islands from the 732 m isobath out to the EEZ boundary, and north of Point Conception, California from the 1,829 m isobath westward to the EEZ outer boundary and northward to 41°N latitude in the Pacific Northwest OPAREA.
- Adults (males >102 cm EFL or 117 JFL; females >144 cm EFL or 162 JFL)—EFH includes oceanic, epipelagic, and mesopelagic waters out to the EEZ boundary, inshore to the 732 m isobath in southern and central California from the U.S./Mexico EEZ border north to 37°N latitude, and in the Pacific Northwest OPAREA beyond the 1,829 m isobath northward to 46°40'N latitude.

4.5 Fisheries Resources

The commercial and recreational fishing industry is a valuable economic resource in the Pacific Northwest OPAREA and Puget Sound Study Area. Various fisheries throughout the study area from northern California to Washington State including Puget Sound make significant economic contributions in both domestic and foreign markets. Recreational fishing, based on angler expenditures, is also economically important to the study area (Thomson 2001). Southern California has more than twice the numbers of resident and non-resident saltwater anglers than northern California, Oregon, and Washington State combined, whereas Oregon had the largest share of non-resident ocean anglers (19%) from 2000 to 2002 (NMFS-NWR 2005). For this reason, there is much emphasis on protecting and managing these resources to maintain viability to both these industries.

4.5.1 Introduction

The varied topography of the study area offers plants and animals a great number of diverse environments. Fishery species utilize spawning, nursery, feeding, and seasonal grounds within the study area's inshore (including bays and estuaries), nearshore, and offshore waters. See Sections 2.3 through 2.6 for detailed descriptions of the oceanographic and biological environment of the Pacific Northwest OPAREA and Puget Sound Study Area.

The occurrence and distribution of fishery activity is naturally related to the occurrence and distribution of target species (i.e., fish and invertebrates) and the ability of fishermen to locate and land these species. For most commercial and recreational fishing endeavors, successful fishing stems from the ability to anticipate the occurrence of target species at a given place and time. The distribution and abundance of

fishery species in the Pacific Northwest OPAREA and Puget Sound Study Area depend greatly on the physical and biological factors associated with the individual species such as: salinity, temperature, dissolved oxygen, food/prey availability, habitat quality, reproductive/life cycles, seasonal movements, population dynamics, and recruitment success, among others (Helfman et al. 1999). With few exceptions, the process of fishing involves constant searching. The affinity of target species for particular habitats, the physiological tolerance to environmental factors, and the availability of food items are the primary factors influencing the spatial distributions of species. Life history stages and movements, along with seasonal environmental changes (e.g., salinity and temperature), are the primary factors that influence the seasonal distribution of fishes (Helfman et al. 1999).

Successful fishermen are able to "read the signs" and make educated guesses about where and when to fish. Recent technologies such as sonar, radar, and global positioning systems (GPS) as well as detailed bottom topography maps and real-time meteorological/hydrological information assist in the search for fishery species. Variations in distribution and abundance of fishery species are influenced by natural as well as human activities (Waite et al. 1994).

4.5.1.1 Fisheries Problems

Although natural patterns of variation are expected in marine fishery stocks, human activities are known to have definite effects on fish distribution and abundance. Primary among these human impacts are excessive fishing, habitat alteration, and water quality degradation (Saila and Pratt 1973; Malakoff 1997; Williams 1998; Lazaroff[10]). Human activities have the ability to affect nearly all estuarine species and the viability of coastal fisheries. Impacts in offshore areas involve habitat destruction and alteration due to fishing methods (e.g., dragging nets and dredges on the seafloor; Auster and Langston 1998).

Over the past two centuries and especially within the last 50 years, the overall intensity of fishery effort (commercial and recreational) has been increasing. High demand for fishery products and increases in recreational fishing activities have resulted in increased fishing pressure on the available resources, causing a decrease in fishery landings (Waite et al. 1994; Parker and Dixon 1998). Increased levels of technology and information have made searching and finding fish easier (SeaWeb 2002). While improvements in fishing gear and methods continue, overall catch rates in relation to effort expended are decreasing. Fishery declines are directly and indirectly attributed to several factors: habitat loss, physical habitat damage, natural events and cycles, fishing pressure, stream flow alteration, and degradation of water quality. Overfishing is considered one of the main causes in current declining catch rates (Waite et al. 1994). As fishery landings diminish, species once targeted as commercially desirable have changed to include those species that are less attractive but still available in harvestable quantities. Smaller fish, as well as those species once discarded as bycatch, are now being targeted for commercial sales (Caddy et al. 1998; Pauly et al. 1998).

4.5.1.2 Fisheries Management

Wise management and an involved fishing community have become crucial to protecting fishery industries and maintaining fishery resources in a harvestable condition. At the federal level, laws, EOs, proclamations, and regulations have been created to aid in the conservation of fishery resources. One of the mandates of the SFA was the creation of a number of interstate management agencies, called FMCs, to oversee the condition of fishery stocks in the federal waters of the EEZ (3 to 200 NM from shore). The FMCs use FMPs to set forth management objectives for specific fishery resources and formulate strategies for the best way to achieve those objectives. The NMFS participates in fishery management efforts by providing fisheries data and analysis and by supervising the management of highly migratory fish species (e.g., sharks, tunas, and billfish/swordfish), seven of which occur in the Pacific Northwest OPAREA (NMFS 2004f).

The PFMC recommends fishery management measures to the NMFS. The PFMC is one of eight FMCs in the U.S. and manages fisheries within the EEZ off the coasts of California, Oregon, and Washington State. The PFMC in conjunction with the CDFG, ODFW, and WDFW manages the majority of the fishery resources in the Pacific Northwest OPAREA and Puget Sound Study Area. The council focuses on the

major fisheries in the Pacific Northwest OPAREA and Puget Sound Study Area that require regional management. The PFMC currently oversees four major FMPs and their associated amendments for Pacific salmon, CPS (including sardines, mackerels, anchovies, squid, and krill), groundfish (including flatfish, rockfish, thornyhead, roundfish, skates, sharks, and chimeras), and HMS (including sharks, tunas, billfish, and dorado). More than 110 species are managed by these FMPs combined (Witherell 2004). The CDFG, ODFW, and WDFW are responsible for managing fisheries within 3 NM offshore. These management practices must remain consistent with federal laws.

4.5.1.3 Fisheries Closures

Fisheries closures are created for the purpose of recovering localized commercial and recreational fishery populations to harvestable levels. Through the fishery management efforts of NMFS, PFMC, and state agencies of CDFG, ODFW, and WDFW, certain marine areas are seasonally or permanently closed (i.e., Yelloweye Rockfish Conservation Area [YRCA], seaward of 30 fathom bottomfish closure area in Marine Areas 2, 3, and 4) to specific fishing activities to help protect sensitive fish stocks (i.e., bottomfish). Permanent (i.e., year-round) closures remain in place for the specified gear types (e.g., limited entry trawl and fixed gears, open access gears) until the managing bodies (i.e., NMFS) change the regulations. Changes to fishery regulations involving area closures are printed annually in the Federal Register. Closed areas may change over years in response to the status of fishery stocks. Seasonal and rolling closures are closed for given parts of the year. Rolling closures persist for a finite duration and are then re-designated and moved to another location to fulfill similar conservation or management goals (NMFS 2005g; 2006e; 2006d).

On March 8, 2006, NMFS approved the closure of bottom trawl fishing (e.g., bottom trawl roller gear: two types, dredge gear, and beam trawl gear) for groundfish within the west coast EEZ west of a line approximating the 1,280 m depth contour. In addition to the 1,280 m closure, NMFS also approved the closure of discrete areas to fishing with specific gear types (e.g., bottom trawling, bottom-contacting gears) (NMFS-NWR 2006; **Figure 4-5**). Within the Pacific Northwest OPAREA, 21 areas encompassing 11,489.3 km^2 have been closed to bottom trawl gear including five areas off Washington State (2,384.4 km^2), nine areas off Oregon (4,802.9 km^2), and five areas off California (2,887.6 km^2) and to all bottom contact gear including two areas off Oregon (1,414.4 km^2) (NMFS 2006d; **Figure 4-5**). The closed areas off Washington State do not apply to the Pacific Coastal Treaty Tribes' U&A Fishery Grounds and Stations described at 50 CFR 660.324 (c).

4.5.2 Commercial Fisheries

The major commercial fisheries in the Pacific Northwest OPAREA and Puget Sound Study Area are salmon, coastal pelagic, groundfish, highly migratory, other major finfish, and invertebrate fisheries. These fisheries contribute to the bulk of commercial fishing activity occurring in the ocean waters off the coasts of northern California, Oregon, and Washington State and the inland marine waters of Strait of Juan de Fuca and Georgia Strait and estuarine areas of Puget Sound. The spiny dogfish is also targeted in the Pacific Northwest OPAREA and Puget Sound Study Area and is associated with the groundfish fishery, while the common thresher shark is associated with the HMS fishery. Commercial fisheries are generally referred to by the species targeted or by the gear type used, and are defined by location and season. The top fishery gears used in the study area and their landings in tons and dollar value for the past 10 years are listed in **Table 4-6**. Below is a list of common gears types used off the coast of the Pacific Northwest (Recht 2003):

- Set Gillnets: are gillnets that are anchored to the seafloor and may be fished on the ocean bottom or floating above the anchors. In California, set gillnets are only allowed outside the 3 NM limit and used to catch California halibut (*Paralichthys californicus*), angel sharks (*Squatina californica*), lingcod, mullet, perch, and rockfish. These nets are banned in Oregon and Washington State except for small numbers of treaty set net fisherman on the Columbia River and on certain small rivers in western Washington State.

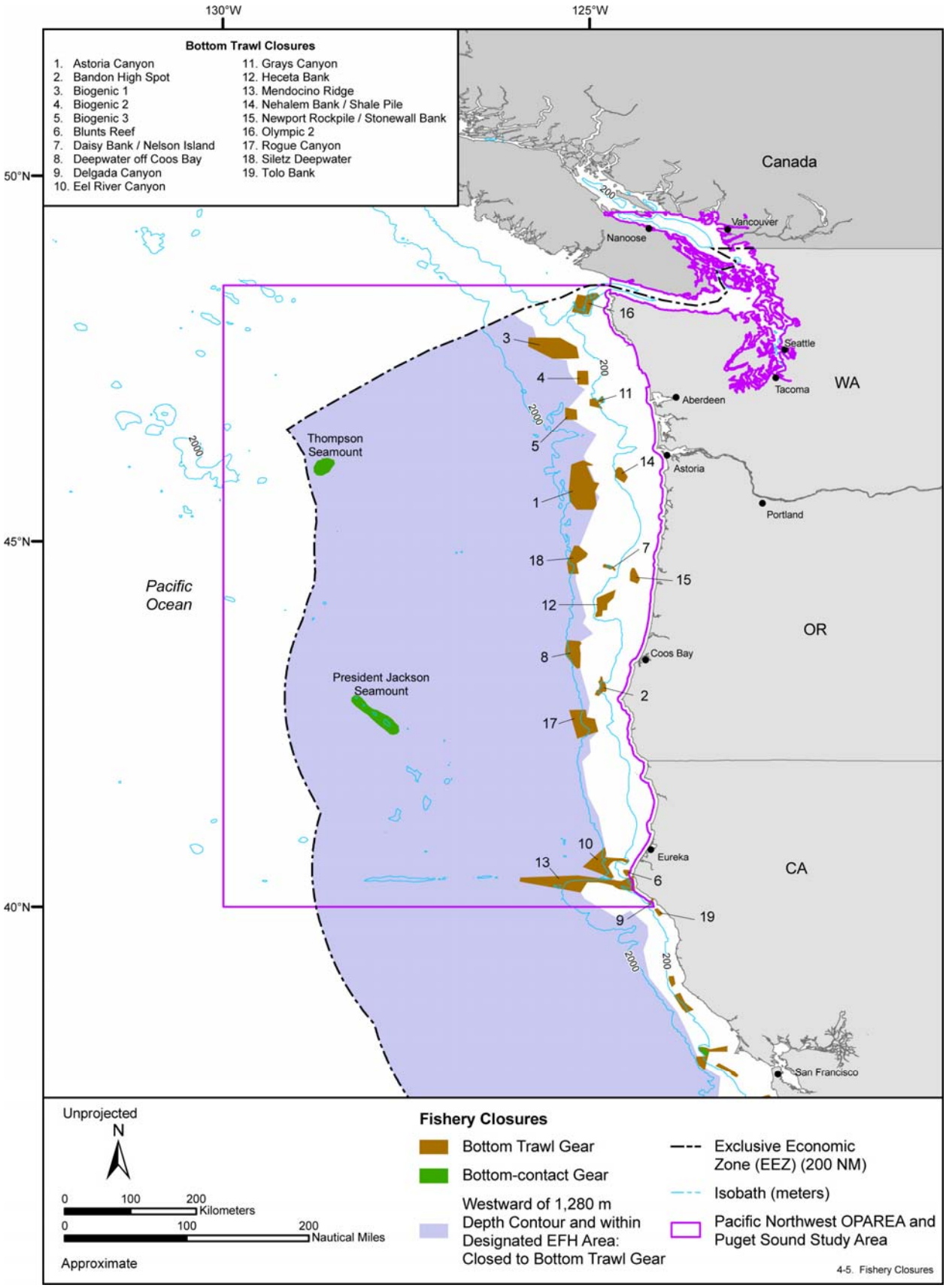


Figure 4-5. Groundfish fishery closures in the Pacific Northwest OPAREA and vicinity. Source data: Sound GIS et al. (2005a, 2005b).

Table 4-6. Top fishery gears used in California, Oregon, and Washington State and their landings in metric tons and dollar value for the years 1994 through 2003 combined.

Gear	Metric Tons	Value
Nets, excluding trawls	1,663,160.90	$616,397,720
Unspecified Gear	686,076.60	$616,957,982
Trawls, Unspecified	1,168,304.20	$487,525,076
Lines Hand, Other	110,958.90	$330,727,976
Pots And Traps, Other	241,182.90	$932,563,614
Lines Troll, Other	137,747.50	$288,285,384
Otter Trawl Bottom, Shrimp	175,053.00	$189,774,251
Dredge Other	5,278.30	$147,727,069
Total:	**4,187,762.30**	**$3,609,959,072**

Source: NMFS[11]

- Drift Gillnets: are gillnets attached to the stern of a fishing boat and allowed to drift below the ocean surface. Sharks and swordfish are among some of the species targeted using drift gillnets. These nets are prohibited in California coastal waters and in Washington State ocean waters.

- Longline Gear: are lines that are deployed horizontally to which gangions and hooks or pots are attached. Longlines can be stationary, anchored, or buoyed lines that may be hauled manually, electrically, or hydraulically. Pelagic longline gear is most often used to catch swordfish, sharks, and tunas, whereas the bottom longline gear targets fish living directly on bottom (Pacific halibut, cabezon, lingcod, etc.) or living very near the bottom (rockfish, sablefish, etc.).

- Troll Gear: consists of up to six stainless steel lines running from hydraulic spools to outrigger poles from which they are spread and suspended from the boat. Baited hooks are then attached to the stainless steel mainlines at regular intervals using monofilament leaders. The lines are then pulled slowly through the water (trolling). Trolling gear is used to target salmon, albacore tuna, and groundfish.

- Trawls: are sock-shaped nets having a wide mouth, which tapers into a narrow tail, called a codend. Trawls can be used to fish on or near the ocean floor (bottom) or higher in the water column (mid-water) and are commonly used to catch groundfish, ocean “pink” shrimp, sea cucumbers, and spot prawn (*Pandalus platyceros*).

- Purse Seines: are long panels of netting used to encircle a school of fish at the surface, while the bottom of the net is cinched closed. Purse seine fisheries commonly target sardines, Pacific herring, mackerel, northern bluefin tuna, and salmon. Except for salmon fishery in Puget Sound, this gear is illegal in Washington State.

- Drum Seines: are purse seines that are hauled into drums requiring less people to operate. Drum seine fisheries commonly target bait fish in California and salmon in Washington State.

- Lampara Nets: a forerunner of the purse seine net, it is shorter and shallower than the purse seine and can be hauled in less time and with less power. Lampara nets are used for species such as sardines, anchovies, and mackerels. In Washington State, this bait net is utilized to fish the herring and coastal anchovy bait fisheries.

- Trap or Pot: gear is generally constructed of galvanized wire that may or may not be vinyl coated. Trap and pot gear are usually distributed throughout shallow water in the spring and summer and are moved into deeper waters as winter arrives. In the Pacific Northwest OPAREA and Puget Sound Study Area, traps and pots are used to target Dungeness crab, spot prawns, other crabs, black cod (sablefish), and finfish (nearshore rockfish, cabezon, greenling).

- Dredge Gear: are composed of a low, rectangular heavy steel frame attached to a bag made of four 10 cm heavy steel rings on the bottom and on the top of the rear end of the bag where the net scallop shells gather.

- Dive Gear: is used to take pursue various fish and shellfish such as urchins, lobsters, and sea cucumbers. Divers use either self-contained air tanks or breath off "hookah" systems consisting of a long air hose connected to an air compressor on the deck of a boat. Specimens are collected by hand utilizing rakes, hoes, or other hand carried implements (harpoons, spears, spearguns, or sticks) or hand-held manually operated water jet or suction devices (e.g., geoducks).

- Net Pens: are large net impoundments suspended below a floating dock-like structure anchored to the bottom, commonly rafted together, and positioned in area with adequate tidal flow to maintain water quality. These nets are used to harvest salmon in Puget Sound.

- Dipnet: consists of a small net attached to the end of a long shaft. Dipnets are used in the harvest of herring and smelt.

In 2004, the total revenue generated by commercial fisheries in California, Oregon, and Washington State was approximately $396 million.[11] However, the actual economic value to the Pacific coast region is far greater, in terms of jobs, goods, and services associated with these fisheries.

Of the directed fisheries off California, Oregon, and Washington State, the Dungeness crab fishery creates the most revenue annually (over $112 million in 2004).[11] The groundfish and salmon fisheries rank next in terms of annual revenue produced (approximately $50 million each in 2004).[11] The Pacific whiting fishery was the chief fishery in terms of landings with greater than 96 mt followed by the Pacific sardine (>89 mt), Dungeness crab (>30 mt), Pacific salmon (>19 mt), and albacore tuna (>14 mt).[11] Pacific sardine ranked fifth in value of landings behind albacore tuna and market squid grossing 10 million.[11] Other significant fisheries in terms of revenues off California, Oregon, and Washington State include Pacific herring, swordfish, Pacific halibut, red sea urchin, sea cucumbers, ocean "pink" shrimp, and spot prawn.[11]

Fishery activities occur at varying degrees throughout the year in virtually every part of the Pacific Northwest OPAREA and Puget Sound Study Area. Types of fishing gear used in the study areas fisheries are listed in **Table 4-7**. The list includes fisheries managed by the PFMC, states of California, Oregon, and Washington, and Native American tribes. The potential of any gear depends on the specific of each fishery and each gear type (e.g., some trawl gear is fished on or near the bottom and some in mid-water, nets vary by configuration and in response to mesh size restrictions, fisheries are controlled by various time and area restrictions, etc.) (PFMC 1999b). A brief description of each primary fishery that occurs within the Pacific Northwest OPAREA and Puget Sound Study Area is presented in the following paragraphs.

4.5.2.1 Salmon Fisheries

Pacific salmon support important an offshore and inshore commercial fisheries in the Pacific Northwest Region. Since 1977, the ocean salmon fisheries in federal waters of the U.S. EEZ off California, Oregon, and Washington State have been managed under a "framework" FMP entitled the Pacific coast salmon FMP (PFMC 2003d). The salmon fisheries region extends from the Washington State/Canadian border south to the Mexican border with nearly all of the salmon fisheries being located north of Point Conception, California (NMFS-NWR 2003b). Three of the four salmon fishery management areas occur

Table 4-7. Major commercial fisheries of the Pacific Northwest OPAREA and Puget Sound Study Area including their seasons and gear used (peak months/seasons given in parenthesis).

Fishery	Season	Gear
Salmon Fisheries		
Chinook Salmon	March through October	Troll, Gill Net, Purse Seine, Hook-and-Line, Dip Net, Weir, Net Pens
Coho Salmon	March through October	Troll, Gill Net, Purse Seine, Hook-and-Line, Dip Net, Weir, Net Pens
Pink Salmon	March through October	Troll, Gill Net, Purse Seine, Hook-and-Line, Dip Net, Weir, Net Pens
Coastal Pelagic Fisheries		
Pacific Sardine	Year Round (Seasonal by region)	Purse Seine, Lampara Net.
Northern Anchovy	Year Round (Seasonal by region)	Purse Seine, Drum Seine, Lampara Net
Jack Mackerel	Year Round (Winter and Spring)	Purse Seine, Lampara Net
Chub Mackerel	Year Round (Harvest Guidelines)	Purse Seine, Drum Seine, Trawl, Dipnet, Gillnet, Line Gear, Lampara Net
Groundfish Fisheries		
Flatfish	Year Round (Seasonal by species and region)	Trawl Gear
Rockfish	Year Round (Seasonal by species and region)	Trawl, Trap, Troll, Gillnet, Longline
Roundfish	Year Round (Seasonal by species and region)	Troll, Longline, Trawl, Set Net, Trap, Gillnet, Hook –and Line
Sharks and Skates	Year Round (Seasonal by species and region)	Gillnet, Longline, Trawl, Hook –and Line, Set Net
Highly Migratory Species Fisheries		
Tunas	Year Round (Seasonal by species and region)	Troll, Gillnet, Longline, Purse Seine, Hook –and Line
Sharks	Year Round (Seasonal by species and region)	Drift Gillnet, Set Gillnet
Swordfish	Year Round (August through December)	Longline, Harpoons, Drift Gill Net
Other Significant Finfish Fisheries		
Pacific Halibut	Year Round (Seasonal by region)	Trawl, Hook-and-Line, Longline
Invertebrate Fisheries		
Abalone	Year Round (Seasonal by species and region)	Diver, Abalone Iron
Red Sea Urchin	Year Round (Closures vary monthly)*	Diver, Hand Rake
Ocean "Pink" Shrimp	April through October	Trawl, Pot, Trap

Table 4-7. Continued.

Fishery	Season	Gear
Invertebrate Fisheries (continued)		
Sea Cucumber	Year Round (Closed March 14 through June 16 in Halibut Trawl Grounds)	Diver, Trawl, Hand Rake
Dungeness Crab	December through March	Pot, Trap
Other Shellfish: Clams, Oysters	Year-Round (Spring through Summer)	Shovel, Hydraulic Dredge, Clam Gun, Hand-held Manually Operated Water-jet, Suction Devices,
Marine Plant Harvest		
Kelp	Year Round	Ships

Sources: Compagno (1984a), Weber (1997), PFMC (1998b; 2003c), NMFS (1999), Radtke and Davis (2000), Leet et al. (2001), CDFG (2004), Recht (2003), and Witherell (2004).

within the Pacific Northwest OPAREA and Puget Sound Study Area: U.S./Canadian border to Cape Falcon, Oregon, Cape Falcon to Klamath Management Zone (KMZ), and Humbug Mountain, Oregon to Horse Mountain, California (comprises the KMZ) (NMFS-NWR 2003a), West coast fisheries in Council-managed waters are directed toward and harvest primarily chinook or king salmon and coho or silver salmon. Small numbers of pink salmon are also harvested, especially in odd-numbered years, primarily off Washington State and Oregon (NMFS-NWR 2004a). There are no directed fisheries for other Pacific salmon species (sockeye, chum, steelhead, sea-run cutthroat) as they occur rarely in Council-managed harvests (PFMC 2005h).

4.5.2.1.1 Ocean Pacific salmon

Ocean Pacific salmon are harvested by commercial troll fisheries along the continental shelf within 65 km of the coastline (NMFS-NWR 2003b). Annual commercials landings of all five salmon species for the past 10 years are presented in **Figure 4-6**. In 2004, chinook, chum, and coho comprised 96% of the landings and 95% of the revenue for the commercial ocean salmon fisheries.[11] The substantial increase in chum salmon fisheries from 2000 to 2004 were harvested mainly in Washington State.[11] Management measures for the ocean salmon fishery are published annually by NMFS (NMFS 2005g). These measures establish fishing areas, seasons, quotas, legal gear, recreational fishing days and catch limits, possession and landing restrictions, and minimum lengths for salmon taken in the U.S. EEZ of California, Oregon, and Washington State. In addition, these measures are intended to prevent overfishing and to apportion the ocean harvest equitable among Pacific Coast Treaty Indian Tribes, non-treaty commercial, and recreational fisheries (NMFS 2006c). The measures also allow a portion of the salmon runs to escape the ocean fisheries to provide for spawning and to provide for inside fisheries occurring in state internal waters.

4.5.2.1.2 Inshore Pacific salmon

Inshore salmon fisheries are conducted within Puget Sound, Grays Harbor, Willapa Bay, and Columbia River as well as the Klamath, Quinault, Queets, Hoh, and Quillayute rivers managed by the respective states (Oregon and Washington State), PSC (established by the PST in 1985), and Native American tribes (PFMC 1999a; NMFS-NWR 2004b; ODFW 2005; WDFW 2005c). Within Puget Sound, commercial and recreational fisheries consisting of chinook, coho, pink, and sockeye salmon are conducted within 38 management and catch reporting areas (WDFW 2005c). Salmon fisheries utilize trolls, set nets and drift

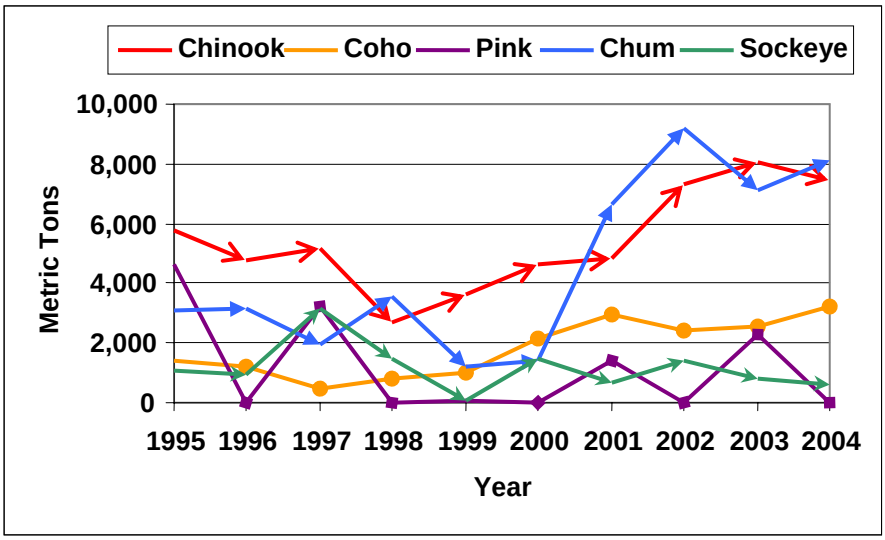


Figure 4-6. Annual landings of chinook, coho, pink, chum, and sockeye salmon for California, Oregon, and Washington State between 1995 and 2004. Source: PacFIN.[12]

gill nets, purse/round-haul seines, beach seines, reef net gear, and salmon net pens in Puget Sound (NMFS-NWR 2004a). Tribal and subsistence (U&A) fisheries also operate in Puget Sound, coastal bays of Washington State, Columbia River and its tributaries, and Klamath River utilizing gillnets, dipnets, and hook-and-line gear (Witherell 2004).

The Puget Sound Region salmon drift gillnet fishery includes all inland waters south of the U.S./Canada border and east of the Bonilla/Tatoosh line, at the entrance to the Strait of Juan de Fuca. This commercial fishery is a limited entry fishery with seasonal openings, area closures, and gear restrictions. It is managed by the WDFW consistent with the U.S./Canada PSC management regimes and the ocean salmon management objectives of the PFMC. U.S. and Canadian Fraser River sockeye and pink salmon fisheries are managed by the bilateral Fraser Panel in Panel Area waters (Carretta et al. 2005b).

In Washington State, the salmon net pen fishery is managed by the Washington Department of Natural Resources (WDNR) through Aquatic Lands Permits as well as WDFW. Net pens are found in the protected waters in the Straits (Port Angeles), northern Puget Sound (in the San Juan Island area) as well as in Puget Sound south of Admiralty Inlet. Salmon pens operate year-round with no known specific regulations. There are no commercial salmon net pens in Oregon (Carretta et al. 2005a).

4.5.2.2 Coastal Pelagic Fisheries

Several CPS stocks support fisheries along the U.S. west coast from southern California to Alaska, including the Pacific sardine, northern anchovy, jack mackerel, chub (Pacific) mackerel, and market squid (PFMC 1998b). The CPS FMP distinguishes between “actively managed” and “monitored” species. Actively managed species (Pacific sardine and Pacific mackerel) are assessed annually by harvest guidelines and fishing seasons (NMFS 2006e). The remaining CPS (northern anchovy, jack mackerel, and market squid) are monitored to ensure their stocks are stable, but annual stock assessments and federal fishery controls are not used. CPS are harvested directly and as bycatch in other fisheries. Generally they are targeted with “round-haul” gear including purse seines, drum seines, lampara nets, and dip nets. These species are also taken incidentally with midwater trawls, pelagic trawls, gillnets, trammel nets, trap pots, hook-and-line, and jigs (PFMC 2005e).

Fisheries for CPS along the west coast can be divided into two areas: north and south of Pigeon Point, California (approximately 37°10’N latitude). Originally, the entire commercial fishery for CPS finfish and market squid took place south of Pigeon Point. However, since 2000, CPS fisheries (notably, targeting

Pacific sardine) increased in waters of the Pacific Northwest. The Pacific Northwest fishery utilizing purse seines or lampara nets targets larger sardine, which are typically sold as bait for Asian longline tuna fisheries (PFMC 2005e).

4.5.2.2.1 Pacific sardine

Pacific sardines are jointly managed by the states of California, Oregon, and Washington State and PFMC. Under the PFMC FMP, the biomass of sardines is estimated each year and a coast-wide harvest guideline is established and allocated by NMFS (ODFW 2005).

Except for the coast-wide harvest guideline, management of sardines north of 39°N latitude (approximately Point Arena, California) continues under state management as long as the management measures are consistent with FMP. In northern California, sardines are a state managed, open access fishery, however, essentially no fishing occurs in this area. The fisheries south of 39°N moved from a state limited entry system to federal limited system managed by NMFS under Amendment 8 to the CPS FMP (PFMC 1998b). In Oregon, the sardine fishery operates as a developmental fishery in an area approximately 45 NM north and 35 NM south of the Columbia River at depths ranging from 12.8 to over 729 m approximately 25 NM offshore. The Washington State sardine fishery operates in an area approximately 90 NM north and 30 NM south of the Columbia River at depths ranging from 12.8 to over 546 m approximately 35 NM offshore. In Washington State, sardines are managed under Emerging Commercial Fishery provisions as an experimental commercial fishery. This fishery allows the harvest of a newly classified species of harvest of a previously classified species in a new area or by new means (PFMC 2005e). Pacific sardine landings for the Pacific northwest has steady increased from 1,155 mt in 2000 to 39,861 mt in 2004 (Conser et al. 2004). Of the total annual landings reported in 2004 for the U.S. west coast, the Pacific northwest fishery accounted for 45% of the total catch.[12] Annual commercials landings of the Pacific sardine for the past 10 years are presented in **Figure 4-7**.

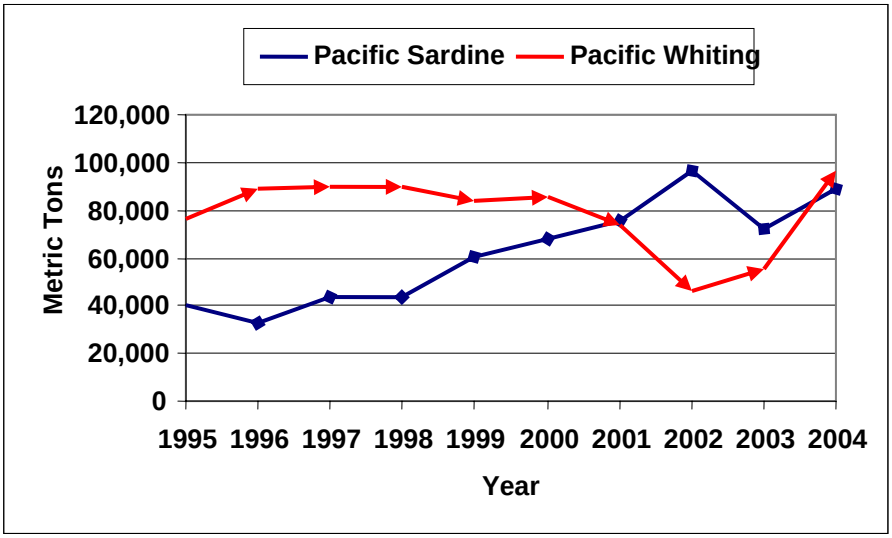


Figure 4-7. Annual landings of Pacific sardine and Pacific whiting for California, Oregon, and Washington State between 1995 and 2004. Source: PacFIN.[12]

4.5.2.2.2 Other coastal pelagic species

The remaining species comprising the coastal pelagic complex do not support a substantial fishery in the Pacific Northwest. The other "actively managed" species, Pacific (chub) mackerel and one of the monitored species, market squid, are currently harvested in southern California/Mexico (Hill and Crone 2005) and southern/central California (CDFG 2005), respectively. The remaining monitored species,

northern anchovy and jack mackerel, contribute minimal landings to the overall fisheries off Oregon and Washington State. From 1981 through 2001, there were no reported landings of northern anchovy in Oregon with 3.1 mt reported in 2002, 39 mt in 2003, and 13 mt in 2004. Washington State reported about 42 mt in 1988, but did not land more until 2003 with 214 mt and not reported for 2004. Oregon reported 161 mt of jack mackerel in 2000, 183 mt in 2001, 8.9 mt in 2002, 73.6 mt in 2003, and 125.8 mt in 2004. Washington State reported 11.5 mt in 2002 and 1.8 mt in 2003, but none was specified in 2004. All of these species have landing of less than one mt in northern California (PFMC 2005e).

4.5.2.2.3 Krill

Currently, there are no directed krill fisheries in PFMC-managed waters (NMFS-SWR 2006). Commercial krill fishing is prohibited in the state waters of Washington State, Oregon, and California. Under Amendment 12, krill have been placed in the "prohibited harvest" category of the management unit species which prohibits the harvest and retention of krill in the U.S. EEZ and denies the use of the exempted fishing permit process under CPS FMP to allow krill fishing (NMFS-SWR 2006). The only krill fishery along the U.S.-Canada Pacific coast exists in the Strait of Georgia, British Columbia (Nicol and Endo 1997). *E. pacific* is typically one of the dominant fished species, accounting for over 70% of the euphausiid biomass (Nicol and Endo 1997). An estimated 50% of the catch is used as aquarium food (Nicol and Endo 1997). Krill fishing areas in Canadian waters are located to the north (Strait of Georgia, Malaspina Strait, and Jervis Inlet) and east (Howe Sound) of the Nanoose Range (Nicol and Endo 1997, 1999).

4.5.2.3 Groundfish Fisheries

The Pacific Northwest OPAREA and Puget Sound Study Area's commercial groundfish fishery involves the grouping of finfishes, which inhabit the bottom level of the water column and are often found in mixed assemblages. Over 75 species are included in the groundfish fisheries off the coast of northern California, Oregon, and Washington State including, 12 species of flatfish, 54 species of rockfish, eight species of roundfish, and seven shark, skate, and chimeras species. Targeted groundfish species in northern California, Oregon, and Washington State include flatfish (flounders, soles), rockfish, roundfish (lingcod, Pacific whiting, Pacific cod, and sablefish), and sharks/skates. Groundfishes are generally harvested in multispecies complexes (i.e., more than one species caught at a time), and the fishery is conducted across a wide range of habitats using an assortment of fishing gears. Gear types include trawl nets, gillnets, longline, troll, jig, rod and reel, vertical hook and line, pots/traps, and other gear (e.g., spears, throw nets) (Witherell 2004). Landings of groundfish peaked in the early 1980's but have leveled off since then. Much of the decline of groundfish species in the 1980's was due to their transition from a lightly exploited, highly abundant stock level to a fully exploited, moderately abundant stock level (PFMC 2004a).

NMFS governs commercial and recreational groundfish fisheries in federal waters of the EEZ within the study area. The U.S. west coast groundfish fishery consists of four components: limited entry, open access, recreational, and tribal. Groundfish are managed through a number of measures including harvest guidelines, quotas, trip and landing limits, area restrictions, seasonal closures and gear restrictions (such as minimum mesh size for nets and small trawl footrope requirements for landing shelf rockfish) (PFMC 1998a). These groundfish specifications and management measures are developed by the PFMC and implemented annually (NMFS 2006d).

4.5.2.3.1 Flatfish

Flatfish species harvested in northern California, Oregon, and Washington State include various sole species, flounders, and sanddab. Flatfish are almost exclusively harvested using trawl gear. Of the 12 flatfish species harvested commercially in northern California, Oregon, and Washington State, Dover sole is the most economically important with arrowtooth flounder, petrale sole, and English sole ranking second, third, and fourth. Annual landings of Dover sole over a 10-year period gradually declined from 11,439 mt (1995 to 1997) to 8,945 mt (1998 to 2000) to 6,934 mt (2001 to 2004); whereas the arrowtooth

flounder has averaged just 4,298 mt per year from 1995 through 2004, peaking in 1999 at 6,453 mt (**Figure 4-8**).[12]

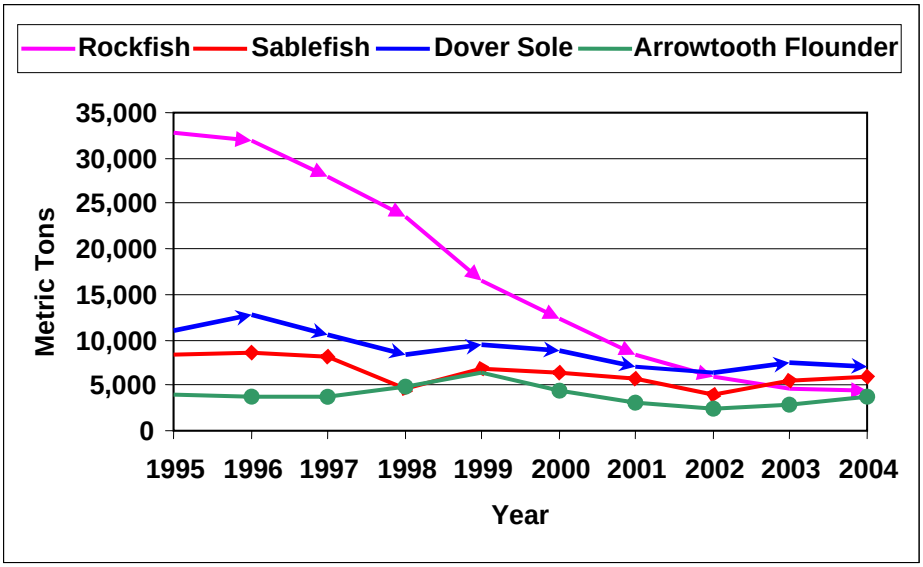


Figure 4-8. Annual landings of rockfish, sablefish, Dover sole, and arrowtooth flounder for California, Oregon, and Washington State between 1995 and 2004. Source: PacFIN.[12]

Dover sole started as an undesirable by-catch of the bottom trawl fishery in the 1940's but has evolved into the most abundant flatfish landed in the states of California and Oregon.[12] This increase was the result of increased market demand during WWII and technological advances in fish handling and processing. Dover sole are targeted by deep-water trawl gear and are a highly valued commercial fishery bringing in over $5.6 million in 2004.[12] Petrale sole and English sole are both harvested using trawl gear, but they are seldom specifically targeted and the majority of the harvest comes from incidental catches in other groundfish fisheries.

4.5.2.3.2 Rockfish

Rockfish (*Sebastes* and *Sebastolobus* spp.) are one of the Pacific coast region's most important groups of commercial fish, bringing in almost $7.6 million in revenue in 2004.[11] Some of the more economically important rockfish in the Pacific Northwest OPAREA include shortspine thornyhead, darkblotched, minor slope (chilipepper, cowcod), and shortbelly, widow, yellowtail, canary, yelloweye, and black rockfish (NMFS 2006d). The majority of rockfish are harvested using bottom trawl gear (89%) with other gears used especially near shore and in high-relief areas (hook and line: 9%) and other gears (traps, troll, gillnet: 2%) (Parker et al. 2000). Rockfish landings have declined dramatically over the past 10 years from 32,832 mt in 1995 to a projected low of 2,689 mt in 2005 (**Figure 4-8**).[12]

4.5.2.3.3 Roundfish

Species of roundfish commonly landed in northern California, Oregon, and Washington State include lingcod, cabezon, Pacific cod, Pacific whiting (hake), and sablefish.[12] Lingcod are caught commercially using bottom trolling, longline gears, trawls, and set gillnets, whereas cabezon are mainly harvested by incidental catch from fisheries utilizing trap, gillnet, and hook and line gears (NMFS-NWR 2004c). Both of these fisheries provide a minor portion of the flatfish fisheries with Pacific whiting, sablefish, and Pacific cod comprising the dominant portion in the Pacific Northwest OPAREA. Pacific cod are harvested primarily using bottom trawling and longlining. Over the past 10 years, Pacific cod annual landings decreased from 923 mt in 1995 to a low of 358 mt in 1999 then rebounded dramatically to a high of 1,594

mt in 2004.[12] The mid-water trawl fisheries for Pacific whiting and sablefish are the two largest components of the groundfish fisheries with Pacific whiting accounting for 77% of the total annual landings and sablefish accounting for 35% of the total revenue in 2004.[12]

The Pacific whiting trawl fishery extends from northern California (about 40°30'N latitude) to the U.S./Canada border. This species migrates from south to north during the fishing season with the shore-based season in most of the Eureka area (between 42°N to 40°30'N latitude) beginning on April 1, the fishery south of 40°30'N latitude opening April 15, and the fishery north of 42°N latitude on June 15. This fishery is annually accessed and jointly managed through federal regulations by the PFMC under the groundfish FMP (Carretta et al. 2005b) and the Canadian Department of Fisheries and Oceans (NMFS-NWR 2004c). Over the past 10 years, Pacific whiting made up more than 66% of the potential annual harvest of west coast groundfish off the coasts of California, Oregon, and Washington State. However, the majority of Pacific whiting are caught in Oregon and Washington State (combined total of 95%), with California only representing a small percentage (<5%) of the total catch (**Figure 4-7**; PacFIN [12]).

Of the three different sablefish stocks along the west coast of North America, the stock distributed from northern California to Washington State is characterized by moderately fast growth, a large maximum size, and supports the bulk of fisheries in the Pacific northwest region (NMFS-NWR 2004c). Sablefish are harvested commercially using longline, trap, bottom trawl, and gillnet gears. Over the past 10 years, sablefish landings averaged 8,412 mt and $27 million in revenue from 1995 through 1997, then declined and leveled off from 1998 to 2004 averaging 5,559 mt and $16 million in revenue (**Figure 4-8**; PacFIN[12]).

4.5.2.3.4 Sharks and skates

Six species of sharks and skates are harvested to varying degrees along the U.S. west coast including leopard shark, soupfin shark, spiny dogfish, big skate, California skate, and longnose skate. Of the sharks with the Pacific Northwest OPAREA and Puget Sound Study Area, both the soupfin and leopard sharks comprise a minor component of the fisheries, whereas the spiny dogfish is the most abundant and economically important shark off North American coasts (NMFS-NWR 2004c) especially in Puget Sound, Washington State (Hanson 1999; PacFIN[12]). In recent years, large numbers of dogfish have been taken in commercial trawl, set net, and longline fisheries, to supply foreign markets (NMFS-NWR 2004c). From 1995 to 1996, spiny dogfish averaged 2,125 mt before gradually declining over to a low of 634 mt in 2004 in Washington State. For the past 10 years, Washington State accounted for 91% of the spiny dogfish fishery landings along the west coast.[12]

Coastal trawl fleets account for the majority of all skate landings off the west coast, although some are caught by trammel nets in California and longline in Puget Sound (NMFS-NWR 2004c). Skates are usually caught incidentally in the sole and rockfish fisheries (PFMC 2004a). Only the wings of skates are marketed, primarily being sold in the Asian fish markets in southern California (NMFS-NWR 2004c). Both California and Oregon dominated the skate fisheries, comprising 81% of the total landings over the past 10 years (1995 to 2004). However, skate landings in California continued to decline dramatically from the average of 844 mt (1996 to 2000) to the average of 104 mt (2001 to 2005), whereas the skate levels in Washington State remained stable.[12]

4.5.2.4 Highly Migratory Species Fisheries

HMS are distributed over wide areas of the open ocean and often occur outside of the effective ranges and jurisdictions of U.S. fisheries. The HMS FMP final rule implements rules and regulations necessary for federal management of U.S fishing vessels targeting HMS within the U.S. west coast EEZ of California, Oregon, and Washington State and to U.S. vessels that pursue HMS on the high seas (seaward of the EEZ) and landed their fish in either of these three states (PFMC 2005d). In addition, effective management of HMS stocks throughout their ranges requires international cooperation. The HMS FMP and associated fisheries are affected by international regulations, primarily resolutions enacted by the Inter-American Tropical Tuna Commission (IATTC), as well as by the recently formed Western and Central Pacific Fisheries Commission (WCPFC) and the U.S./Canada Albacore Treaty (PFMC 2005d). Species include tunas (albacore, yellowfin, bigeye, skipjack, and northern bluefin), sharks (common,

bigeye, and pelagic threshers, shortfin mako, and blue), billfish (striped marlin), broadbill swordfish, and the dorado (dolphinfish or mahi mahi). Some of these species are highly valued by both commercial and recreational fisheries (PFMC 2003c). In the Pacific Northwest OPAREA, the only HMS harvested in significant quantities is the albacore tuna (PFMC 2005d).

4.5.2.4.1 Albacore tuna

The U.S./Canada Albacore Treaty is a 1981 agreement between the governments of Canada and the U.S., amended in 2002, and codified by law in April 2004 (NMFS 2004i). It allows U.S. vessels to fish albacore in Canadian waters seaward of 12 NM from shore and Canadian vessels to fish for albacore in U.S. waters seaward of 12 NM form shore. In addition, the treaty allows Canadian vessels to use certain U.S. ports to obtain supplies and services and to land fish, and it allows U.S. vessels to use certain Canadian ports for the same purpose (PFMC 2005d).

Albacore are usually harvested by trollers and live bait but may also be caught with longlines, purse seine, drift gillnet, and hook and line gears. Fishing efforts for albacore along the U.S. west coast usually range from about July through September and occasionally, weather permitting, into November. The albacore tuna fishery along the U.S. west coast has seen a steady increase in landings from 1995 through 2004 (**Figure 4-9**). The recent decline in California landings (1,352 mt) in 2004 does not necessarily reflect a decline in the albacore population but a shift in fishing effort by California-based vessels into waters off Oregon and Washington State where albacore have been more available due to oceanographic conditions (PFMC 2005d). Commercial landings of albacore in Oregon and Washington State in 2004 were 4,807 mt and 8,309 mt, respectively.[12]

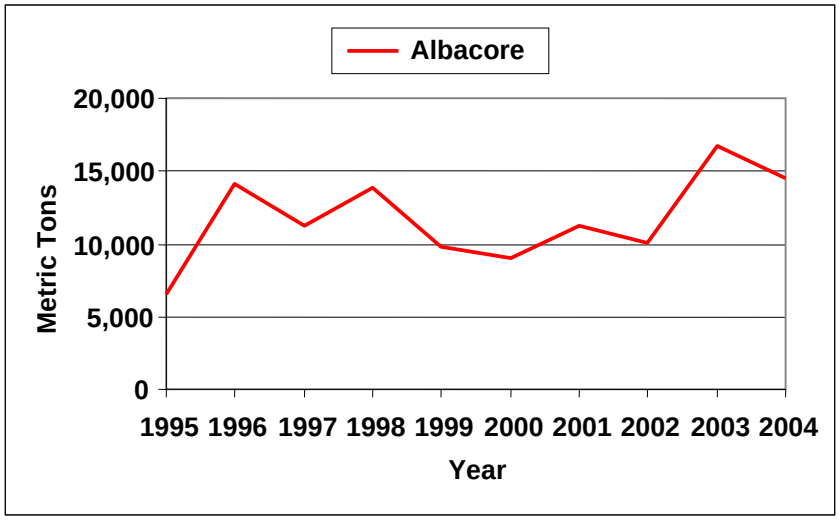


Figure 4-9. Annual landings of albacore tuna for California, Oregon, and Washington State between 1995 and 2004. Source: PacFIN.[12]

Oregon's commercial albacore jig-caught (troll-caught) fishery is a cooperative effort between ODFW, NMFS, and PSMFC. Landings of albacore in to Oregon ports usually begin in June generally continue into November with the peak occurring in July or August (PFMC 2005d). The albacore fisheries off Washington State include commercial troll, bait boats, charter boats, and recreational fishing boats. Fishing begins in early to mid-July and continues until tuna are no longer accessible, usually around late September (PFMC 2005d).

4.5.2.4.2 Other highly migratory species

The remaining species comprising the HMS do not support a substantial fishery in the Pacific Northwest OPAREA. The northern blue fin tuna is currently harvested utilizing coastal purse seine fisheries in the SCB (PFMC 2005d). Annual landings of northern bluefin tuna were punctuated by a relatively high peak in 1996 of 4,687 mt followed by a gradual and then rapid decline to 9.7 mt in 2002.[12]

Common thresher sharks are fished with swordfish off California/Oregon utilizing drift gillnets, whereas the blue shark is harvested by surface longline fishery off Oregon (Carretta et al. 2005a). The drift-net fishery is a limited entry fishery with seasonal closures and gear restrictions. A season-area closure to protect leatherback sea turtles which prohibits utilizing this fishery occurs from August 15 through November 15, in the area abounded by straight lines from Point Sur, California (36°17'N) to 34°27'N 123°35'W, west to 129°, north to 45°N, then east to Oregon coast. In addition, this fishery is prohibited from February 1 through May 15 within 200 NM from shore and from May 16 to August 14 within 75 NM of the California coastline (Carretta et al. 2005a). This fishery is managed under FMP administered by PFMC (Carretta et al. 2005a). The bulk of harvested common thresher sharks occurs off California where their annual landings have averaged 301 mt from 1995 to 2003, declining to 114 mt in 2004.[12] From Oregon to Washington State, the following restrictions apply concerning thresher sharks. In Oregon, it is unlawful to take thresher sharks for commercial purposes with gillnets except as bycatch in the swordfish fishery. Thresher shark, taken with gear legal for other ocean food fish and within catch and season restrictions for other fish food, may be landed in Oregon. In Washington State, it is unlawful to land thresher sharks taken by any means from state and offshore marine waters north of Oregon-Washington State border and south of the U.S./Canadian boundary (PFMC 2005d).

The blue shark surface longline fishery is a limited entry fishery with gear and bycatch restrictions that are managed by ODFW, Developmental Fisheries Program. This fishery occurs year-round, however, the effort in this fishery generally terminates by late fall (Carretta et al. 2005a). Commercial landings of blue shark off Oregon have been usually less than 10 mt per year (NMFS-NWR 2004a). Broadbill swordfish are mainly harvested with thresher sharks off California utilizing the drift gillnet fishery and off Oregon using swordfish surface longline fishery. Both the thresher shark drift gillnet fishery for California/Oregon and the blue shark surface longline fishery for Oregon apply to the same fishery regulations utilized for the broadbill swordfish (Carretta et al. 2005a). The Oregon commercial drift gillnet fishery is an extension of the California fishery. With implementation of the seasonal closure off northern California and southern Oregon, fishing effort off Oregon has dropped considerably which explains why the main swordfish harvest is situated in California. The annual landings of harvested broadbill swordfishes off California have averaged 1,702 mt from 1995 to 2004 peaking in 2000 at 2,653 mt.[12]

4.5.2.5 Other Major Fisheries

4.5.2.5.1 Pacific halibut

Pacific halibut (*Hippoglossus stenolepis*) is a demersal flatfish inhabiting the continental shelf of the U.S. and Canada ranging from Punta Camalu, Baja California to the Bering Sea (Allen and Smith 1988). The major spawning grounds for Pacific halibut are in the North Pacific Ocean within the Gulf of Alaska and Bering Sea (IPHC 1998).

The Pacific halibut fishery is managed by the IPHC according to the Northern Pacific Halibut Act of 1982 with implementing regulations set by the federal governments of Canada and the U.S. in their respective waters (NMFS 2004b; 2006f). For the U.S. in Area 2A (marine waters off California, Oregon, and Washington State), NMFS-Northwest Region (NWR) is responsible for allocation and management with close coordination with ODFW and WDFW. Halibut in Area 2A is divided between tribal (35%) and non-tribal (65%) fisheries, between commercial (31.7%) and recreational (68.3%) fisheries, and between recreational fisheries in these different states: Washington State – 36.6% and Oregon/California – 31.7% (NMFS 2004b; 2006f). The commercial fishery is divided into two sectors: a directed (traditional longline) commercial fishery that is allocated 85% of 31.7% (26.95% of the non-treaty harvest) and an incidental (troll salmon) commercial fishery that is allocated 15% of the 31.7% (4.75% of the non-treaty harvest).

Both the directed and non-treaty commercial fishery is confined to south of Point Chehalis, Washington State (46°53'18"N latitude), Oregon, and California (NMFS 2004b; 2006f).

Retention of incidental halibut during primary sablefish fishery north of Point Chehalis, are required to fish outside of a mandatory closed area known as the Rockfish Conservation Area (RCA). This area extends along the coast from the U.S./Canada border south to 40°10'N latitude. The RCA boundaries are as follows: between the U.S./Canada border and 46°16'N latitude (Washington State/Oregon border), the eastern boundary extends to the shoreline; between 46°16'N latitude and 40°10'N latitude; the RCA is defined along an eastern boundary approximating 55 m depth; and between the U.S./Canada border south to 40°10'N latitude, the RCA is defined along a western boundary approximating 183 m depth (NMFS 2004b; 2006f). West coast catch limits set by IPHC for the combined commercial setline, tribal, and sport fisheries have increased since the late 1990s (NMFS 2004b; 2006f). From 1995 to 2004, Washington State accounted for 76% of the Pacific halibut fishery landings (1,128 mt) of the 1,474 mt report within Area 2A (**Figure 4-10**; PacFIN[12]).

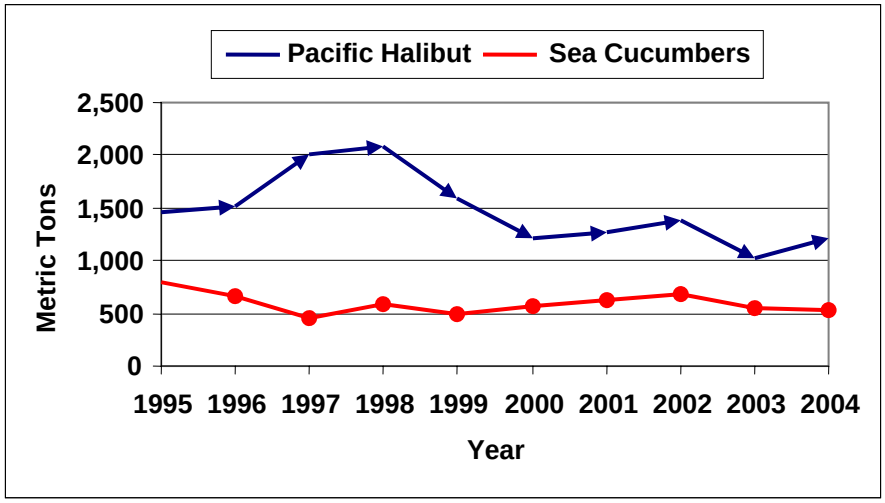


Figure 4-10. Annual landings of Pacific halibut and sea cucumbers from California, Oregon, and Washington State between 1995 and 2004. Source: PacFIN.[12]

4.5.2.6 Invertebrate Fisheries

The invertebrate fisheries off the coasts and within the bays/estuaries of northern California, Oregon, and Washington State are comprised of crustaceans (crabs, shrimp), echinoderms (sea urchins, sea cucumbers), and shellfish (clams, oysters). Harvest methods associated with the invertebrate fisheries include trawls pulled by large ocean-going vessels (shrimp), traps fished from smaller boats (crabs and prawns), ring nets (a circular frame holding a bag of web), and bare hands (recreational crabs), etc. Invertebrates make up some of the U.S. west coast's most highly prized marine resources (Kalvass 2001a, 2001b).

4.5.2.6.1 Dungeness crab

The Dungeness crab (*Cancer magister*) is found from the eastern Aleutian Islands to around Santa Barbara, California generally on sandy bottoms from the intertidal zone to 170 m in areas subject to moderate to strong currents (Emmett et al. 1991). Dungeness crabs are the most important species of crab harvested along the U.S. west coast and are managed as a "recruitment" fishery on the basis of the "3-S" principles (size, sex, season) off California, Oregon, and Washington State (ODFW 2001). Off California, this species is commercially fished in two main areas: northern and central California beginning in late fall to early summer. The northern California fishing grounds extends from Fort Bragg to

the California-Oregon border with the prime area located between Eureka and Crescent City (Hankin and Warner 2004). Almost all of California's commercial Dungeness crab catch is landed in trap fishery, whereas Oregon and Washington State utilize crab pots (or rings) (ODFW 2001; Hankin and Warner 2004). West coast seasonal regulations are designed to insure that most harvest occurs well after or before major molting periods (ODFW 2001). Both Oregon and Washington State seasons extend into low production level summer fisheries (July through August) when molting activity and soft-shell abundance are typically high (ODFW 2001). Washington State's coastal commercial crab grounds extend from the Columbia River to Cape Flattery near Neah Bay and include the estuaries of the Columbia River, Grays Harbor, and Willapa Bay.[13] In 2004, over $112 million in revenue was generated by commercial fisheries for Dungeness crab in California, Oregon, and Washington State.[11] Over the past ten years, the commercial Dungeness crab fishery along the west coast has averaged 20,965 mt peaking in 1996 (26,824 mt) and in 2003 and 2004 (36,288 mt and 30,441 mt, respectively; **Figure 4-11**; PacFIN[12]).

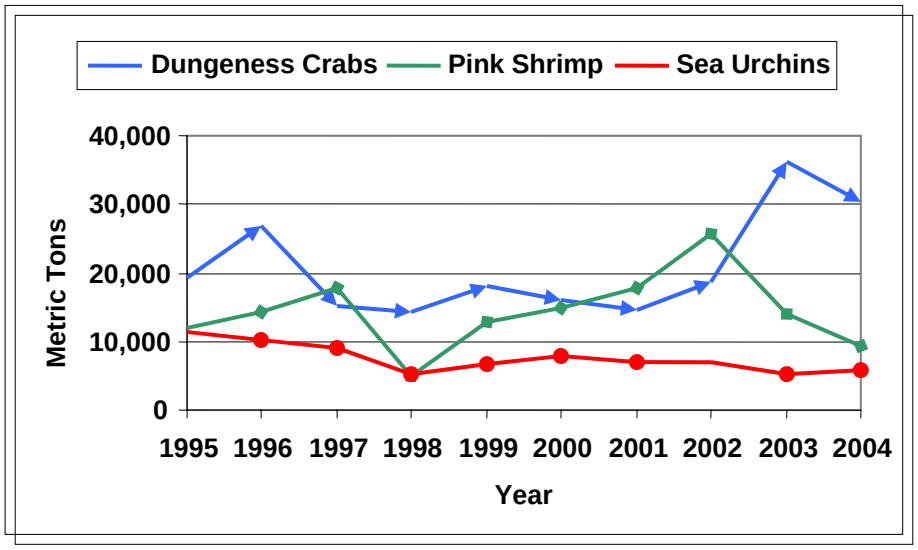


Figure 4-11. Annual landings of Dungeness crabs, ocean "pink" shrimp, and sea urchins for California, Oregon, and Washington State between 1995 and 2004. Source: PacFIN.[12]

4.5.2.6.2 Ocean shrimp

The commercial ocean shrimp (*Pandalus jordani*), also called pink shrimp, occurs from the Aleutian Islands to San Diego, California at depths ranging from 46 to 366 m over green mud and muddy-sand bottoms (NMFS-NWR 2004c). The primary gear used to harvest ocean shrimp is trawl nets (Radtke and Davis 2000). Fishing occurs in northern California from the Oregon border to False Cape and off the central and southern coast of Washington State (Collier and Hannah 2001; WDFW[16]). This limited entry fishery is managed using consistent state regulations for California, Oregon, and Washington State plus the Washington State treaty tribes rather than through a federal FMP (NMFS-NWR 2004c). The principal management regulation is a maximum count-per-pound (CPP) rule specifying that all landings in excess of 3,000 pounds (lbs) must have an average count of 160 CPP or lower (ODFW 2001). Ocean shrimp annual landings averaged approximately 13,257 mt from 1995 through 2004 peaking in 2002 to 25,587 mt (PacFIN[12]; **Figure 4-11**).

Approximately 75% of the total landings during 10-year period (1995 to 2004) were harvested off Oregon's coast.[12] Off Oregon, annual recruitment success is linked to the strength and timing of the spring transition in coastal currents immediately following larval release. An early, strong transition produces large year classes. Consequently, ocean shrimp may be inherently resistant to overfishing (Collier and Hannah 2001).

4.5.2.6.3 Sea urchins

Red (*Strongylocentrotus franciscanus*), purple (*S. purpuratus*), and green (*S.droebachiensis*) sea urchins are commercially harvested along the west coast of North America.[14] Both the red and purple sea urchins range from tip of Baja California to Sitka and Kodiak, Alaska occurring in shallow waters (mid to low intertidal zones to 50 m) on rocky substrates and exposed and semi-protected areas at depths up to 64 m, respectively; whereas the green sea urchin occurs from Point Barrow, Alaska southward to Washington State on rocky, gravelly, or shelly bottoms from intertidal pools to depths of 24 to 27 m.[14]

Red sea urchins are the most commonly harvested species within the Pacific Northwest OPAREA and Puget Sound Study Area with purple sea urchins being harvested on a limited basis only in California (Parker and Ebert 2004) and Oregon (ODFW 2001) and green sea urchins only in Washington State, mainly from San Juan Islands and Port Angeles.[15] Sea urchin harvest occurs primarily in California, Washington State, and British Columbia (Carter and VanBlaricom 2002). The sea urchin fishery began in the early 1970's in southern California and Washington State has catered mainly to the Japanese export market (Kalvass and Rogers-Bennett 2001). This fishery was spawned by an effort from the NMFS to promote fishing for "underutilized" species and to reduce sea urchin grazing on kelp beds (Kalvass and Rogers-Bennett 2001). Harvests along parts of the U.S. west coast (southern California and Washington State) declined substantially in the mid to late 1980s (Carter and VanBlaricom 2002) which then fueled the fishery expansion into northern California and Oregon (ODFW 2001; Kalvass and Rogers-Bennett 2004). The northern California fishery is centered in Fort Bragg, with ports in Albion, Point Arena, and Bodega Bay accounting for two-thirds of the catch (Kalvass and Rogers-Bennett 2001). Each individual state manages its own sea urchin fishery: California - a restricted access program, Oregon – detailed limited entry system, and Washington State – uses harvest quotas, size limits, license restrictions, limited entry, mandatory log books and closures within seven harvest districts (ODFW 2001; Carter and VanBlaricom 2002; Kalvass and Rogers-Bennett 2004; WDFW[15]).

Sea urchins are harvested by commercial divers using "hooka" gear at depths from 1.5 to 30.0 m. Divers collect sea urchins from the ocean bottom with a hand-held rake or hook and put into hoop net bag or wire basket, which is then winched onto the surface vessel.[15] It is possible for a diver to harvest up to a ton of sea urchins in one day (Weber 1997). Average annual commercial landings for the red sea urchin along the west coast from 1995 through 2004 averaged 7,416 mt with California comprising 92% of the total catch. This fishery gradually declined from its peak of 11,314 mt in 1995 to less than 5,000 mt projected for 2005 (PacFIN[12]; **Figure 4-11**).

4.5.2.6.4 Sea cucumbers

The giant red sea cucumber (*Parastichopus californicus*), also known as the California sea cucumber, is distributed from Baja California to Alaska in areas of little water movement from the low intertidal zone to depths of 91 m (Rogers-Bennett and Ono 2001). This is the only sea cucumber species that is fished commercially off northern California, Oregon, and Washington State. In recent years, sea cucumber harvest by divers has accounted for approximately 80% of all sea cucumbers landed. Most sea cucumber products are shipped overseas to Hong Kong, Taiwan, China, and Korea, with Chinese markets within the U.S. purchasing some of the sea cucumber catch (Rogers-Bennett and Ono 2001). For the past ten years (1995 to 2004), sea cucumber landings along the U.S. west coast (excluding Alaska) have averaged over 500 mt per year (PacFIN[12]; **Figure 4-10**).

Oregon's sea cucumber fishery began in 1993. At that time, it was placed within the Developmental Fisheries Program, which was developed to allow for the controlled development of new commercial fisheries. Commercial collection in Oregon waters is done primarily by hand using dive gear. Harvesting by trawl is also allowed, but requires an experimental gear permit. During the first year of the commercial fishery program, nine divers landed 2.3 mt. In 1994, 22 divers landed 4.8 mt. Aside from 1997, there has been very little harvesting of sea cucumbers in Oregon waters. Permits were issued until 2003, when sea cucumbers were moved to category B of the Developmental Fisheries Program species list, which includes those species with less potential for a viable fishery. Currently, sea cucumber harvesting in Oregon no longer requires a developmental fishery permit (ODFW 2005).

Sea cucumbers are found along the outer coast of Washington State, in the Strait of Juan de Fuca, and in Puget Sound. Commercial fisheries occur in five districts encompassing the Straits, San Juan Islands, and in Puget Sound.[17] In Washington State, it is unlawful to fish for or possess sea cucumbers taken with trawl gear without an experimental permit. As a result, sea cucumbers are primarily harvested by scuba divers. Harvests of sea cucumbers in Washington State increased dramatically from the late 1970s (around 180 mt annually) to the early 1990s (over 1,300 mt annually). As a response to heightened overfishing in the late 1980s and early 1990s, the WDFW implemented several measures that seem to have stabilized the resource. These measures included a six-month fishing season, limited entry, and a rotation of harvest between five district areas to give the resource a 3.5 year period for reproduction.[17] Since 1996, sea cucumber landings in Washington State have remained at or below 300 mt per year.[12]

4.5.2.6.5 Shellfish

Organisms representative of the various shellfishes encompassing coastal beaches and estuaries along the west coast include clams and oysters. Within Washington State, Pacific razor clam (*Siliqua patula*), geoduck (*Panopea abrupta*), Manila clam (*Veneruplis philippinarum*), and Pacific oyster (*Crassostrea gigas*) are harvested as a commercial fishery. The Pacific razor clam occurs from western Alaska to Pismo Beach, California on flat or gently sloping sandy beaches with heavy to moderate surf (Moore 2001b). Commercial fishing for this species is presently prohibited in California, but is fished on 18-miles of Clatsop Beach between Tillamook Head and the Columbia River in Oregon (ODFW 2001; Moore 2001a). In Washington State, Pacific razor clams are harvested from five major management zones: Long Beach, Twin Harbors, Copalis Beach, Mocrocks, and Kalaloch. Both the Kalaloch and Mocrocks harvest areas are within the northern and southern portions of the Quinault Range W237A.[18]

The remaining two clams and one oyster provide a most valuable commercial fishery on the Pacific coast of North America (e.g., Puget Sound; Bradbury et al. 2000). In Washington State (Strait of Juan de Fuca and Puget Sound), these clams and oysters are harvested in six management regions and jointly managed by WDFW and WDNR as well as the treaty Native American tribes with shellfishing rights affirmed by a 1994 federal district court judgment (the Rafeedie decision) (Bradbury et al. 2000). Geoducks range from Forrester Island, Alaska to Scammon's Lagoon, Baja California and in the northern Gulf of California. They are found from the lower intertidal zone to depths of 110 m in bays, estuaries, and sloughs on unshifting mud or sand (Moore 2001a). From 1995 to 2002, geoduck annual landings averaged 1,576 mt and revenue of $12.6 million.[12] Manila clams range from Elkhorn Slough, California to British Columbia within the intertidal zone to about 10 m depth on a variety of substrates (gravel to mud to sand) (Emmett et al. 1991). From 1995 to 2002, Manila clams annual landings averaged 2,710 mt and revenues of $11.25 million.[12] The Pacific oyster is a temperate species that ranges along the North American from southeast Alaska to northern Mexico within the lower intertidal zone to about 7 m below the MLLW on mud or mud-sand bottoms (Emmett et al. 1991). From 1995 to 2002, Pacific oyster annual landings averaged 3,400 mt and revenues of $18.125 million.[12] Within the Puget Sound Study Area, approximately five harvest areas occur within Hood Canal of the Dabob Range Complex.[19]

4.5.2.7 Kelp Fisheries

The dominant canopy-forming species in kelp forests off the Pacific Northwest coast is the bull kelp (*Nereocystis luetkeana*) which ranges from Monterey Bay area northward to Alaska on hard substrates at depths of 3 to 21 m (Kalvass and Larson 2004). Until the late 1980s, there was little targeted harvest of bull kelp in California, except as a small component of the localized edible seaweed industry. In southern Oregon, bull kelp was harvested from Orford Reef in the mid-1990s as an ingredient in liquid fertilizer. However, the Oregon Division of State Lands has since discontinued permitting that harvest (Kalvass and Larson 2001). Recent experimental leases in Oregon have proven inconclusive about the effects of commercially harvesting kelp. Significant questions remain regarding the ecological impacts of sustainable harvests and late-seasonal thinning on the quality of surface habitat, rates of recovery and growth, and the structural arrays of stipes and fronds that support kelp forest communities (Oregon Progress Board 2000). Commercial harvest of kelp is prohibited by law. Kelp does not recover well from harvest in Puget Sound so it is protected from collection in that area.[20]

4.5.2.8 Commercial Ports

There are two ports in northern California, five ports in Oregon, and 12 ports in Washington State (**Table 4-8**) that help support the commercial fishery fleet operating in the vicinity of the Pacific Northwest OPAREA and Puget Sound Study Area. According to the NMFS, Astoria, Oregon, recorded the highest commercial landings; with Newport, Oregon recorded the highest revenues in 2004 (**Table 4-7**). Ports lying in different regions along the Pacific Northwest OPAREA and Puget Sound Study Area, target different species.[11] At Washington State ports, spiny dogfish, chum salmon, Pacific halibut, albacore tuna, and shellfish (geoduck, Manila clam, and Pacific oyster) are fished more heavily, whereas, Oregon ports focus efforts on ocean shrimp and skates and northern California ports on red sea urchin, chinook salmon, and Pacific herring. Sablefish and Dungeness crab are harvested at all ports in all three states.[12]

Table 4-8. Major commercial fishery ports of the PACIFIC NORTHWEST OPAREA and Puget Sound Study Area.

Port	Landings (Pounds – lbs)	Revenue
Northern California		
Crescent City	16,900,000	$20,100,000
Eureka	19,400,000	$13,100,000
Oregon		
Newport	111,200,000	$29,600,000
Astoria	135,800,000	$19,900,000
Brookings	6,200,000	$8,600,000
Port Orford	3,000,000	$4,800,000
Tillamook	3,700,000	$3,800,000
Washington State		
Westport	92,800,000	$23,400,000
Bellingham	23,500,000	$21,900,000
Bay Center-South Bend	7,000,000	$14,800,000
Ilwaco-Chinook	30,900,000	$11,700,000
Seattle	7,700,000	$8,000,000
Anacortes-La Conner	5,400,000	$6,100,000
Neah Bay	4,800,000	$4,900,000
Tacoma	3,400,000	$4,900,000
La Push	2,100,000	$3,700,000
Port Townsend	1,800,000	$2,900,000
Port Angeles	2,200,000	$2,700,000
Everett	1,900,000	$1,500,000

Source: NMFS[11]

4.5.3 Recreational Fisheries

Recreational fishing is an industry in itself. Anglers are not looking to generate revenue from their catch but rather fish for pleasure and/or to provide food for personal consumption (Thomson 2001). Advanced fishing technologies and gear types have made finding and catching fish easier in recent decades. Recreational fisherman may use a variety of gears, but rod and reel gear (angling) with artificial lures, live bait, or dead bait is the most common type. Typical species targeted by recreational anglers within the various states of the study area are described in the following paragraphs.

Within the Northern Management Area (40°10'N line near Cape Mendocino, California to the Oregon border), recreational anglers catch the following fishes/invertebrates: federally managed groundfish (shelf and nearshore rockfish, flatfish: sanddabs, California halibut, roundfish: cabezon, lingcod, shark/skates), ocean salmon, greenlings of the genus *Hexagrammos*, surfperches (red: *Amphistichus rhodoterus*, pile: *Damalichthys vacca*, etc.), Dungeness crab, striped bass (*Morone saxitilis*), tunas, monkeyfaced eels (*Cebidichthys violaceus*), and red abalone (*Haliotis rufescens*) (NMFS-NWR 2003b; CDFG21). Along the Oregon coast, the following marine fish/invertebrate species most likely to be caught by recreational anglers include: chinook/coho salmon, shelf and nearshore rockfish (black, blue, canary, yellowtail), lingcod/cabezon, rock/kelp greenlings, sharks/rays/skates, tuna and mackerel, billfish, surfperch, sculpins, Pacific halibut, albacore tuna, herring/anchovy/smelt/sardine, abalone, and shellfish (bay/razor clams, crabs, etc.) (ODFW 2001; NMFS-NWR 2003b; ODFW[22]). Within Puget Sound and along the Washington State coast, recreational fishes/invertebrates commonly targeted by anglers include salmon, trout (sea-run cutthroat, *O. clarkia*), Dolly Varden (*S. malma*), Pacific halibut, forage fish (herrings, smelt, anchovies, sardines, Pacific sand lance), bottomfish (cabezon, flatfish, lingcod, Pacific cod, shelf and nearshore rockfish, sablefish), albacore tuna, mackerels, and invertebrates (clams, shrimps, etc.) (Palsson 1998; NMFS-NWR 2003b; WDFW 2005a).

Within the ocean segment of the Pacific Northwest OPAREA and Puget Sound Study Area, recreational fishing for chinook and coho salmon and Pacific halibut takes place primarily in two modes: anglers fishing from privately owned pleasure crafts and anglers employing the services of the charter boat fleet (PFMC 2005h).

Recreational salmon fisheries takes place in the following management areas: Cape Flattery, Washington State to Cape Falcon, Oregon, Cape Falcon to Humbug Mountain, Oregon, and Humbug Mountain to Horse Mountain, California (NMFS-NWR 2003a). The following port areas provide the bulk of the recreational ocean salmon angler trips: central/northern California (Monterey, San Francisco, Fort Bragg, Eureka, and Crescent City), Oregon (Brookings, Coos Bay, Newport, Tilamook, and Astoria), and Washington State (Columbia River, Westport, La Push, and Neah Bay) (PFMC 2005h).

Sport fisheries for the Pacific halibut is conducted within the various management subareas (NMFS 2004b). Washington State is divided into four subareas: Inside Waters (all waters east of the Sekiu River mouth and includes Puget Sound, most of the Strait of Juan de Fuca, San Juan Islands area, Hood Canal, and Admiralty); North coast (west of the Sekiu River mouth and north the Queets River), South coast (south of Queets River and north of Leadbetter Point), and Columbia River (between Leadbetter Point and Cape Falcon, Oregon). Oregon's subareas include in the Central coast (Cape Falcon to Humbug Mountain) and South of Humbug Mountain and off the California coast (NMFS 2004b). The sport fishery in this area is a non-target fishery with incidental catches primarily occurring in the Shelter Cove area of California (NMFS 2004b).

Within the marine and estuarine waters of the inshore basins of Puget Sound, sport fishing for salmon and steelhead is a very popular recreational activity. Chinook and coho salmon are the primary species caught by sport anglers in the following Marine Catch Areas in descending order of popularity: 11 (Tacoma-Vashon Island), 5 (Sekiu and Pillar Point), 10 (Seattle-Bremerton), 9 (Admiralty Inlet), and 8 (Deception Pass, Hope Island, Skagit Bay, and Ports Susan and Gardner) (NMFS-NWR 2004a; ODFW 2005). Salmon ports and major launch areas are presented in **Table 4-9**. Pink, chum, and sockeye salmon are predominately caught in freshwater areas (NMFS-NWR 2004a).

4.5.3.1 Fishing Areas

Popular fishing sites commonly visited by recreational anglers are known as hot spots. Within the Pacific Northwest OPAREA and Puget Sound Study Area, hot spots usually involve areas with some structural features, such as shoals, rocks, and reefs (artificial: Puget Sound and natural: Williams off Grays Harbor, Washington State; Yaquina and South off Newport, Oregon; St. George off Crescent City, California). Areas with greater vertical profiles, as found near bank ledges and canyons (Mendocino, Eel River, Rogue, Astoria, Grays), help fishes regulate their temperatures by allowing them to quickly reach deep or

Table 4-9. Salmon ports and major launch areas within the inshore marine and estuarine basins of the Puget Sound Study Area.

Regions	Major Salmon Ports	Other Salmon Ports	Major Marine Launch Areas
Strait of Juan de Fuca/North Hood Canal	Port Angeles	Port Townsend	Neah Bay Area (3), Seiku Area (3), Port Angeles Area (4)
North Puget Sound	Everett, Anacortes	Friday Harbor	Point Roberts Area, Nooksack River, Fisherman's Cove, Rocche Harbor, West Sound, Friday Harbor, Anacortes Area (3), Howard Miller Park, Skagit River-Hamilton, Mount Vernon (3), Deception Pass, Fort Casey, Camano Island, Bush Point, Everett Area (3), Mukilteo, Edmonds, Monore Area (6)
South Puget Sound/South Hood Canal	Seattle	Tacoma, Olympia	Point No Point, Salsbury Point, Kingston Cove, Eddie Vine Boat Ramp-Ballard, Lake Washington Area, Don Armeni Boat Ramp-Seattle, Bremerton, Soos Creek-Green River, Point Defiance-Tacoma, Narrows Marine-Tacoma, Olympia Area (5), Port of Allyn, Twanoh, Hood Canal

Source: NMFS-NWR (2004c)

shallow bottom habitats as needed, while maintaining close proximity to bottom habitat (NMFS-NWR (National Marine Fisheries Service-Northwest Region) 2005). Natural areas (e.g., Seamounts: Thompson, President Jackson, Cobb, Banks: Heceta, Daisy, Stonewall off Pacific coast and Hein, Eastern, Partridge, and Dallas in Strait of Juan de Fuca) and man-made features such as piers, docks, rock and concrete jetties, and beach groins that extend over water or out into waters are generally well-fished sites (Squire and Smith 1977; Wilson and Kaufmann 1987; NMFS-NWR (National Marine Fisheries Service-Northwest Region) 2005). Hydrographic features also concentrate fish and subsequently, anglers often target currents and waters rich with nutrients (e.g., Columbia River bi-directional plume, coastal upwellings, eastward-flowing currents: Davidson, North Pacific Drift, etc.) (Squire and Smith 1977; Emmett et al. 2004; Beamish et al. 2005).

4.5.3.2 Fishing Activity Statistics

Recreational fishing activity can be divided into inshore and offshore components (**Figures 4-12**, **4-13**, and **4-14**). Inshore recreational fishing involves fishing along the shore from boats (skiffs) and inshore off beaches, marshes, docks, piers, etc. Rod-and-reel fishing is the most common method used by recreational anglers in inshore or state waters (Spira 2000). Offshore fishing usually involves larger boats that make trips into federal waters and includes charter and party boats. Charter boats take any number of anglers for a fixed daily rate, while party boats or head boats, take guests (usually on larger boats) on a per person rate (Abbas 1978).

From 1998 to 2002, the proportion of total effort encompassing the number of salt water fishing trips by fishing modes (man-made structures: piers, bank/beaches, commercial passenger fishing vessels (CPFV), and private/rental boats) was 45% in northern California, 36% in Washington State, and 19% in

Oregon. Within each state, the private/rental boats were the dominant fishing mode (**Figures 4-12**, **4-13**, and **4-14**; NMFS[11]). In northern California, the man-made and private/rental boats were constant, whereas the bank/beaches exhibited lows in 1999 and 2001 and party/charter vessels more than doubled from 1998 to 2002 (**Figure 4-12**; NMFS[11]). Washington State's party/charter vessels more than doubled from 1998 to 2002 with the remaining three fishing modes exhibiting a constant fluctuation (**Figure 4-13**; NMFS[11]). The private/rental boats in Oregon increased from 1999 through 2001, while the other fishing modes more than tripled and/or doubled from 1998 through 2002 (**Figure 4-14**; NMFS[11]).

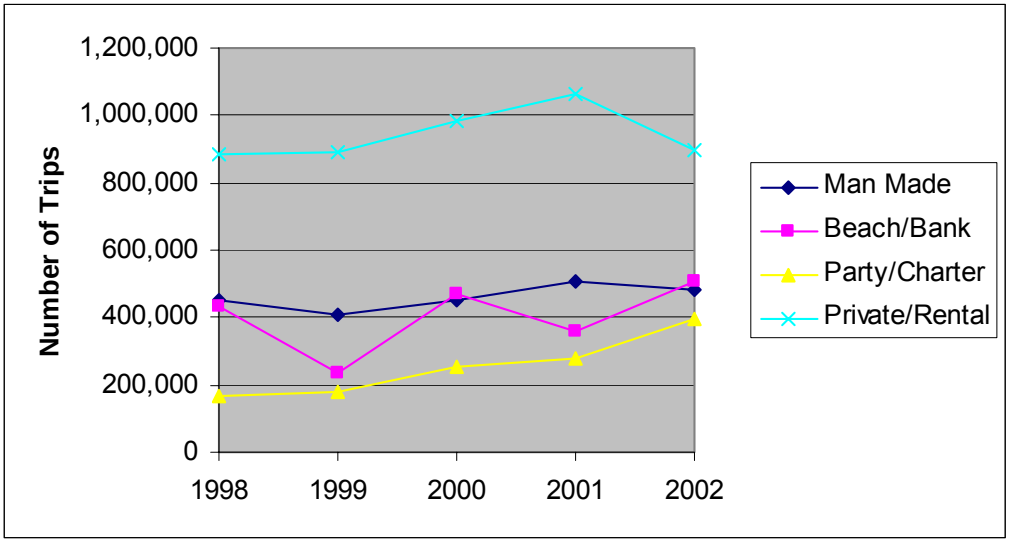


Figure 4-12. Number of recreational saltwater fishing trips originating from northern California from 1998 through 2002, broken down by fishing mode. Source data: NMFS.[11]

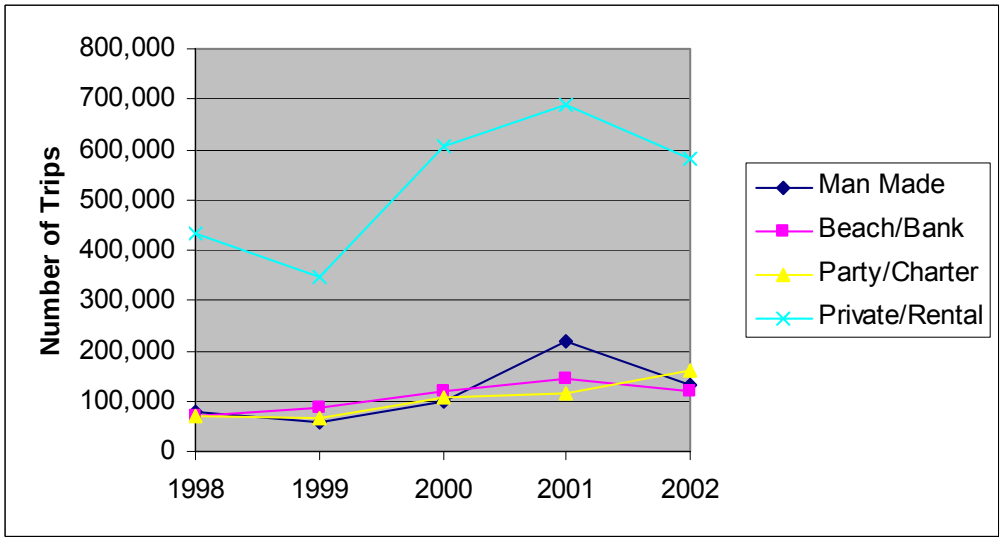


Figure 4-13. Number of recreational saltwater fishing trips originating from Oregon from 1998 through 2002, broken down by fishing mode. Source data: NMFS.[11]

From 1998-2002, the proportion of total effort encompassing the number of salt water fishing trips by fishing areas (state, federal, and inshore) was 43% in Northern California, 39% in Washington State, and 19% in Oregon. In Oregon and Washington State, the federal area was dominant salt water fishing trip area, whereas both inshore and state areas were dominant in northern California (**Figures 4-15**, **4-16**, and **4-17**; NMFS[11]). In northern California, the inshore and federal areas were constant with the state salt water fishing trip area increasing from 1999 through 2002 (**Figure 4-15**; NMFS[11]). Washington State's inshore area increased from 1998 to 2001, federal salt water fishing trip area increased from 19,000 to more than 100,000, then dramatically declined to less than 20, and the state area declined from over 100,000 trips to less than 21,00 trips (**Figure 4-16**; NMFS[11]). Both the state and the inshore areas in Oregon increased from 1999 through 2001, while the federal areas more than quadrupled from 1998 through 2002 (**Figure 4-17**; NMFS[11]).

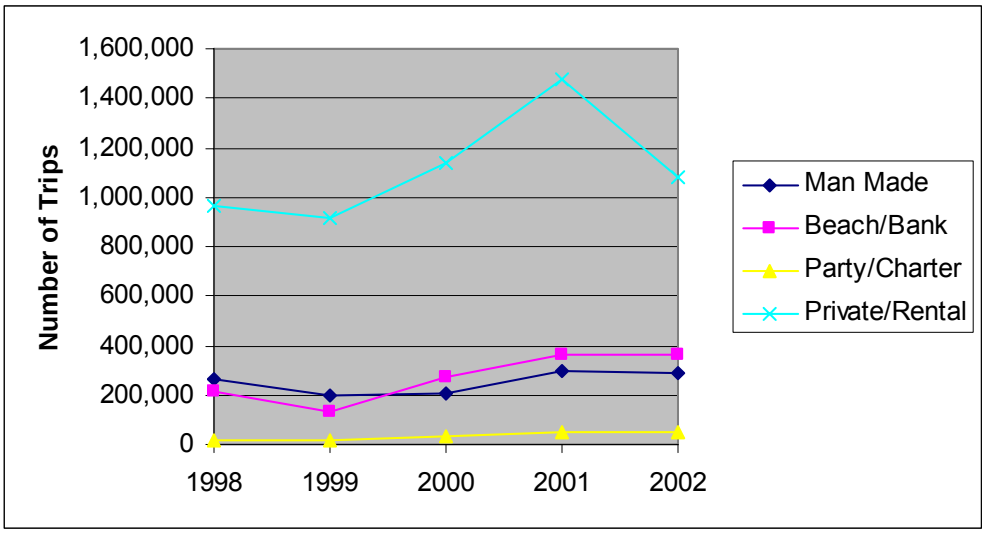
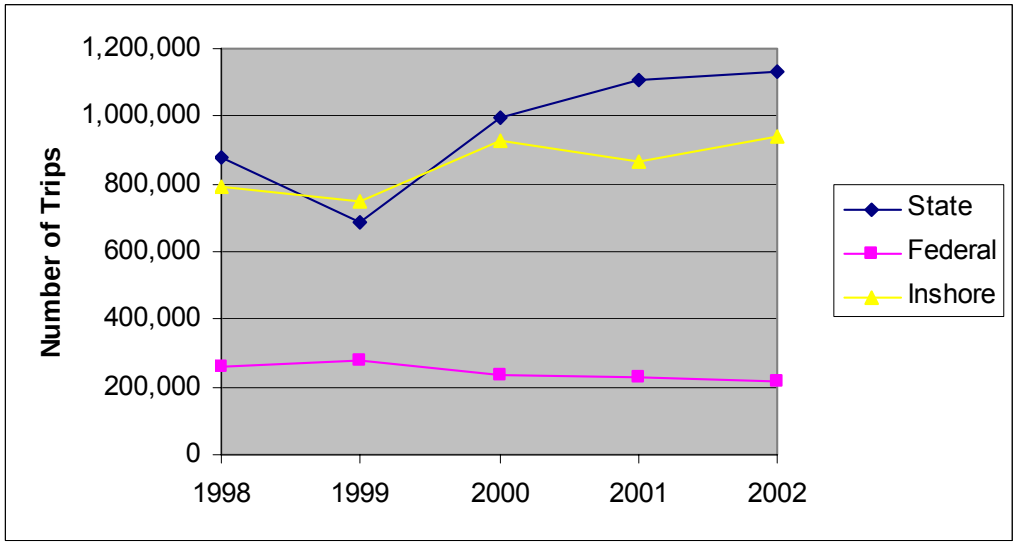


Figure 4-14. Number of recreational saltwater fishing trips originating from Washington State from 1998 through 2002, broken down by fishing mode. Source data: NMFS.[11]



*Inshore means inshore saltwater and brackish water bodies such as bays, estuaries, sounds, etc. It does not include inland freshwater areas.

Figure 4-15. Number of recreational saltwater fishing trips originating from northern California from 1998 through 2002, broken down by fishing area. Source data: NMFS.[11]

In northern California, Oregon, and Washington State, recreational fishing is monitored year round. The Marine Recreational Fisheries Statistics Survey (MRFSS) under the direction of NMFS conducts surveys of recreational anglers using telephone surveys and intercept/interviews with anglers at fishing access sites (NMFS 2005e). For California and Washington State's Puget Sound, the intercept portion of the MRFSS is now estimated through For-Hire Surveys (FHS). These surveys differ from the MRFSS because they use a telephone survey of boats, rather than households, as the primary method for estimating fishing effort (NMFS 2005e). In place of the MRFSS, Oregon and Washington State conduct ocean boats surveys to produce catch and effort estimates. Oregon's Ocean Recreational Boat Survey (ORBS) and Washington State's Ocean Sampling Program (OSP) consist of a field intercept survey for effort and catch of passenger and private boats (NMFS 2005e).

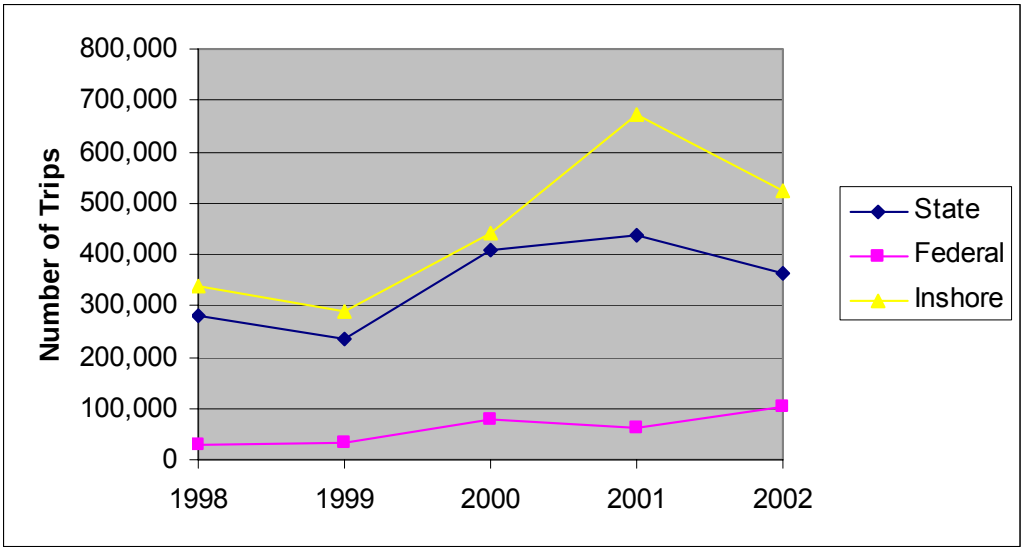


Figure 4-16. Number of recreational saltwater fishing trips originating from Oregon from 1998 through 2002, broken down by fishing area. Source data: NMFS.[11]

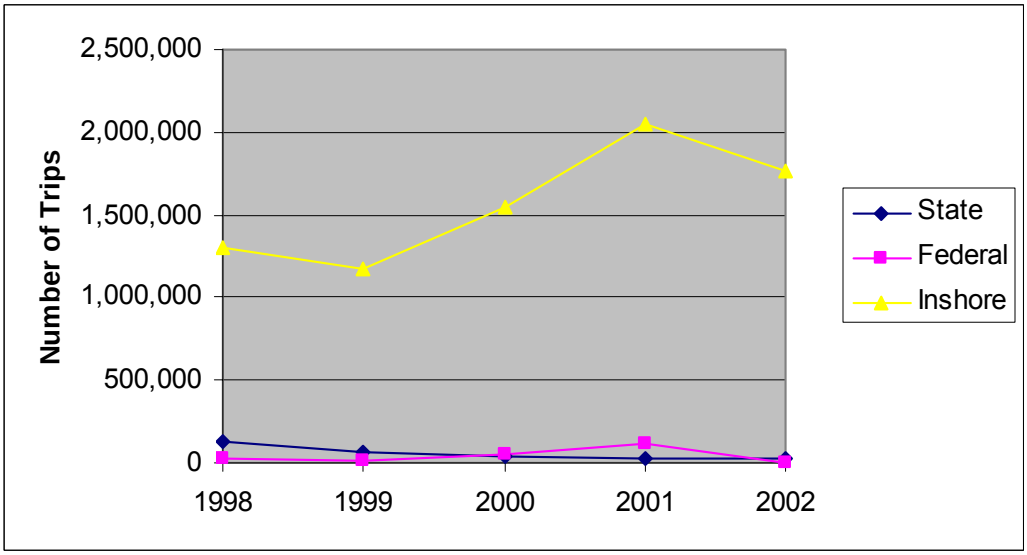


Figure 4-17. Number of recreational saltwater fishing trips originating from Washington State from 1998 through 2002, broken down by fishing area. Source data: NMFS.[11]

Approximately 2.2 million marine recreational angler boat trips were made in northern California, Oregon, and Washington State in 2003. More than 1.6 million (73%) of those party/charter and private/rental vessel trips operated from northern California ports, demonstrating the importance of recreational fishing industry in that part of the state (NMFS-NWR 2005). Fishing effort is related to weather, with relatively more effort occurring in the milder months of summer, and relatively less in winter. In 2003, the months of May through August show an increase in fishing activity in both Oregon (75%) and Washington State (73%), whereas northern California marine recreational angler boat activity runs from May through December peaking in July and August (57%) (NMFS-NWR 2005).

4.5.3.3 Fish Species

In 2004, the most commonly caught non-bait species (in numbers of fish) in state marine waters along the U.S .west coast included barred sand bass (*Paralabrax nebulifer*), Pacific bonito (*Sarda chiliensis*), Pacific barracuda (*Sphyraena argentea*), kelp bass (*P. clathratus*), black rockfish, and coho salmon (NMFS 2005e). All these species with the exception of the Pacific bonito and Pacific barracuda were caught in 2003 along with lingcod, white croaker, California halibut, and barred surfperch (*Amphistichus argenteus*) (NMFS 2005e). By weight, the largest harvests in 2004 were Chinook salmon, coho salmon, black rockfish, albacore tuna, barred sand bass, and Pacific barracuda (NMFS 2005e). With the exception of coho salmon and Pacific barracuda, the remaining species along with lingcod and California halibut were by weight the largest harvest in 2003 (NMFS 2005e). The most common caught Pacific coast species in federally managed waters were barred sand bass, Pacific sanddab, kelp bass, California scorpionfish (*Scorpaena guttata*), and chinook salmon in both years (NMFS 2005e). The composition of these recreational harvested species tends to vary among areas and fishing modes (NMFS 1999). Recreational catches of kelp/barred sand basses, California barracuda, Pacific bonito, white croaker, barred surfperch, and California scorpionfish were harvested in larger numbers within the warm waters of southern California (NMFS-NWR 2003b).

Total annual catch of lingcod has varied between 240,000 fish (1995) and 584,000 (2000) fish over the past 10 years, reached 1.2 million fish and 1.3 million fish (2003), but decreased to 323,000 in 2004. Total black rockfish, which has varied between 595,000 fish (1997) and 1.4 million (2000) over the past 10 years, exceeded 1.2 million fish in 2002, increased to 1.3 million fish in 2003, then decreased to 700,000 fish in 2004 (NMFS 2004c; 2005e).

4.5.3.4 Charter and Headboats

Overall, charter and headboats provide a substantial amount of employment and are economically important to coastal communities (NMFS 2004f). Charter boats, headboats and fishing guides are all available throughout the study area. Charter outfits offer fishing services to those who do not own their own boats or fishing gear. A single group of anglers typically hire a charter boat on a per-trip basis, while head boats are regularly scheduled and take groups of anglers who pay a flat rate per person.

Charter and head boats more commonly fish further offshore compared to private boats, due to the high cost of private large boat ownership, the capability of the larger charter and head boats to go farther, and the greater experience of professional captains. Charter and head boats usually perform full day trips, and some charter boats may occasionally spend nights at sea (Abbas 1978).

In the U.S., over nine million anglers took part in 76 million marine recreational fishing trips in 2000. The west coast accounted for about 22% of the salt water anglers and 12% of fishing trips. Along the west coast, 70% of the trips were made off California, 19% off Washington State, and 11% from Oregon.

4.5.3.5 Fishing Tournaments

Organized fishing tournaments that are most prevalent in southern California do not occur in the Pacific Northwest OPAREA and Puget Sound Study Area due to sea and weather conditions and the natural terrain. Along the rugged coastline, the inconsistence nature of the sea-state (e.g., relatively cold water due to coastal upwellings, strong currents, rapid tidal influxes, Columbia River bi-directional plume, and unexpected waves of great size) and weather conditions (e.g., prevailing northwest winds, early morning/late evening fog, southerly storms) can change rapidly making some areas extremely dangerous to salt water angler fishing boat trips (Squire and Smith 1977; Hickey et al. 2005).

4.5.4 Usual and Accustomed Fisheries

4.5.4.1 Introduction

Five treaties ratified by the U.S. and various Washington State tribes between 1854 and 1856 guaranteed Tribes fishing rights in common with citizens of the Territory. These are the treaties of Medicine Creek, Quinault, Neah Bay, Point Elliot, and Point-No-Point. Essential for securing Native American consent to the treaties was the promise that continued access to fisheries would be guaranteed for future generations. This guarantee was included in the Treaty of Medicine Creek (Article III, 10 Statute 1132), in a provision typical of that found in Treaties (Point Elliot, 12 Statute 927; Point-No-Point, 12 Statute 933; Neah Bay, 12 Statute 939; and Olympia, 12 Statute 971 – hereinafter referred to as the "Stevens Treaties") with other Northwest tribes.

These fishing clauses of the Stevens Treaties have been at the center of litigation for more than 100 years. In 1974, Judge Boldt ruled that the Stevens Treaties reserved to the Tribes the right to take up to 50% of the harvestable surplus of fish passing their "usual and accustomed (U&A) grounds and stations" (U.S. versus Washington 1974). The Supreme Court affirmed the substance of the Boldt decision following several years of resistance on the part of Washington State (Washington versus Washington State Commercial Passenger Fishing Vessel Association 1979).

Subsequent proceedings determined that the treaty rights also pertain to hatchery fish, shellfish and all other species found at the U&A grounds and stations of a given tribe (U.S. versus Washington reporter volume 759, 1985 and U.S. versus Washington 1998 and 1999). There are no restrictions on the methodology that tribes may use to take fish and the fish may be taken for any purpose (U.S. versus Washington 1974).

The treaty fishing right is generally described as the opportunity to take a fair share of the fish which is interpreted as up to 50% of the harvestable surplus of fish that pass through the tribes' U&A grounds. The treaty right was originally adjudicated with respect to salmon and steelhead. However, it is now recognized as applying to all species of fish and shellfish within the tribes' U&A grounds (NMFS-NWR 2004c).

4.5.4.2 Pacific Coast and Puget Sound Indian Tribes

Within the Pacific Northwest OPAREA and Puget Sound Study Area, there are seven federally-recognized Pacific coast Indian tribes and 19 federally-recognized Puget Sound Indian tribes. The Pacific Coast Treaty Tribes include the Makah, Quileute, and Hoh Indian tribes and the Quinault Indian Nation in Washington State and the Yurok, Hoopa, and Round Valley Tribes in California. The Californian Tribes practice commercial and ceremonial and subsistence fisheries only in freshwater. There are no Pacific Coast Treaty Tribes in Oregon (NMFS 2003a).

NMFS recognized the following areas (**Figure 4-18**) as marine U&A fishing grounds of the four Washington State coastal tribes (PFMC 2003d). The Makah U&A grounds were adjudicated in U.S. versus Washington, 626 F. Supplement 1405, 1466 (W.D. Wash. 1985), and affirmed in 730 F.2d 1314 (9th Cir. 1984). See also Makah Indian Tribe versus Verity, 910 f.2d 555, 556 (9th Cir. 1990); Midwater Trawlers Co-op. versus Department of Commerce, 282 F.3d 710, 718 (9th Cir 2002). The U&A grounds of the Quileute, Hoh, and Quinault tribes have been recognized administratively by NMFS (see, e.g., 67 Federal Register 30616, 30624 May 7, 2000 – U&A grounds for salmon; 50 CFR 660.324(c) U&A grounds for groundfish; and 50 CFR 300.64(i) – U&A grounds for Pacific halibut). The U&A grounds recognized by NMFS may be revised as ordered by a federal court. These tribes also have treaty rights to harvest HMS in their U&A fishing areas in U.S. waters (NMFS 2004e). Currently, there is no Pacific Coast Treaty Tribes fishing for krill. Amendment 9 to the CPS established a regulatory process (codified in 50 CFR 660.518) to deal with any future expressions of fishing interest for CPS species (PFMC 2001; 2005e). This codified regulatory process would also apply in the event any tribal interest is expressed in krill fishing (NMFS-SWR 2006). The Makah tribe has informed the PFMC of their intent to enter the sardine fishery in 2006 (PFMC 2006).

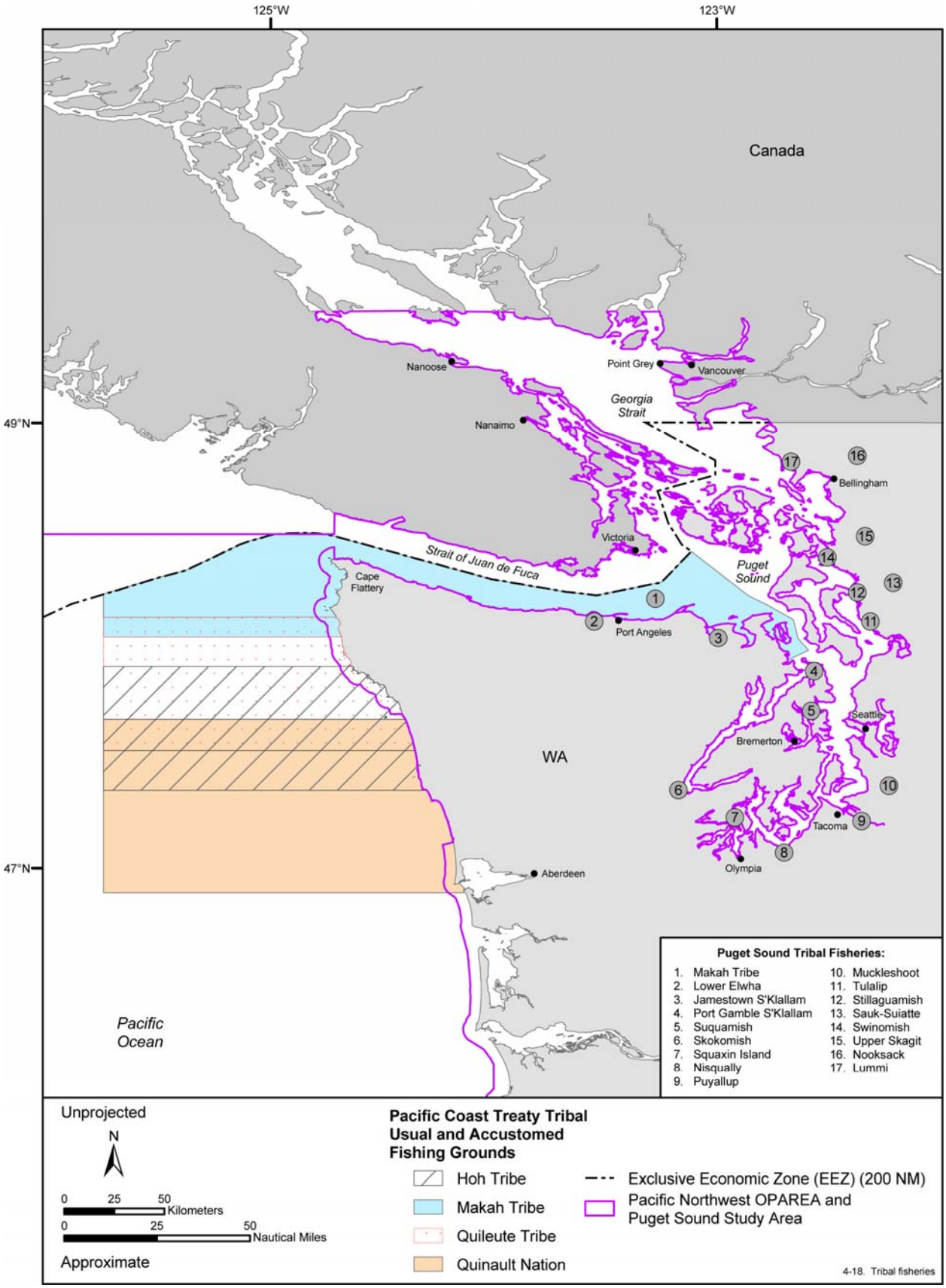


Figure 4-18. Tribal fishery grounds in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source information: NMFS-NWR (2004c), 50 CFR 660.324.

The Puget Sound Indian tribes (**Figure 4-18**) include the Pacific Coast Treaty Tribe, Makah, plus the tribes of Lower Elwha (Klallam), Jamestown S'Klallam, Port Gamble S'Klallam, Skokomish, Squaxin Island, Nisqually, Puyallup, Muckleshoot, Suquamish, Tulalip, Stillaguamish, Sauk-Suiattle, Swinomish, Upper Skagit, Nooksack, and Lummi (NMFS-NWR 2004a). Of these tribes, only the Samish and Snoqualmie tribes do not have federally-recognized treaty fishing rights (NMFS-NWR 2004a). The remaining treaty tribes utilize the Northwest Indian Fisheries Commission (NWIFC) which was established to coordinate the activities of these tribes for implementation of orders arising from U.S. versus Washington 1974 decision. This commission provides technical support to Pacific Coast Treaty and Puget Sound Indian tribes assisting in intertribal coordination on harvest policy (PFMC 1999a).

The Puget Sound treaty tribes co-manage Puget Sound fisheries with Washington State, and participate with tribes from California, Oregon, and other Washington State areas in managing fisheries under the jurisdiction of the PFMC and the PST (NMFS-NWR 2004b).

4.5.4.3 Salmon Fishery

Salmon is key resource to the Pacific Coast and Puget Sound Treaty tribes of the Pacific Northwest OPAREA and Puget Sound Study Area. This species is treated ceremoniously by providing a core symbol of tribal identity, individual identity, and the ability of the Indian culture to endure as well as being of nutritional and economic importance (NMFS-NWR 2004a). Their ceremonial and subsistence salmon fishery refers to a non-commercial fishery that tribal members catch and use for either ceremonial or subsistence purposes. Fishers engaged in commercial fisheries may take a portion of their catch for ceremonial and subsistence use, and designate that as "take home fish." A tribe may also open a fishery specifically to catch fish for a ceremony or other community use when there is no concurrent commercial opening (NMFS-NWR 2004a).

4.5.4.3.1 Tribal ceremonial and subsistence fisheries

The Pacific Coast Treaty tribes' ceremonial and subsistence fishery takes place as a coast-ocean fishery and as a coast-inside fishery. Indian regulations in the coast-ocean fishery have restricted ceremonial and subsistence harvest with the Makah limited to no more than eight fixed line per boat with four hand-held lines and the Quinault Indian Nation and the Quileute and Hoh tribes trolling limited to no more than two chinook over 24 inches per day per person (PFMC 1999a).

Within coast-inside fisheries, the Makah tribe has ceremonial and subsistence fisheries in the Sooes River, Quinault Indian Nation in Grays Harbor system and its tributaries as well as the Quinault and Queets river systems, Hoh tribe in Hoh River, and Quileute tribe in the Quillayute River and its tributaries (PFMC 1999a). These fisheries use primarily gill nets, but other gears can be used, as regulated by the tribe. They occur at any time of the year round when harvestable fish are present. Catch limits are determined by the status of the individual run, but are typically one or two fish per day of a certain size (PFMC 1999a).

Regulations in Puget Sound for the harvest of ceremonial and subsistence fish generally allow fishing year round with one or two fish per day of a certain size. Ceremonial salmon are generally taken in special fisheries that allow a certain number (e.g., 50) to be harvested by a group for use in a particular ceremony (PFMC 1999a).

4.5.4.3.2 Tribal fisheries

In the coast-ocean fisheries along the Washington State coast (Areas 2 [Westport], 3, 3N [LaPush], and 4A [Neah Bay]), trolling gear is utilized by all four tribes. Since 1983, tribal regulations allow all-except-coho fisheries in May and June and all-salmon fisheries for portions of the summer depending on stock abundance. The duration of the summer all-salmon fisheries has varied from 12 to 92 days with most years running between 20 and 42 days (PFMC 1999a). In Area 4B at the entrance to the Strait of Juan de Fuca (Binilla-Tatoosh line east to the Sekiu River), the Makah tribe has troll fisheries along with two Puget Sound tribes: the Lower Elwha (Klallam) and the Jamestown and Port Gamble S'Klallam tribes (PFMC

2003d). Area 4B is considered part of the ocean fisheries from May through October (PFMC 1999a). From 1997 to 2004, chinook salmon averaged 26.807 catch (thousands of fish) with a low of 7.625 in 2000 and a high of 49.175 in 2004; whereas coho salmon averaged 28.360 with a low of 7.927 in 1998 and a high 61.749 in 2004 (PFMC 2005h).

Within the coast-inside fisheries, the Quinault Indian Nation fishes with primarily gill nets for spring, summer, and fall chinook, chum, sockeye, and coho salmon from spring through early spring on the Quinault and Queets rivers. Both the Hoh and Quileute tribes harvest coho salmon and spring, summer, and fall chinook salmon with commercial gill nets from spring through early winter in the Hoh and Quillayute rivers, respectively. The precise timing and harvest levels vary and are determined by stock status and agreements with the State of Washington (PFMC 1999a).

In the Strait of Juan de Fuca, Puget Sound, and Hood Canal, the primary harvest means are drift gillnets, set gillnets, purse seine, trap, hook and line, trolling gear, dip nets, round haul, and beach seine by Native American fishers (NMFS-NWR 2004a). These gears may vary by tribe and location. The primary salmon species targeted are sockeye, coho, chum, chinook, and pink salmon in the Strait of Juan de Fuca. In north Puget Sound, sockeye, chum, and pink salmon are targeted for harvest, whereas the coho, chum, and chinook salmon are harvested in central/south Puget Sound and Hood Canal. Fishing occurs primarily from summer through late in Puget Sound, but can extend through the winter months in the Strait of Juan de Fuca (PFMC 1999a). In freshwater areas, fisheries can occur in any month year round when harvestable salmon are present. Each tribe regulates its own fisheries including allowable gears and locations individually within its U&A area. A coordinated management approach is dictated if these areas overlap the U&A areas of other tribes. A detailed listing of agreed to treaty and non-treaty fisheries (e.g., dates, areas, target species) is published annually by the NWIFC and WDFW (PFMC 1999a). Multiple tribes may fish the same marine (Squaxin Island: Carr Inlet, etc.) and/or freshwater (Nisqually: Nisqually River) areas or both (e.g., Puyallup: Commencement Bay/Puyallup River; Skokomish: southern Hood Canal and adjacent freshwater drainage, etc.) (NMFS-NWR 2004a). For additional information pertaining to the southern Puget Sound tribal U&A fishing grounds please refer to the Boldt Decision (U.S. versus Washington 1974) and NWIFC.[28]

4.5.4.4 Other Fishery

4.5.4.4.1 Groundfish

In 1994, the U.S. government formally granted the four Pacific Coast Treaty Tribes treaty rights to fish for groundfish, and concluded that, in general terms, the quantification of those rights is 50% of the harvestable surplus of groundfish available in the tribe's U&A areas (described at 60 CFR 660.324). These tribes have formal allocations for sablefish, black rockfish, and Pacific whiting and participate in ceremonial and subsistence and commercial fisheries off Washington State coast (NMFS-NWR 2003b). All tribes participating in groundfish fisheries use longline vessels in their fleet, but only the Makah tribe has trawlers (NMFS-NWR 2005). Groundfish fishing occurs primarily with hook and line and pots. From 2000 to 2004, tribal shoreside groundfish averaged 7,092,140 lbs and $6,124,329 revenue peaking at 14,265,779 lbs and $8,117,500 revenue in 2003.[12]

Tribal fisheries are place-oriented, limited to the adjudicated U&A areas. This results in immobile fisheries that cannot move to a new location if the resources or habitat are depleted. Because tribes are limited in the areas they fish, they all work to practice good stewardship. This is evident in the Makah bottom trawl fishing for Pacific whiting which allowed for efficient harvest of abundant species while minimizing the bycatch of overfished species through restrictions (NMFS-NWR 2005). To date, only the Makah tribe has fished on the tribal Pacific whiting allocation which takes place May through September (NMFS-NWR 2003b). The tribal at-sea catch of Pacific Whiting averaged 14,599,542 lbs from 2000 to 2001 more than tripling to an average 52,941,911 lbs for the years 2003 and 2004.[12]

4.5.4.4.2 Pacific halibut

Twelve western Washington State Indian tribes possess and exercise treaty fishing rights to Pacific halibut, including the four Pacific Coast Treaty Tribes that possess treaty fishing rights to groundfish. Specific halibut allocations began in 1986 with the tribes in 1989 harvesting their full allocation in Area 2A (marine waters off Washington State, Oregon, and California). In 1993, judicial confirmation of treaty halibut rights occurred and treaty entitlement was established at 50% of the harvestable supply of halibut in the tribes combined U&A fishing grounds (NMFS 2004b; 2006f). Tribal allocations are divided into a commercial component and a year-round ceremonial and subsistence component. Tribal Pacific halibut fisheries start at the same time as Alaskan and Canadian commercial halibut fisheries (NMFS-NWR 2003b). Tribal ceremonial and subsistence begins on January 1 and continues through December 31, whereas tribal fisheries begins between March 1 and April 1 and continues through November 15 or until tribal fisheries is taken, whichever is earlier (NMFS 2004b; 2006f). The tribal halibut allocation is divided so that approximately 80 to 85% of allocation is taken in brief open competition derbies, in which vessels from all halibut tribes compete against each other for landings (NMFS-NWR 2003b). From 1992 to 2003, the ceremonial and subsistence allocation averaged 5.7% of the commercial allocation and the ceremonial and subsistence averaged 5.7% of the commercial catch. In 2004, the tribes agreed upon a new management plan which divided the commercial fisheries into “separately managed” fisheries (75% of Tribal Total Allowable Catch [TAC]) and “joint restricted” (25% of Tribal TAC) (NMFS 2004b; 2006f).

4.5.4.4.3 Shellfish

Shellfish have been a mainstay of western Washington State Native American tribes for thousands of years. As with salmon, the right to harvest shellfish lies within a series of treaties signed with representatives of the federal government in the 1850s (i.e., Treaty of Point-No-Point). Clamming was dominated by the tribes well into the 1920s. This changed when tideland areas eventually being purchased by non-Indians were slowly excluding the tribes from utilizing their traditional shellfish harvest areas. In 1989, the tribes were forced to file suit in federal court with the resulting recognition of their treaty shellfish harvest rights. After years of unsuccessful negotiations, the issue was addressed with Rafeedie Decision in December 1994. This decision ruled that the tribes had reserved harvest rights to half of all shellfish from all of the U&A places, except those places “staked or cultivated” by citizens – or those that were specifically set aside for non-Indian shellfish cultivation purposes. With the Supreme Court’s final refusal to hear the case in 1999, several parties (e.g., tribes, shellfish growers, etc.) began work on implementation plan. Tribal shellfish managers have developed harvest management and supplementation plans, and harvest data are collected and shared with other tribes and Washington State.[23]

The tribes have two distinct types of shellfish harvest: commercial and ceremonial and subsistence. Shellfish harvested during the commercial fishery are sold directly to licensed shellfish buyers who either sell shellfish directly to the public or to other commercial entities. Ceremonial and subsistence harvests of shellfish, which have a central role in tribal gatherings (e.g., weddings, funerals, etc.) and daily nutrition, are utilized for tribal use only.[23]

Fifteen of the 19 western Washington State Indian tribes are able to harvest intertidal shellfish (e.g., clams: Manila, butter, native little neck, horse, geoduck, eastern soft shell and cockles and oysters: Pacific and Olympia) in accordance with the 1994 ruling. These tribes include the Jamestown S’Klallam, Lower Elwha (Klallam), Lummi, Makah, Muckleshoot, Nisqually, Nooksack, Port Gamble S’Klallam, Puyallup, Skokomish, Squaxin Island, Squamish, Swinomish, Tulalip, and Upper Skagit. Each of these tribes has U&A harvest areas that reflects the historical region in which the collection of shellfish occurs on public lands and privately owned tidelands. The harvestable amount of clams and oysters on all public beaches is shared equally among sport harvesters and treaty tribes, whereas on private tidelands the private owner and treaty tribes are each limited to taking up 50% of the harvestable surplus of shellfish.[24]

On private-owned tidelands, tribal shellfish harvesting involves: conducting shellfish population surveys/estimates to determine tribes’ share of naturally occurring population, notifying the tideland property owner and WDFW of the harvest dates/times, and acquiring a valid harvest identification card.

According to Judge Rafeedie's implementation plan, the tribes are allowed to harvest no more than five days on any beach with one additional day granted for every additional 50 ft beach over 200 ft in length.[24] By agreement, tribal commercial clam and oyster harvest must be scheduled for certain days on certain beaches. The tribal fishery is closed on these beaches when the tribal share of clams and oysters is reached for the year.[25]

Along the Pacific coastal sandy beaches from the Columbia River to Kalaloch, FMPs are signed each year between WDFW and tribal governments with razor clam harvest rights. Razor clam harvests are set and monitored within each of the five management beaches: Long Beach Peninsula from the Columbia River north to the mouth of Willapa Bay, Twin Harbors from Willapa Bay north to the south jetty at the mouth of Grays Harbor, Copalis Beach from the north jetty at the mouth of Grays Harbor to the Copalis River, Mocrocks from the Copalis River to the Moclips River (south boundary of the Quinault Indian Reservation), and Kalaloch from the South Beach campground to Olympic National Park Beach Trail 3 (WDFW 2001; WDFW[18]).

4.6 WEBSITES ACCESSED

[1] Marine Resources. Accessed 2 January 2006. http://biology.usgs.gov/s+t/SNT/noframe/ mr181.htm.

[2] Summary report from a literature and data search on the status of marine resources in Jefferson County. Accessed 12 January 2006. http://www.biomes.net/FinalMRCReport2a.htm.

[3] WDFW studies causes of Cherry Point herring decline. Accessed 20 February 2006 http://wdfw.wa.gov/science/ articles/herring/.

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[5] Key to the fishes of Puget Sound. Accessed 12 October 2005. http://www.vwfishcollection.org/fishkey/psthome.html.

[6] Species of fishes and life-history stages with designated EFH in the waters of Puget Sound. Accessed 7 October 2005.

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5.0 ADDITIONAL CONSIDERATIONS

5.1 MARITIME BOUNDARIES: TERRITORIAL WATERS, CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE

Maritime boundaries are critical elements that affect the planning of activities in the marine environment.[1] 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**). **Figure 5-1** is a generic representation of the U.S. maritime boundaries and the continental shelf may fall within the EEZ in certain areas. 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.[2]

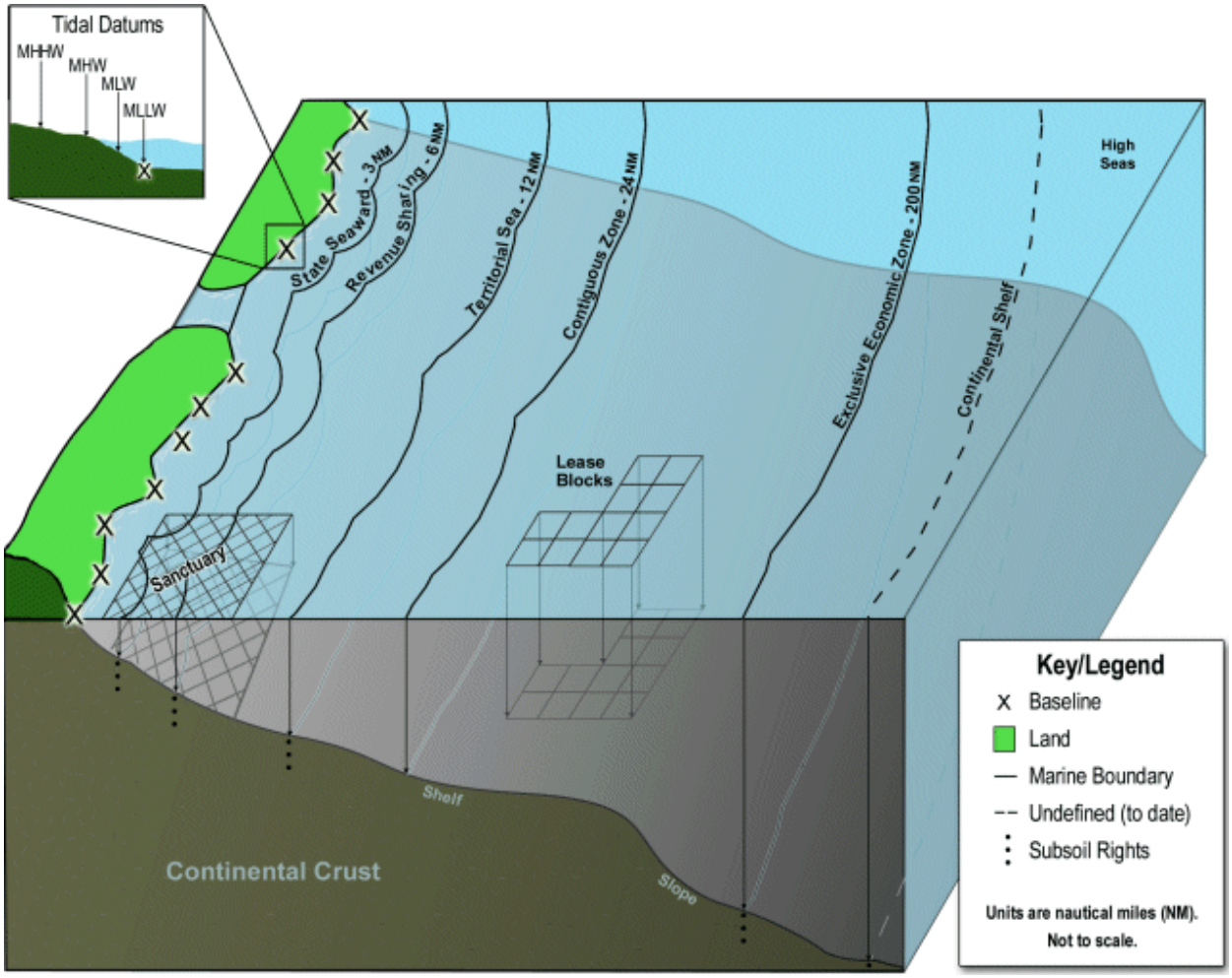

Figure 5-1. A 3D depiction of the U.S. maritime boundaries. Tidal datums – MHHW, MHW, MLW, and MLLW. Image taken from: NOAA[2], used with the permission of Mr. David Stein.

Although the U.S. and other nations historically used 3 NM as their seaward territorial limit, some American states (e.g., Texas and the Gulf coast of Florida) and territories (e.g., Puerto Rico) have historical seaward boundaries of 3 marine leagues or 9 NM. These territorial limits were measured from the baseline of each nation or state. The U.S. has traditionally used the "rule of the tidemark" as the

baseline from which to measure the width of its territorial waters. This baseline coincides with the MLLW/tide line found along the shore and is often termed the "normal" baseline (Kapoor and Kerr 1986; Prescott 1987; **Figure 5-1**). At the mouths of bays, rivers, or other areas where the coastline is not continuous, a straight baseline is drawn over the coastal feature. Rather than use the normal baseline, an increasing number of countries use either the straight baseline or archipelagic baseline system from which to measure their territorial waters (Kapoor and Kerr 1986; Prescott 1987).

The 3 NM limit was the standard until the latter half of the twentieth century when the extent of U.S. territorial waters was redefined. In 1945, President Truman issued Presidential Proclamation No. 2667 (also known as the Truman Proclamation) claiming jurisdiction and control over all the natural resources of the seabed and subsoil of the entire continental shelf adjacent to the coasts of the U.S. The Truman Proclamation did not include jurisdiction or control over the waters overlying the U.S. continental shelf. In 1953, the Truman Proclamation was nullified and replaced by the OCS Act. The OCS Act placed the subsoil and seabed of the OCS under U.S. jurisdiction. Section 1331 of this act defines the OCS as "…all submerged lands lying seaward and outside of the area of lands beneath navigable waters as defined in section 1301 of this title…".[3] Like the Truman Proclamation, the OCS Act did not give the U.S. authority over the waters above the continental shelf seabed, thereby leaving them open to navigation and fishing (**Table 5-1**).

In 1976, the U.S. followed the trend established by the U.N. by drafting a piece of legislation known as the FCMA. The FCMA established a 200 NM fishery conservation zone extending outward from the U.S. baseline. This 200 NM zone was designed to protect and conserve the fisheries of the U.S. and its territories. With the official enactment of the FCMA in 1977, the U.S. formally claimed a 200 NM fishery conservation zone in which it exercised exclusive fishery management authority, except in cases where a country was situated within 400 NM (**Table 5-1**). In the Gulf of Mexico, for instance, Cuba and Mexico are located less than 400 NM away from the U.S. fishery conservation zone boundary. Pending the establishment of permanent maritime boundaries by treaty or agreement with these nations, the FCMA set forth fishery limits based on a median line drawn equidistantly between two nations where a 200 NM limit is not possible (DoS 1977).

In 1976, Mexico established an EEZ at 200 NM. To delineate the maritime boundaries between the U.S. fishery management zone and Mexico's EEZ, an agreement between the two nations was signed and entered into force in 1976 that provisionally established the maritime boundaries in the Gulf of Mexico and the Pacific Ocean so that the two nation's maritime zones did not overlap.[4] A treaty between the U.S. and Mexico in 1978 formalized the maritime boundaries established by the 1976 agreement; the treaty was ratified by Mexico in 1979, but was not ratified by the U.S. until 1997 (**Figure 5-2**).[4]

By the early 1980s, it was evident that the U.S. needed to control more than fisheries outside of its territorial waters. In 1983, President Reagan recognized the necessity of protecting, controlling, and developing the ocean area adjacent to the territorial waters of the U.S. by issuing Presidential Proclamation No. 5030 (**Table 5-1**). This proclamation established an EEZ that extended 200 NM from the U.S. baseline and included all areas adjoining the territorial waters of the U.S. and its territories, except where another country is less than 400 NM from the U.S. The establishment of the EEZ gave the U.S. sovereign rights over the natural resources within the 200 NM zone, but it did not affect the lawful use of this zone by other nations for navigation or overflight (**Table 5-2**).[3] Sovereign rights include the rights to explore, exploit, conserve, and manage natural resources.

The U.S. EEZ covers approximately 7.8 million km^2 of ocean space, half of which is found in the western Pacific Ocean around U.S. possessions such as Hawai'i, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI). Overlapping boundaries with other nations exist in 25 situations. International maritime boundaries are those agreed upon by one or more countries to resolve these overlapping claim issues. In cases where a nation's 200 NM EEZ overlaps with that of another country, both 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.

Table 5-1. Timeline detailing the establishment of U.S. jurisdiction and maritime boundaries in the Pacific Northwest OPAREA and Puget Sound Study Area by treaty, legislation, and presidential proclamation.

- **From Antiquity to the Early Twentieth Century:** nations individually established seaward boundaries of 3 to 9 NM under the "cannon shot" concept.
- **1945–Truman Presidential Proclamation No. 2667 on the Continental Shelf:** for the purpose of conserving and utilizing natural resources, the U.S. claimed jurisdiction and control of the subsoil and seabed of the continental shelf contiguous to its coast. The waters overlying the continental shelf were not affected.
- **1945–Truman Presidential Proclamation No. 2668 on Coastal Fisheries:** conservation zones were established in areas of the high seas contiguous to U.S. coasts for the purpose of protecting coastal fishery resources.
- **1953–Outer Continental Shelf Act:** the subsoil and seabed of the OCS was declared to be under U.S. jurisdiction, control, and power. The waters overlying the OCS were not affected by this act, so fishing and navigation were unrestricted. This act nullified Presidential Proclamation No. 2667 (67 Stat. 462, 43 U.S.C. 1331 et seq.).
- **1958–U.N. Convention on the Law of the Sea I:** the U.N. convened the first international conference on maritime boundaries.
- **1960–U.N. Convention on the Law of the Sea II:** the second U.N. conference convened on international maritime boundaries.
- **1973–U.N. Convention on the Law of the Sea III:** the third U.N. conference convened on international maritime boundaries.
- **1976–Fishery Conservation and Management Act:** this legislation established a fishery conservation zone extending 200 NM from the U.S. baseline, except in several areas such as the Caribbean Sea, where to the west, south, and east of Puerto Rico and the USVI, the limit of the fishery conservation zone was determined by geodetic or straight lines connecting points of latitude and longitude that were delineated in the act.
- **1977–Fishery Conservation and Management Act:** the fishery conservation zone, established by the 1976 FCMA, went into effect.
- **1982–U.N. Convention on the Law of the Sea Treaty:** an international treaty developed by the U.N. but not yet ratified by the U.S. The U.N. Convention on the Law of the Sea lays down a comprehensive regime of law and order in the world's oceans and seas by establishing rules governing all uses of the oceans and their resources. Most nations, including the U.S., adhere to its guidelines for maritime boundaries, including territorial seas, contiguous zones, and EEZs.
- **1983–Reagan Presidential Proclamation No. 5030 on the EEZ:** an EEZ was formally established to facilitate wise development and use of the oceans consistent with international law as well as to recognize the zone adjacent to a nation's territorial seas where a nation may assert certain sovereign rights over natural resources. Establishment of the U.S. EEZ advanced the development of ocean resources and promoted protection of the marine environment but did not affect other lawful uses of the zone, including navigation and overflight. This proclamation set the EEZ at 200 NM from the baselines of the U.S. and its territories, except where nations are less than 400 NM apart. In such cases, equidistant lines delineated the EEZ boundary. The EEZ boundaries coincided with those established by the 1976 FCMA. This proclamation did not affect existing U.S. policies concerning the continental shelf, marine mammals, or fisheries. Jurisdiction and sovereign rights will be exercised in accordance with rules of international law.
- **1988–Reagan Presidential Proclamation No. 5928 on the Territorial Sea:** the seaward extent of the U.S. territorial sea was extended to 12 NM from the baseline of the nation and its territories by this proclamation. The territorial sea is the zone over which the U.S. exercises supreme sovereignty and jurisdiction from the airspace over the sea to the seabed and its soil. This extension of the territorial sea advanced national security and other interests of the U.S. This proclamation did not extend or alter existing federal or state laws (jurisdiction, rights, legal interests, or obligations).
- **1994–UN Convention on the Law of the Sea:** the UN entered into force the 1982 Law of the Sea Treaty. It has yet to be ratified by the U.S.
- **1999–Clinton Presidential Proclamation No. 7219 on the Contiguous Zone:** the contiguous zone of the U.S. was established 24 NM from the nation's baseline by this proclamation. The contiguous zone is the area where the U.S. exercises the control necessary to prevent and punish infringement of its fiscal, customs, immigration, or sanitary laws and regulations within its territorial sea. Establishment of the U.S. contiguous zone advanced the law enforcement and public health interests of the nation. This proclamation did not change existing federal or states law and did not alter the rights of the U.S. in the EEZ.

Source: DoS (1977), U.S. President (1988), de Blij and Muller (1999), DOALOS[3], and Rosenberg.[5]

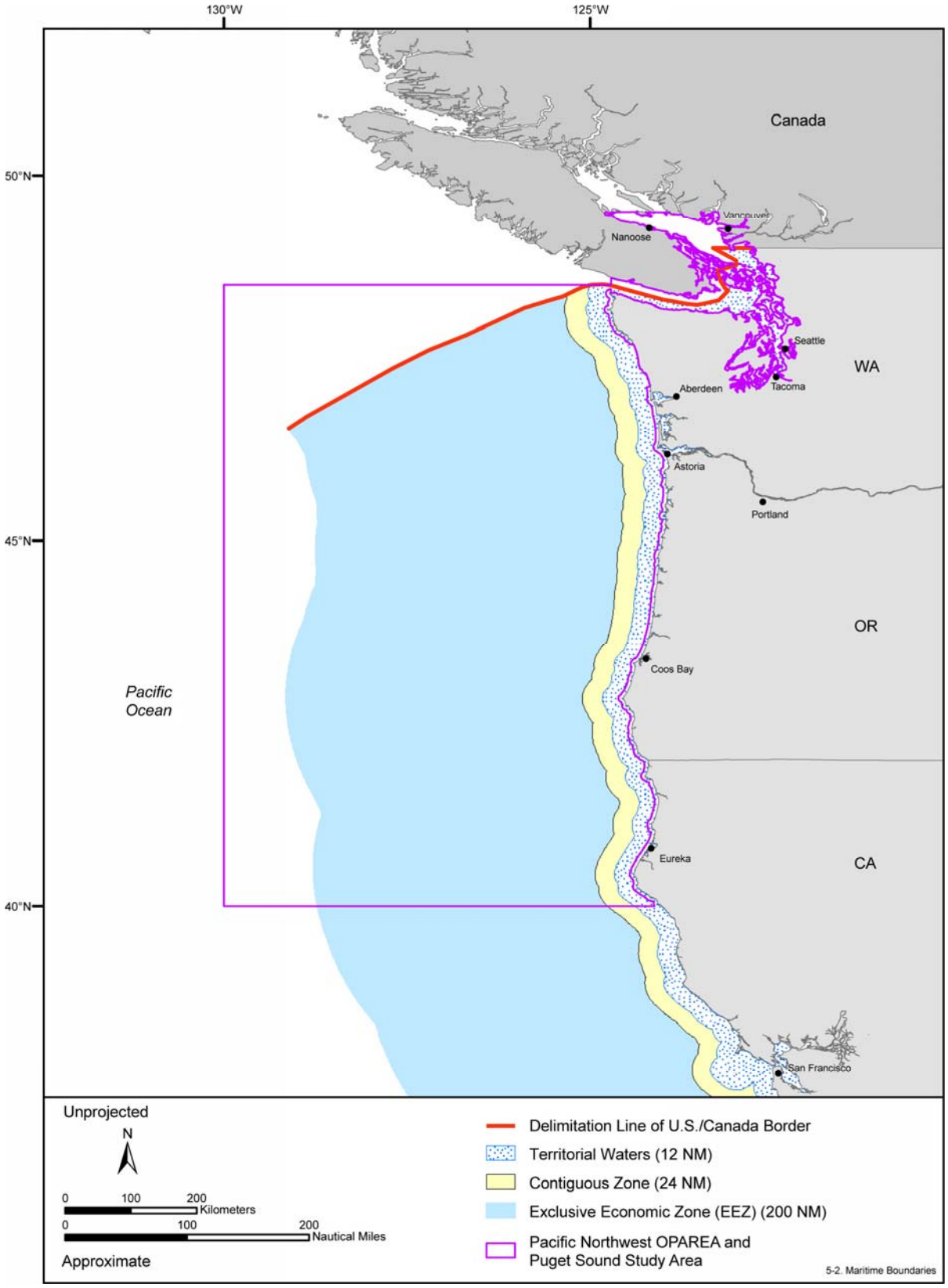

Figure 5-2. U.S. maritime boundaries in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. The territorial waters (12 NM), contiguous zone (24 NM), and EEZ (200 NM) are each measured outward from the baseline (usually mean low-tide line) along the shore. Source data: GDAIS (2004) and DOALOS.[4]

Table 5-2. The maritime boundaries of the U.S. and their seaward and jurisdictional extents.

Maritime Boundary	Seaward Extent	Jurisdictional Extent
State Waters	3 to 9 NM from U.S. baseline (depending on state's historical maritime boundary)	State or territory jurisdiction over the air, sea, and seabed
Territorial Waters	12 NM from U.S. baseline	Federal jurisdiction over the air, sea, and seabed
Contiguous Zone	24 NM from U.S. baseline	Power to prevent and punish for infringement of fiscal, customs, immigration, and sanitary laws
Exclusive Economic Zone (EEZ)	200 NM from U.S. baseline	Sovereign rights over all natural resources and jurisdiction to protect the marine environment

Source: DOALOS[3]

The U.N. Law of the Sea Treaty, created in 1982 and entered into force in 1994, delimited the international maritime sovereignties of coastal nations as 12 NM for territorial seas, 18 to 24 NM for a contiguous zone, and 200 NM for an EEZ (54 FR 777). While the U.S. has not yet signed the Law of the Sea Treaty, it does recognize and abide by many of its rules. For instance, in 1988, U.S. Presidential Proclamation No. 5928 extended the seaward territorial limit of the U.S. to 12 NM from the baseline (**Table 5-1**). This expansion of federal territorial waters from 3 NM (or in some cases 9 NM) to 12 NM provided the U.S. with jurisdiction and supreme power over this area (**Table 5-2**). The seabed and its resources, the biota found in the water column, and the airspace above the territorial seas, as well as the use of surface waters, are all under the jurisdiction of the U.S. Although the territorial waters of the U.S. extend 12 NM seaward from its baseline, the part of the territorial sea closest to shore (3 to 9 NM) remains under the primary jurisdiction of each coastal state.

U.S. control over the waters adjacent to its shores was further solidified in 1999 when President Clinton's Presidential Proclamation No. 7219 extended U.S. federal jurisdiction by the additional 12 NM maximum allowed by international law. This 24 NM contiguous zone is measured from the U.S. baseline and, as its name implies, is an area contiguous or next to a nation's territorial waters that provides an added area of limited jurisdiction. The U.S. makes no territorial claims within its contiguous zone, but it does, however, claim the right to exercise the control necessary to prevent infringement of its fiscal, customs, immigration, or sanitary laws/regulations and to punish infringement of these laws/regulations committed within the zone.[3] The establishment of the U.S. contiguous zone additionally advances both the law enforcement and public health interests of the U.S. (**Table 5-1**).

5.1.1 Maritime Boundaries in the Pacific Northwest OPAREA and Puget Sound Study Area

The Pacific Northwest OPAREA and Puget Sound Study Area is located almost entirely within the U.S. EEZ (**Figure 5-2**). The northern portion of the Pacific Northwest OPAREA extends into Canadian EEZ waters including the northern warning ranges in W-237. Several warning areas lie off the Pacific coast of the Pacific Northwest OPAREA including W-237A through W-237J, W-570, and W-93. Warning areas W-237A and W-237B extend inshore along the Washington coast. Various military bases and operating areas are also located within the Puget Sound Study Area including but not limited to the DBRC, Darrington OPAREA, Puget Sound Naval Shipyard, NBK Bangor, Naval Station Everett, and NAS Whidbey Island. The Nanoose Range Site is found in Georgia Strait which is located in Canadian waters. For more information on these locations see Chapter 1.

5.1.2 U.S. Maritime Boundary Effects on Federal Legislation and Executive Orders

According to the presidential proclamations and treaties that established or extended the maritime boundaries of the U.S. (territorial waters, contiguous zone, and EEZ), existing federal or state laws or any associated jurisdiction, rights, legal interests, or obligations were not extended or altered in any way. The following federal legislation and EOs have associated maritime zones or boundary limitations. The maritime boundary associations detailed in the legislation or orders relevant to the Pacific Northwest OPAREA and Puget Sound Study Area are listed below (see Section 1.3 for a full description of the legislation and their applications). The term 'high seas' generally refers to international waters outside the jurisdiction of any single nation.

- The MMPA protects, conserves, and manages marine mammals in waters under the jurisdiction of the U.S., which are defined by the MMPA as the U.S. territorial seas, EEZ, and the eastern special areas between the U.S. and Russia. The act further regulates "takes" of marine mammals on the global commons (i.e., the high seas or Antarctica) by vessels or persons under U.S. jurisdiction.

- The ESA regulates the protection, conservation, or management of endangered species in the U.S. territorial land and seas as well as on the high seas.

- The MSFCMA, also known as the SFA, claims sovereign rights over fish and fishery management in the U.S. EEZ, except for HMS. The U.S. cooperates with nations or international organizations involved in fisheries for the HMS in order to conserve and promote optimum yields of the species in their entire range in and beyond the U.S. EEZ.

- The NEPA establishes a CEQ and a national policy that encourages productive harmony between humans and their environment. It also promotes efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man. Jurisdiction of this act includes the territorial lands and waters of the U.S. to the limit of the territorial seas.

- The MPRSA regulates the dumping of materials in the ocean. It is applicable to material transported by any U.S. person, vessel, aircraft, or agency from any location in the world and by any person outside the U.S. intending to dump materials in U.S. territorial seas and the contiguous zone.

- EO 12114 extends environmental impact evaluation requirements for U.S. federal agencies beyond the territorial seas and contiguous zone to include the environments of other nations and the global commons outside the jurisdiction of any nation.

- The MPPRCA prohibits pollution of the marine environment by any vessel with U.S. registry or under U.S. authority and all vessels in the U.S. territorial waters or EEZ.

5.2 NAVIGABLE WATERWAYS AND COMMERCIAL SHIPPING LANES

Navigable waterways of the U.S. are those waters that are presently used to transport interstate or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the water body and is not extinguished by later actions or events that impede or destroy navigable capacity (33 CFR 329.4). There are more than 40,000 km (21,000 NM) of commercially navigable waterways under the U.S. transportation system.

Commercial vessels enter and cross the Pacific Northwest OPAREA and Puget Sound Study Area on a routine basis. Along the western U.S. coast, commercial shipping routes are highly structured and controlled, even in open ocean areas. Commercial shipping in the Pacific Northwest is dominated by cargo transports, container freight, crude oil tankers, and barges. Tug and tow operations, steamships, military vessels, ferries, and large and small commercial and recreational fishing vessels also converge in the Pacific Northwest OPAREA and Puget Sound Study Area (USCG 2002). Highly diversified ports assist the U.S. and Canada with international commerce between the Pacific Northwest region, East Asia, western North America, Indo-Pacific, and Central America (Elston 1997). In smaller numbers, vessels

going to and from Atlantic Europe, the Mediterranean, eastern North America, and South America also transit the region (Elston 1997). The largest ferry fleet in the U.S. operates throughout the many islands of Puget Sound Study Area and generally moves in routes perpendicular to those of larger transiting vessels (Washington State Ferries 2003; **Figure 5-3**).

Vessel traffic in the vicinity of the Pacific Northwest OPAREA and Puget Sound Study Area's major ports is often governed by a system of Traffic Separation Schemes (33 CFR 167). A Traffic Separation Scheme is an internationally recognized routing designation created by the USCG that separates opposing flows of vessel traffic into lanes, including a zone between lanes where traffic is to be avoided. These schemes, which are delineated by a series of geographic (latitude/longitude) coordinates, allow for safe navigation into and out of major ports. Vessels are not required to use designated Traffic Separation Schemes, but failure to use one, if available, would be a major factor for determining liability in the event of a collision. Canada and U.S. coast guards jointly manage portions of Puget Sound transportation through Traffic Separation Schemes, the Co-operative Vessel Traffic System (CVTS), and the International Tug Opportunity System (ITOS). The International Maritime Organization (IMO) supplements domestic legislation relating to technical matters of international trade and encourages mariners to recognize the highest practicable standards concerning maritime safety, efficiency of navigation, and prevention and control of marine pollution from ships in international waters.[6]

Within the Puget Sound Study Area, extensive Traffic Separation Schemes commence just west of the Strait of Juan de Fuca in the Pacific Ocean and in the entrance of the Port of Vancouver, British Columbia (**Figure 5-4**). In response to increased maritime activity, amendments to existing Traffic Separation Schemes in the Puget Sound, Georgia Strait, Haro Strait, and the Strait of Juan de Fuca have been recognized by the IMO to improve traffic flow and reduce collisions (Spectrum Management and Telecommunications 1993; USCG 2002). Deep waters throughout Puget Sound are ideal for navigation; additionally, Traffic Separation Schemes in the Strait of Juan de Fuca are a mile or more wide, enhancing navigation conditions and preventing collisions. Although there are no designated Traffic Separation Schemes located in the waters off the coasts of Washington State, Oregon, or northern California, the U.S. government established a Regulation Navigation Area in portions of the Strait of Juan de Fuca and along northwest Washington State to reduce dangers of proximity during federally recognized Makah Tribe whale hunts (USCG 1998). Effective December 2002, the IMO extended a voluntary Area to be Avoided (ATBA) off the coast of Washington State, within the boundaries of the Olympic Coast National Marine Sanctuary (NMS), to prevent marine resource damage by maritime activities. Navigation restrictions apply to all vessels carrying cargos classified by the U.S. as hazardous materials and all ships 1,600 gross tons and above solely in transit (NOS 2002). See Section 5.3.1 for more information on Olympic Coast NMS.

No major port cities are located along the outer coasts of northern California or Washington State; however, the Port of Portland is situated in northern Oregon and serves as a terminal for marine transportation along the western U.S. coast. Puget Sound represents the nation's third largest naval port complex and includes three major port cities in the regions' shared waters: Seattle, Vancouver, and Tacoma (USCG 2002). Additionally, minor ports are located throughout the region and along the Strait of Juan de Fuca: Anacortes, Angeles, Bellingham, Bremerton, Everett, Ludlow, Olympia, and Townsend. Tacoma, Seattle, and Portland were ranked twenty-fourth, twenty-fifth, and twenty-seventh, respectively, among U.S. ports in foreign waterborne commerce for calendar years 2000 through 2004.[7] Several shipping lanes begin at western U.S. ports and terminate at a common, perpendicular shipping lane that transits the coast approximately 70 NM from shore. Four primary shipping lanes radiate out from the west coast to Honolulu, Hawaii. Three shipping lanes leave the Puget Sound Study Area via the Georgia Strait and run to various locations of Alaska and British Columbia (**Figure 5-4**).

5.3 Federal Marine Managed Areas in the Pacific Northwest OPAREA and Puget Sound Study Area

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

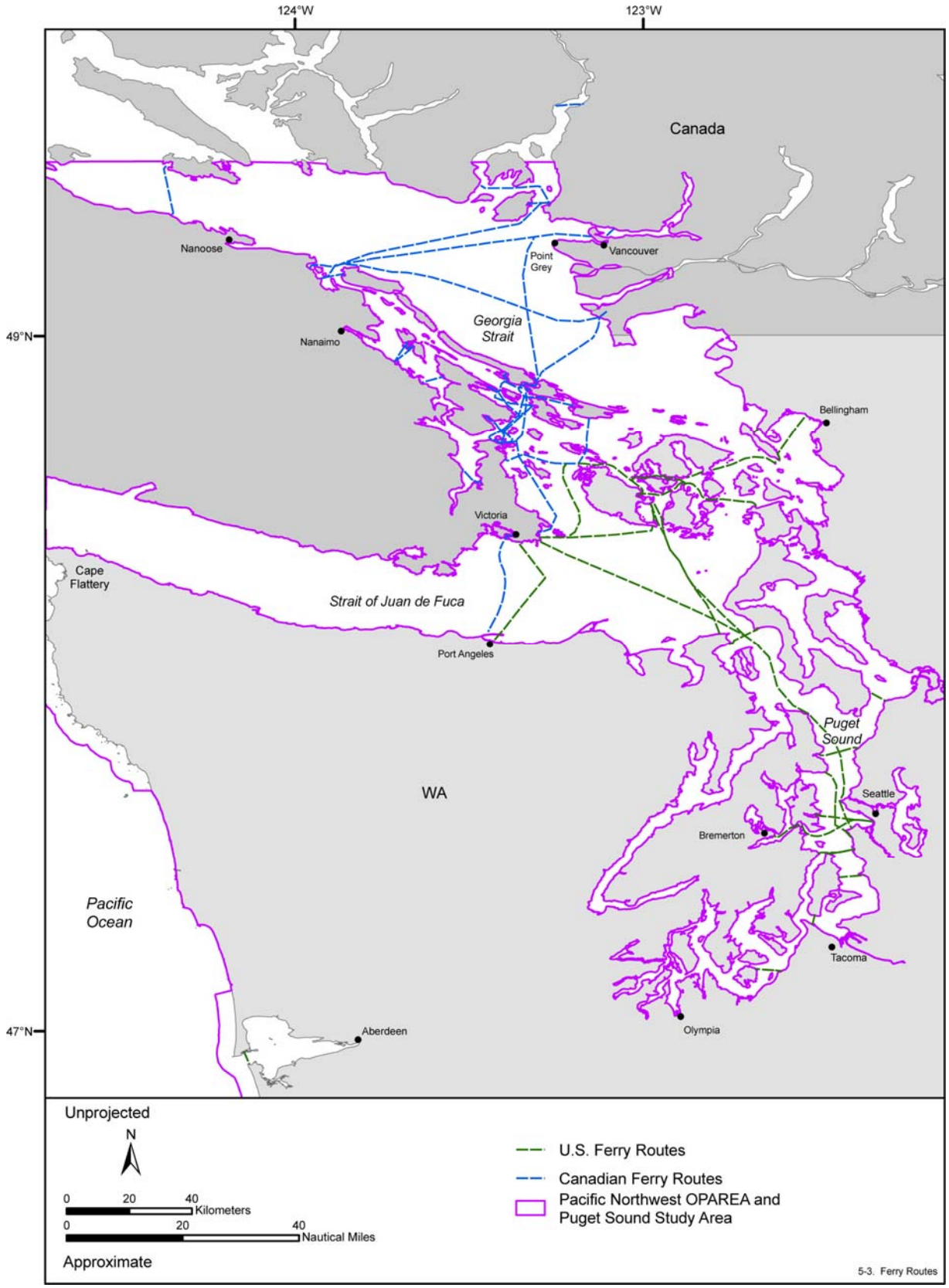

Figure 5-3. U.S. and Canadian ferry routes of the Puget Sound Study Area. Source data: Province of British Columbia.[8] Map adapted from: Province of British Columbia[8], AFerry[9], Dan Youra Studios[10], and WSDOT.[11]

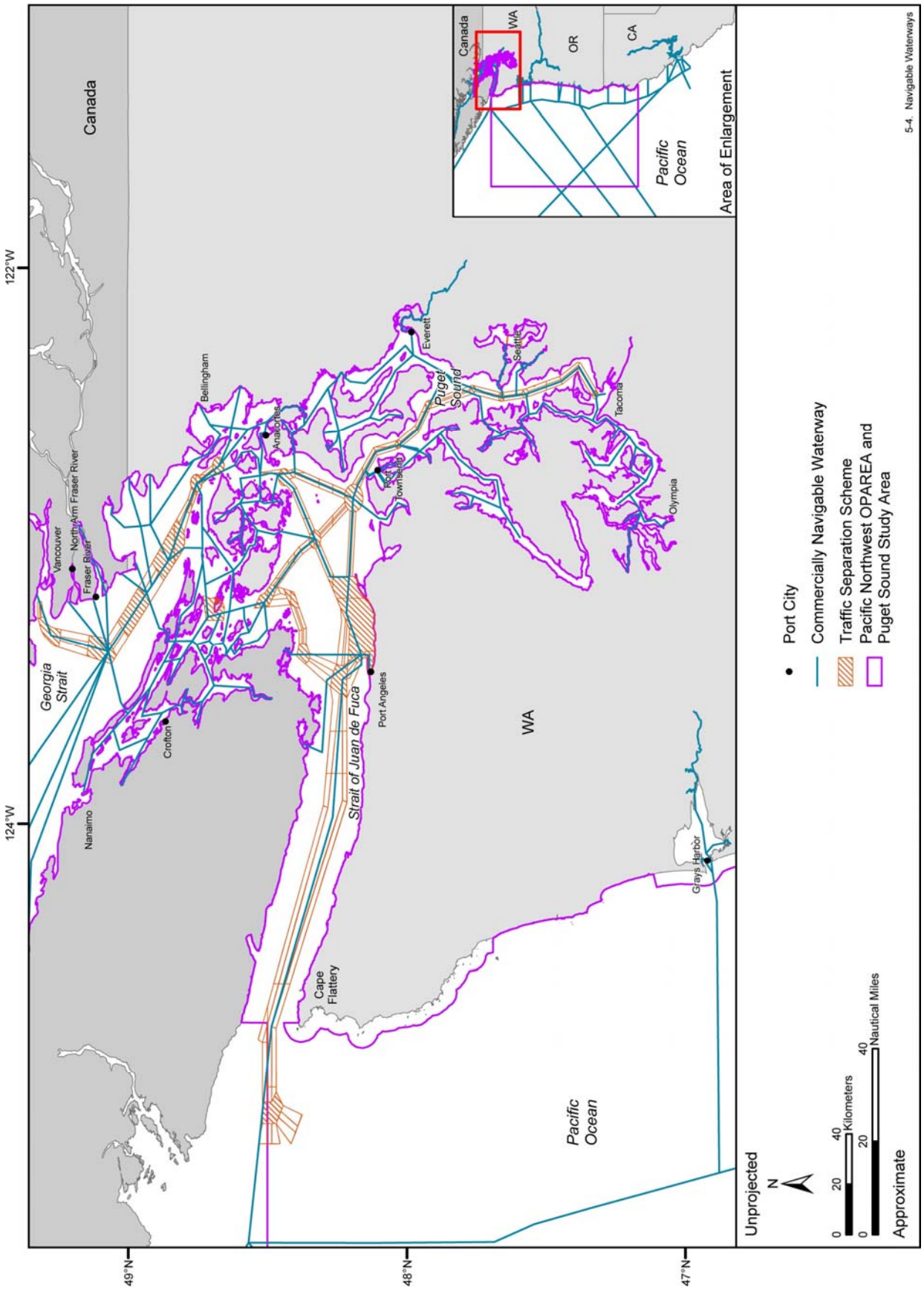

Figure 5-4. Commercially navigable waterways and traffic separation schemes in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: DoT[12], DoT[13], and NOAA[14].

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 a 'marine protected area'. As such, the National MPA center has developed a MPA classification system providing definitions and qualifications for the various terms within the EO (NMPAC 2005).

The new MPA definition is narrower and has stricter criteria. The new classification system is designed to objectively define MPAs by six 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 is to be an effective conservation tool for sustaining ocean ecosystems (NRC 1999; NRC 2000).

Many areas of U.S. marine waters receive some level of managed protection. NOAA and the DoI are documenting all marine sites, and the National MPA Center is compiling a comprehensive inventory of all federal, state, tribal and local sites that meet certain criteria of either a MMA or an MPA. MMAs are similar to MPAs in that they have a conservation or management purpose, defined boundaries, and some legal authority to protect resources. However, MMAs encompass a wider range of management intents, which include areas of protection for geological, cultural, or recreational resources that might not be included under the definition provided in EO 13158 for MPAs. MMAs may also include areas that are managed for reasons other than conservation (e.g., security zones, shellfish closures, sewage discharge areas, and pipeline and cable corridors).

To date, federal sites have been added to the national MMA Inventory with an initial subset of data being collected. Full data sets are at various stages of completion for some sites. The data are in the process of being reviewed and updated by each responsible agency, and a final Inventory is expected in 2006. Estimates predict that upon completion of the Inventory, approximately 1,500 to 2,000 sites will be included in the database (NMPAC 2005). Once the MMA Inventory is complete, the MPA Classification System will be applied and official MPA designations will be made. Only sites in the MPA list are subject to the ‘avoid harm’ stipulation stated in EO 13158. Twenty-six federal sites are located in the Pacific Northwest OPAREA and Puget Sound Study Area (**Table 5-3**, **Figure 5-5**, and **Figure 5-6**).

Table 5-3. MPAs in the Pacific Northwest OPAREA and Puget Sound Study Area.

Site Name	Type of Site
Oregon	
Federal	
Brandon Marsh National Wildlife Refuge	National Wildlife Refuge
Cape Meares National Wildlife Refuge	National Wildlife Refuge
Columbia River Salmon Conservation Zone	Federal Threatened/Endangered Species Protected Area
Lower Columbia River Estuary	National Estuary Program
Nestucca Bay National Wildlife Refuge	National Wildlife Refuge
Oregon Islands National Wildlife Refuge	National Wildlife Refuge
Siletz Bay National Wildlife Refuge	National Wildlife Refuge
South Slough National Estuarine Research Reserve	National Estuarine Research Reserve
Three Arch Rocks National Wildlife Refuge	National Wildlife Refuge
Tillamook Bay	National Estuary Program
State	
Boiler Bay Research Reserve	Intertidal Research Reserve
Brookings Research Reserve	Intertidal Research Reserve
Cape Arago Research Reserve	Intertidal Research Reserve
Cape Kiawanda Marine Garden	Marine Garden

Table 5-3. Continued.

Site Name	Type of Site
Oregon	
State (continued)	
Cape Perpetua Marine Garden	Marine Garden
Gregory Point Research Reserve	Subtidal Research Reserve
Harris Beach Marine Garden	Marine Garden
Haystack Rock Marine Garden	Marine Garden
Neptune State Park Research Reserve	Intertidal Research Reserve
Netarts Bay Reserve	Shellfish Reserve
Otter Rock Marine Garden	Marine Garden
Pirates Cove Research Reserve	Subtidal Research Reserve
Pyramid Rock	Marine Habitat
Whale Cove Research Reserve	Intertidal Research Reserve
Yachats Marine Garden	Marine Garden
Yaquina Bay Reserve	Shellfish Reserve
Yaquina Head Marine Garden	Marine Garden
California	
Federal	
Castle Rock National Wildlife Refuge	National Wildlife Refuge
Humboldt Bay National Wildlife Refuge	National Wildlife Refuge
Redwood National Park	National Park
State	
California Coastal Sanctuary	State Coastal Sanctuary
Kelp Beds at Trinidad Head	Area of Special Biological Significance
Kings Range California State	Marine Reserve
Kings Range National Conservation Area	Area of Special Biological Significance
Redwood National and State Parks	Areas of Special Biological Significance
Tolowa Dunes	California State Park
Washington State	
Federal	
Columbia River Salmon Conservation Zone	Federal Threatened/Endangered Species Protected Area
Copalis National Wildlife Refuge	National Wildlife Refuge
Flattery Rocks National Wildlife Refuge	National Wildlife Refuge
Grays Harbor National Wildlife Refuge	National Wildlife Refuge
Lower Columbia River Estuary	National Estuary Program
Olympic Coast National Marine Sanctuary	National Marine Sanctuary
Pacific Whiting Columbia River Salmon Conservation Zone	Federal Threatened/Endangered Species Protected Area
Quillayute Needles National Wildlife Refuge	National Wildlife Refuge
Willapa National Wildlife Refuge	National Wildlife Refuge
Yelloweye Rockfish Conservation Area	Federal Fishery Management Zone
Olympic National Park	National Park
State	
Bone River Natural Area Preserve	Natural Area Preserve
Elk River Natural Resources Conservation Area	Natural Resources Conservation Area
Gunpowder Island Natural Area Preserve	Natural Area Preserve
Niawiakum River Natural Area Preserve	Natural Area Preserve
North Bay Natural Area Preserve	Natural Area Preserve
Sand and Goose Islands Natural Area Preserve	Natural Area Preserve
Teal Slough Natural Resources Conservation Area	Natural Resources Conservation Area
Washington State Parks (79)	State Park
Whitcomb Flats Natural Area Preserve	Natural Area Preserve
Puget Sound	
Federal	
Dungeness National Wildlife Refuge	National Wildlife Refuge
Nisqually National Wildlife Refuge	National Wildlife Refuge
Padilla Bay National Estuarine Research Reserve	National Estuarine Research Reserve
Protection Island National Wildlife Refuge	National Wildlife Refuge

Table 5-3. Continued.

Site Name	Type of Site
Puget Sound	
***Federal* (*continued*)**	
Puget Sound	National Estuary Program
San Juan Islands National Wildlife Refuge	National Wildlife Refuge
State	
Admiralty Head Marine Preserve	Marine Preserve
Argyle Lagoon San Juan Islands Marine Preserve	Marine Preserve
Bare Island Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Bell Island Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Blake Island Underwater Park	State Park
Brackett's Landing Shoreline Sanctuary Conservation Area	Recreational Marine Preserve
Cattle Point Natural Resources Conservation Area	Natural Resources Conservation Area
Charles Island Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Cherry Point Aquatic Reserve	Aquatic Reserve
City of Des Moines Park Conservation Area	Marine Conservation Area
Colvos Passage Marine Preserve	Marine Preserve
Cypress Highlands Natural Area Preserve	Natural Area Preserve
Cypress Island Aquatic Reserve	Aquatic Reserve
Cypress Island Natural Resources Conservation Area	Natural Resources Conservation Area
Dabob Bay Natural Area Preserve	Natural Area Preserve
Deception Pass Underwater Park	State Park
Edmonds Underwater Park	Underwater Park
False Bay San Juan Islands Marine Preserve	Marine Preserve
Fidalgo Bay Aquatic Reserve	Aquatic Reserve
Fort Casey Underwater Park	State Park
Fort Ward Underwater Park	State Park
Fort Worden Underwater Park	State Park
Friday Harbor San Juan Islands Marine Preserve	Marine Preserve
Gull Rock Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Haro Strait Special Management Fishery Area	Marine Species Preserve
Hat Island Natural Resources Conservation Area	Natural Resources Conservation Area
Kellett Bluff Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Kennedy Creek Natural Area Preserve	Natural Area Preserve
Keystone Conservation Area	Marine Conservation Area
Kopachuck Underwater Park	State Park
Lawrence Point Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Lime Kiln Lighthouse Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Lummi Island Natural Area Preserve	Natural Area Preserve
Lummi Island Natural Resources Conservation Area	Natural Resources Conservation Area
Maury Island Aquatic Reserve	Aquatic Reserve
Octopus Hole Conservation Area	Marine Conservation Area
Orchard Rocks Conservation Area	Marine Conservation Area
Pile Point Voluntary No-take Bottomfish Recovery Area	Marine Species Preserve
Point Doughty Natural Area Preserve	Natural Area Preserve
Saltar's Point Beach Conservation Area	Marine Conservation Area
Saltwater Underwater Park	State Park
San Juan Channel and Upright Channel Special Management Fishery Area	Marine Species Preserve
San Juan County/Cypress Island Marine Biological Preserve	Marine Preserve
Shaw Island San Juan Islands Marine Preserve	Marine Preserve
Shipwreck Point Natural Resources Conservation Area	Natural Resources Conservation Area
Skagit Wildlife Area	Wildlife Area
Skookum Inlet Natural Area Preserve	Natural Area Preserve
South 239th Street Park Conservation Area	Marine Conservation Area
South Puget Sound Wildlife Area	Wildlife Area
Sund Rock Conservation Area	Marine Conservation Area
Titlow Beach Marine Preserve	Marine Preserve
Tolmie Underwater Park	State Park
Tongue Point Marine Life Sanctuary	Nature Preserve
Waketickeh Creek Conservation Area	Marine Conservation Area

Table 5-3. Continued.

Site Name	Type of Site
Puget Sound	
***State* (*continued*)**	
Woodard Bay Natural Resources Conservation Area	Natural Resources Conservation Area
Yellow and Low Islands San Juan Islands Marine Preserve	Marine Preserve
Zee's Reef Marine Preserve	Marine Preserve
Zella M. Schultz / Protection Island Seabird Sanctuary	Seabird Sanctuary
Canada	
Alasken National Wildlife Area	Marine Protected Area
Ballenas Island Rockfish Conservation Area	Federal Fishery Closure
Beaumont Shoal Rockfish Conservation Area	Federal Fishery Closure
Becher Bay II Rockfish Conservation Area	Federal Fishery Closure
Bedwell Harbour Rockfish Conservation Area	Federal Fishery Closure
Bentinck Island Rockfish Conservation Area	Federal Fishery Closure
Bowyer Island Rockfish Conservation Area	Federal Fishery Closure
Brackman Island Ecological Reserve	Marine Protected Area
Burgoyne Bay Rockfish Conservation Area	Federal Fishery Closure
Christie Islet Migratory Bird Sanctuary	Marine Protected Area
Crocker Island Rockfish Conservation Area	Federal Fishery Closure
D'Arcy Island Rockfish Conservation Area	Federal Fishery Closure
Danger Reefs Rockfish Conservation Area	Federal Fishery Closure
Discovery Island Rockfish Conservation Area	Federal Fishery Closure
Domville Island Rockfish Conservation Area	Federal Fishery Closure
Endeavour Hydrothermal Vents	Marine Protected Area
Esquimalt Lagoon Migratory Bird Sanctuary	Marine Protected Area
Finlayson Arm Rockfish Conservation Area	Federal Fishery Closure
Gabriola Island Rockfish Conservation Area	Federal Fishery Closure
Galiano Island North Rockfish Conservation Area	Federal Fishery Closure
Gonzales Point Rockfish Conservation Area	Federal Fishery Closure
Ladysmith Rockfish Conservation Area	Federal Fishery Closure
Lasqueti Island South Rockfish Conservation Area	Federal Fishery Closure
Maple Bay Rockfish Conservation Area	Federal Fishery Closure
Mayne Island II North Rockfish Conservation Area	Federal Fishery Closure
Miller's Landing Rockfish Conservation Area	Federal Fishery Closure
Pam Rock Rockfish Conservation Area	Federal Fishery Closure
Pasley Island Rockfish Conservation Area	Federal Fishery Closure
Patey Rock Rockfish Conservation Area	Federal Fishery Closure
Pirates Cove Marine Provincial Park	Marine Protected Area
Portland Island Rockfish Conservation Area	Federal Fishery Closure
Prevost Island Rockfish Conservation Area	Federal Fishery Closure
Pylades Island Rockfish Conservation Area	Federal Fishery Closure
Race Rocks Ecological Reserve	Marine Protected Area
Race Rocks Rockfish Conservation Area	Federal Fishery Closure
Royal Roads Rockfish Conservation Area	Federal Fishery Closure
Saltspring Island Rockfish Conservation Area	Federal Fishery Closure
Satellite Channel Ecological Reserve	Marine Protected Area
Saturna Island Rockfish Conservation Area	Federal Fishery Closure
Senanus Island Rockfish Conservation Area	Federal Fishery Closure
Sidney Spit Marine Provincial Park	Marine Protected Area
Sooke Inlet Rockfish Conservation Area	Federal Fishery Closure
South Arm Marshes Wildlife Management Area	Marine Protected Area
South Pender Island Rockfish Conservation Area	Federal Fishery Closure
Thetis – Kuper Island Rockfish Conservation Area	Federal Fishery Closure
Thormanby Island Rockfish Conservation Area	Federal Fishery Closure
Trincomali Channel Rockfish Conservation Area	Federal Fishery Closure
Valdes Island Rockfish Conservation Area	Federal Fishery Closure
Wallace Island Marine Provincial Park	Marine Protected Area
Whaleboat Island Marine Provincial Park	Marine Protected Area

Source: Didier (1998), Murray and Ferguson (1998), Murray (2000), Taylor (2004), NOAA[15], DFO[16], DFO[17], MPA Global[18], NOAA[19], WDNR[20] and WDNR[21].

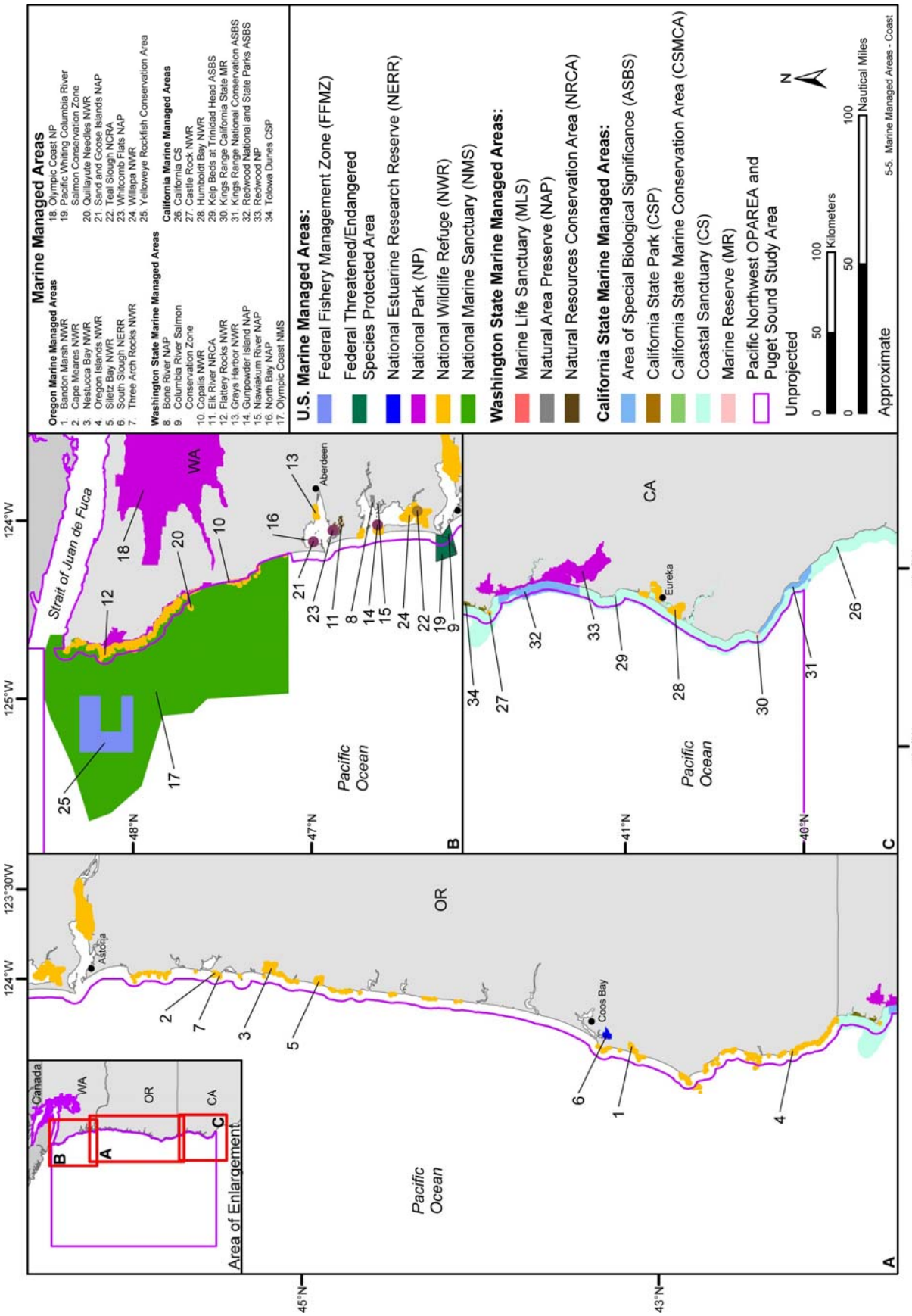

Figure 5-5. Marine managed areas in the Pacific Northwest OPAREA. Source data: NMFS (2004) and NOAA.[22] Map adapted from: WDNR[20], WDNR[21], and NOAA.[23]

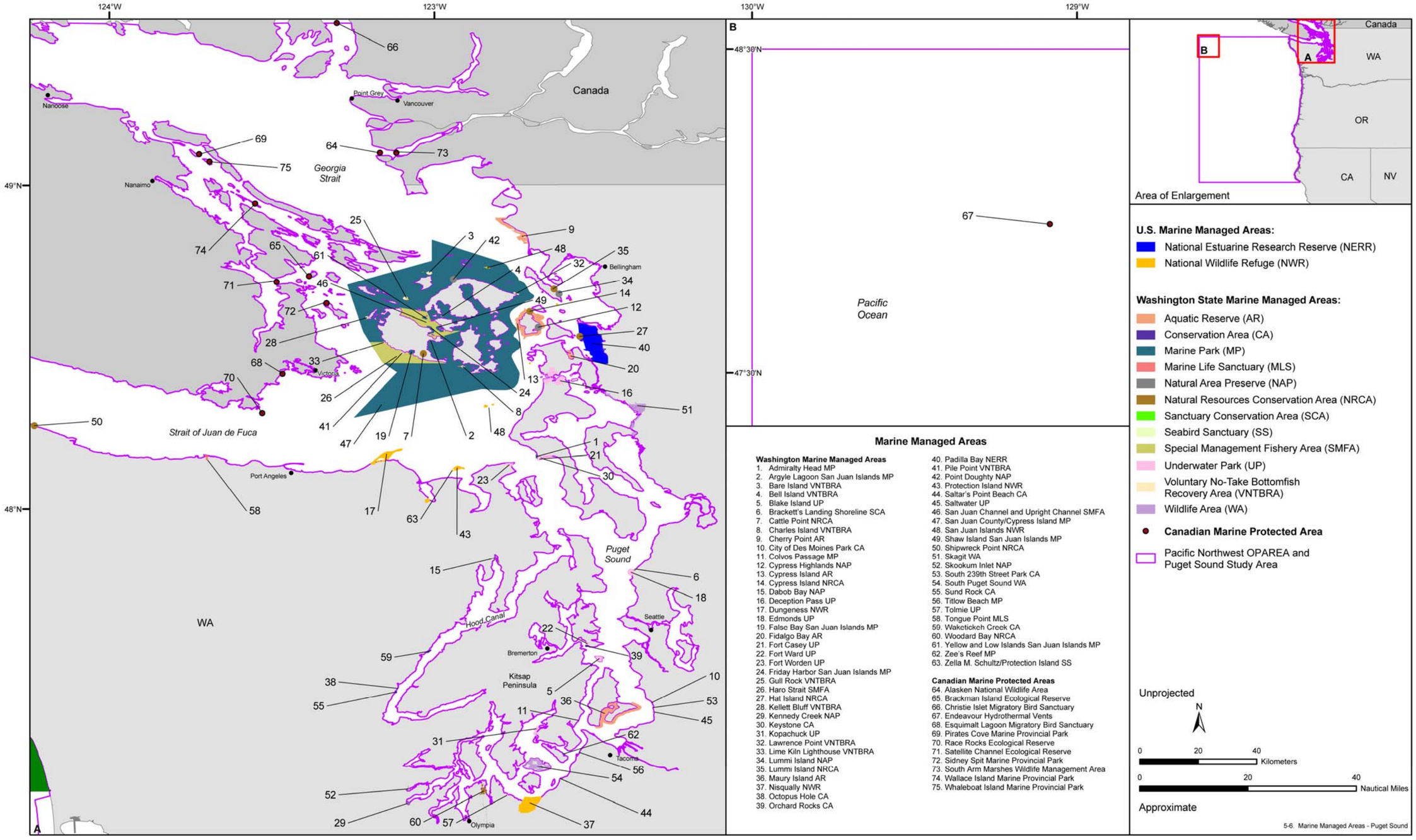

Figure 5-6. U.S. and Canadian marine managed areas within the Puget Sound Study Area. Source data: MPA Global[18] and NOAA.[22] Map adapted from: WDNR[20], WDNR[21], and WDNR.[24]

5.3.1 National Marine Sanctuaries

There are 14 sites in the NMS Program, creating a system that protects over 150,000 km^2 of U.S. ocean waters and habitats. The program includes 13 designated NMS throughout the U.S., as well as the recently designated Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NOAA-NMS 2005). Each NMS has an established management plan that guides the activities and sanctuary programs, sets priorities, and contains relevant regulations. More information on NMS may be found at the NMS Program website.[25]

Olympic Outer Coast NMS is located within the northern boundaries of the Pacific Northwest OPAREA along the Pacific coast of Washington (**Figure 5-5**). The NMS extends 117 NM north to south from the Canada/U.S. international boundary to the Copalis River, just north of Grays Harbor (NOAA SRD 1993). Sanctuary waters cover over 2,500 NM^2 from Washington State's Olympic Peninsula coastline to 30 NM offshore (Hyland and Bowlby 2003). Designated a sanctuary in 1994, the area is utilized by 29 species of marine mammals and a diverse array of seabirds that reside in or migrate through the marine environment (NOAA and WSDE 2001; NOAA-NMS 2004; NOAA[15]). Furthermore, the surroundings are ideal for the proliferation of invertebrates and numerous fish species. Native American tribes, such as the Makah, Quileute, and Hoh, and the Quinault Nation continue to assist in the area's natural resource management to ensure the environment's survival, as well as that of their traditional culture (NOAA and WSDE 2001; NOAA-NMS 2004). Federal regulations set by NOAA have been developed with the intent of protecting the area's historical, ecological, recreational, and natural resources and qualities. Under these regulations, various activities are prohibited within the sanctuary. The Sanctuary Advisory Council provides advice and guidance to the sanctuary manager with resource concerns and decisions. The council contains a conglomerate of regional experts, conservationists, representatives for fishermen and maritime industry, and state, local and federal organizations that include, but are not limited to, the Navy, NMFS, USFWS, and tribal representatives.[26] Additional regulatory agencies manage and oversee research, monitoring, and conservation initiatives that directly or indirectly benefit the surrounding marine habitat (Bowlby 2005). Navigation within the sanctuary is restricted to prevent damage to the surrounding environment from maritime activities (see Section 5.2 for more details).

5.3.2 National Park System Sites

The National Park Service (NPS) administers all areas that are protected and managed under the U.S. National Park System. The NPS Organic Act of 1916 established the NPS with "the fundamental purpose to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment for the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (DoI 2000).

The National Park System is composed of 388 areas covering more than 340,000 km^2 in 49 states, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the USVI (DoI 2003). The system includes national parks, monuments, seashores, memorials, preserves, historical parks, historical sites, and recreational areas that are distinguished for their historic or prehistoric importance, scientific interest, or superior recreational assets (DoI 2000). Within the Pacific Northwest OPAREA, Redwood National Park is located in northern California and Olympic National Park lies within Washington State (**Figure 5-5**).

5.3.2.1 National Parks

- Redwood National Park is located along the coast of northern California, approximately 121 km north of the southern boundary of the Pacific Northwest OPAREA. Forests, high peaks, coastline, and desert environments are all present within park boundaries and provide refuge for 49 ha of ancient redwood forest that shelters 23 species of concern. The park's establishment occurred in 1968 (P.L. 90-545; 16 USC 79b) due to overwhelming concern of the detrimental effects to redwoods in California caused by adjacent timber industries (DeForest 1999). At this time, 23,472 ha were placed under the NPS, and since then, several modifications have been made to the original legislation pertaining to park boundary expansion (U.S. Senate 2005). Three state parks

are located in the borders of the national park: Jedediah Smith Redwoods, Del Norte Coast Redwoods, and Prairie Creek Redwoods. In 1994, a cooperative agreement was established between NPS and the California Department of Parks and Recreation in regards to management of park lands and the facilities thereon. Today, the park consists of 53,823 ha controlled by the federal government and the state of California (U.S. Senate 2005).

- Olympic National Park is located within the interior of Washington State's Olympic Peninsula and also extends along portions the Pacific coast. The extreme northwest setting and glacial isolation has created a unique and diverse ecosystem that supports several rare species. In 1938 the 373,400 ha park received national protection and in 1988 over 95% of the lands were designated wilderness, providing added protection to the natural environment and species therein. Coastal portions of the park extend along northern Washington State and a separate, inshore area lies within the interior of the state. Sandy beaches lie adjacent to lakes and meadows that extend inland to heavily timbered temperate rainforest and glacial mountains.

5.3.2.2 National Seashores

NPS protects and manages 10 national seashores in the U.S. There are no national seashores located within the boundaries of the Pacific Northwest OPAREA or Puget Sound Study Area. The only national seashore in California is Point Reyes National Seashore, which is located off the coast of central California.

5.3.2.3 Ecological/Historical Preserves

Ecological preserves are managed by the NPS. No ecological or historical preserves exist in the Pacific Northwest OPAREA or Puget Sound Study Area.

5.3.3 Critical/Protected Habitats

NMFS responsibilities include rebuilding and maintaining sustainable fisheries, promoting the recovery of protected species, and protecting and maintaining the health of coastal marine habitats. To satisfy these responsibilities, NMFS uses protected areas as one of several tools to conserve and manage marine resources. Critical habitat areas exist in the western U.S. states for 19 species of salmon and steelhead, several bull trout populations, and one marine mammal (i.e., Steller sea lion; NMFS 2005h; 2005c). Designated critical habitat was recently proposed for the North Pacific right whale, and it includes an area in the western Gulf of Alaska and in the southeastern Bering Sea (NMFS 2005b). Further information regarding critical habitat is available in Chapters 3.1 and 4.0 of this MRA.

5.3.4 National Wildlife Refuges

The USFWS, which oversees the National Wildlife Refuge System (NWRS), protects a significant amount of marine habitat within U.S. waters. The NWRS is comprised of 538 established NWR within 38 million ha of diverse ecosystems. Approximately 140 to 150 refuges contain marine and estuarine habitat. These MMAs provide important habitat for a number of threatened and endangered mammals, plants, birds, and reptiles. The NWRS also contains about 10,500 km^2 of coral reefs and adjacent ocean habitat. There are 15 NWR that encompass some portion of land in the Pacific Northwest OPAREA and Puget Sound Study Area.

Within the boundaries of the Pacific Northwest OPAREA and the state of Oregon, the following NWR span 514 km of rugged coastline (**Figure 5-5**):

- Brandon Marsh NWR—The refuge encompasses 4.05 km^2 of land within the Coquille River Estuary and protects the largest remaining zone of salt marsh in the riparian region. In addition, the purpose of the refuge is to protect the mudflat, Sitka spruce and riparian alder communities that provide habitat to migratory shorebirds and waterfowl (USFWS 2000a; NOAA[15]).

- Cape Meares NWR—The marine refuge covers 0.61 km^2 of land and seas along the Pacific coast of northern Oregon.[15] The area includes one of the last remaining coastal old growth forests, containing towering Sitka spruce and western hemlock, some hundreds of years old. The refuge also protects habitat for federally threatened bird species, migrating seabirds and marine mammals, and rocky intertidal habitat (USFWS 2000a).

- Nestucca Bay NWR—Established in 1991, the 14.82 km^2 estuarine refuge protects and provides habitat for dusky and Aleutian Canada geese (USFWS 2000a; NOAA15). The refuge supports the only population of Aleutian Cackling geese; the designation to protect these lands enhanced the species survival and abundance, removing them from list from endangered species in 2001. This land also supports refuge habitat such as wooded uplands, riparian wetlands, salt marsh, and coastal environments for migrating seabirds, shorebirds, mammals and plant life. [15,27]

- Oregon Islands NWR—The 2.25 km^2 marine refuge composed of rocks and islands was designated within the Oregon Islands Wilderness in 1935.[15] The massive rocks protrude seaward along 515 km of coastline and offer habitat and sanctuary for thirteen species of seabirds and provide breeding and haulout areas for pinnipeds (USFWS 2000a).

- Siletz Bay NWR—The scenic habitat protected by this 7.99 km^2 estuarine refuge is salt marsh, brackish marsh, tidal sloughs, mudflats, and coastal coniferous and deciduous forest. (USFWS 2000a; NOAA15). The main purpose of the refuge is to return the salt marsh to its natural, tidally-influenced condition, thereby enhancing the habitat for migrating and residential birds. Avian wildlife associated with these lands include brown pelicans, bald eagles, peregrine falcons, Aleutian and dusky Canada geese, waterfowl, wading birds, shorebirds, and migrants. (USFWS 2000a; NOAA15; USFWS27).

- Three Arch Rocks NWR—Established in 1907, this marine refuge is the oldest NWR west of the Mississippi River, as well as one of the smallest Wilderness Areas in the country. It covers 0.77 km^2 and consists of only three large and six small rocks off the coast of Oregon.[15] The site was designated to protect several species of marine mammals and seabirds, such as tufted puffins and common murre. Steller sea lions use the protective refuge rocks for breeding and hauling out sites during mating seasons (USFWS 2000a).

Eight NWR lie within the boundaries of the Pacific Northwest OPAREA and Puget Sound Study Area; three of which are in the Puget Sound Study Area. Three of the five coastal refuges of Washington State, Flattery Rocks NWR, Quillayute Needles NWR, and Copalis NWR, make up the Washington Islands National Wildlife Refuges (WINWR; **Figure 5-5**). The islands encompass approximately 209 ha of islands, rocks and reefs that stretch over 160 km of the Pacific coast from Cape Flattery to south of Copalis (Washington Islands 2005). All islands along this stretch of the Washington coast, with the exception of Destruction, James and Tatoosh islands, are designated Wilderness, barring human trespass to ensure the protection of the various species of wildlife. The islands and rocks within the WINWR provide sanctuary to numerous species of seabirds, as well as to birds exploiting the area for rest stops during migration and passage of the Pacific. Several cetaceans, pinnipeds, and sea otters also frequent the islands and surrounding seas (Washington Islands 2005).

The remaining five NWR along the Pacific coast of Washington State and within the Puget Sound Study Area are as follows (**Figures 5-5** and **5-6**):

- Grays Harbor NWR—Established in 1988, this refuge lies in the northeast corner of Grays Harbor Estuary and provides suitable habitat for shorebirds and wildlife along the coast of Washington State. Tidal flats, salt marsh, and surrounding upland forests cover approximately 607 ha within the refuge. Mudflats offer protection and sustenance for thousands of shorebirds settling in the area each spring to as they prepare for seasonal migrations to northern breeding grounds.[29]

- Willapa NWR—Established in 1937, Willapa NWR lies within Willapa Bay, the second largest estuary on the Pacific coast.[15,30] Many species of waterfowl and shorebirds find refuge in the ecosystems that include over 673.4 km^2 of brackish habitat that ranges from salt marshes, tidal flats, and old growth forest to coastal beaches and dunes.[31]

- Dungeness NWR—The refuge lies along the northern coast of Washington State, just east of Port Angeles, in the Puget Sound Study Area. Protruding from Olympic Peninsula's northern coast and projecting five and a half miles seaward is the Dungeness Spit.[32] The spit is a sandbar that formed by the movement of sediment along shore, developing seaward, creating Dungeness Harbor. The majority of the refuge lies within the spit and is characterized by several types of vegetation and habitat ideal for numerous species of birds, fish, and mammals.[33] Harbor seals, in particular, occupy the area for hauling out and pupping.[15] Bald eagles and peregrine falcon reside within the refuge together with several other threatened and endangered birds.[32]

- Nisqually NWR—The 30.95 km^2 refuge is located in the Nisqually River Delta and provides protection for migrating and wintering bird species, coho and Chinook salmon, and several other threatened and endangered species (USFWS n.d.; NOAA[15]). Established in 1974, the delta contains an exceptional coastal salt marsh system, as well as estuarine, freshwater marsh, riparian woodland, and freshwater wetland habitats that support biologically diverse flora and fauna (USFWS n.d.).

- Protection Island NWR—The refuge contains approximately 70% of the nesting seabird population of the Puget Sound Study Area, including one of the last remaining nesting colonies of the tufted puffin in the region. The 147 ha island is located just north of Washington State at the mouth of Discovery Bay and is closed to the public to protect nesting seabird and harbor seal habitat. In addition to the tufted puffin, other bird species nest on the island including rhinoceros auklets and glaucous-winged gulls. A large community of harbor seals can also be observed within the vicinity of the island.[34]

- San Juan Islands NWR—The San Juan archipelago consists of 83 islands within 182 terrestrial ha of reefs, rocks, and grassy and forested lands located in northern Puget Sound at the convergence of the Strait of Juan de Fuca and the Strait of Georgia (Don 2003; USFWS[35]). The islands were designated a refuge to protect nesting seabird habitat. Other wildlife, including harbor seals and bald eagles, frequent the islands and also benefit from security due to the fact that all but two islands are prohibited from human impact.[35]

Within the Pacific Northwest OPAREA and the state of California, Humboldt Bay NWR and Castle Rock NWR are managed together by the Humboldt Bay National Wildlife Refuge Complex (NWRC). The primary purpose of the refuge complex is to protect and improve eelgrass beds, mudflats, and other wetland habitat provide for many species of migratory waterfowl, particularly, the black brant. Castle Rock NWR lies just offshore of the California coast, encompasses 5.6 ha, and steeply protrudes 102 m above sea level.[36] The rock provides valuable habitat for nesting Aleutian Canadian geese and other marine animals such as the common murre, harbor seals, northern elephant seals, California sea lions, and Steller sea lions.[36,37,38]

5.3.5 National Estuarine Research Reserves

The National Estuarine Research Reserve System (NERRS) is a partnership between NOAA and the coastal states. The system is a network of 26 reserves, consisting of relatively pristine estuarine areas that contain key habitat and are protected from significant ecological change or developmental impacts.[39] The reserves also provide reference sites for research, monitoring, and educational programs that focus on functional estuarine ecosystems. National Estuarine Research Reserves (NERR) include a variety of rare, endangered, and threatened species. The DoD is not exempt from any NERR regulations (15 CFR 921).

The two NERR located within the Pacific Northwest OPAREA along the coasts of Oregon and Washington State follow (**Figure 5-5**):

- South Slough NERR—South Slough NERR is located within the southwestern extension of the Coos Bay estuary located along the Oregon coast. Established in 1974, South Slough NERR is the oldest federal NERR in the U.S. and actively participates in ecological research, monitoring, education, and restoration (Good 1999; NOAA[15]). The reserve supports upland forests, wetlands, salt marshes, mud flats, and eelgrass habitat that provide valuable settings for a wide range of species of small terrestrial mammals, amphibians, shorebirds, fish and invertebrates (Good 1999; NOAA[15]).

- Padilla Bay NERR—Designated as a 4,451 ha reserve in 1980, Padilla Bay NERR is located along the delta edge of the Skagit River in Washington State, north of Seattle and adjacent to Anacortes. Nominated by NOAA and Washington State under the Coastal Zone Management Act (CZMA), the reserve is administered and operated by the Washington State Department of Ecology (Murray 2000). The waters of Padilla Bay are a mixture of freshwater (i.e. Fraser and Skagit Rivers) and saltwater (i.e. Pacific Ocean) sources. This combination of waters, together with high concentrations of sediment, creates an intertidal bay where eelgrass and mudflats are abundant. Approximately 3,232 ha of eelgrass within Padilla Bay provide key habitat for the Dungeness crab, salmon, perch, herring, black brant, bald eagle, and peregrine falcon.[40,39]

5.3.6 Fishery Closures

NMFS has the responsibility of determining declining fish stocks and utilizing tools to conserve and maintain fisheries and marine resources. Several articles of legislation affect living marine resources and influence the decisions of NMFS in designating protected areas: MSFCMA, ESA, MMPA, and the Atlantic Coastal Fisheries Cooperative Management Act. NMFS currently has 36 protected areas in the MMA Inventory, three of which are located along the western U.S. coast in the Pacific Northwest OPAREA (**Figure 5-5**).[41]

- Yelloweye Rockfish Conservation Area—Established in 2003 under the authority of the MSFCMA, this Federal Fishery Management Zone protects yelloweye rockfish populations off the coast of northern Washington State. Yelloweye rockfish were declared overfished along the northern U.S. west coast beginning in 2001. Since then, regulations have been established within the U.S. EEZ with the purpose of protecting essential rockfish habitat and regulating declining fish stocks. NOAA and the Pacific Fishery Management Council (PFMC) co-manage the c-shaped region off the coast of Washington State (NMFS 2004e; NOAA[15]).

- Columbia River Salmon Conservation Zone—This 46.73 km^2 reserve lies immediately seaward of the mouth of the Columbia River, containing all habitat within the Columbia River Basin and open ocean. The purpose of the site is to protect threatened and endangered salmon species upon their return from the Pacific Ocean. Established in 1992 under the authority of the MSFCMA, the conservation zone is co-managed by NOAA and PFMC.[15]

- Pacific Whiting Columbia River Salmon Conservation Zone—The reserve is situated at the mouth of the Columbia River, within Columbia River Salmon Conservation Zone boundaries, and provides added protection to threatened salmon stocks. Closure of Pacific whiting fisheries reduces salmon bycatch, further regulating vulnerable salmon stocks (NMFS 2004e; NOAA[15]).

5.3.7 National Estuary Program

Established by Congress in 1987, the National Estuary Program's (NEP) primary objective is to "protect estuaries of national significance that are threatened by degradation caused by human activity" (Jerrick 1999). Section 320 of the CWA directs the EPA to protect and improve the quality of estuaries of national importance by developing plans to safeguard coastal and estuarine water quality, wildlife, and surrounding upland habitat (PSAT 2000). While the EPA provides technical and financial assistance to

each program, the NEP encourages local community participation in the management of each estuary and delegates individuals to create a Management Plan unique to each area. Currently, 28 programs exist in the United States, three of which are located within the vicinity of the Pacific Northwest OPAREA (Jerrick 1999).

- Lower Columbia River Estuary—Nominated and accepted as one of the programs in the NEP in 1995, the estuary has been managed by a partnership between representatives of Oregon and Washington State (Jerrick 1999). Protection is afforded to the 614,767 km^2 watershed as the river traverses various wetland and forest habitats. Within the area, the Lower Columbia River Estuary Partnership conducts a variety of programs that include educational outreach, habitat mapping, monitoring, and species recovery (Jerrick 1999).

- Tillamook Bay—Located along the coast of Oregon, the estuary provides habitat to several federally threatened and endangered species including Steller sea lion, Aleutian Canada goose, brown pelican, marbled murrelet, western snowy plover, northern spotted owl, peregrine falcon, coastal Coho salmon and steelhead salmon.[43] The area is generally bordered by rugged mountains and coastal plains that plunge into the watershed, creating an estuarine environment in which run-off potentially becomes a negative impact to the region. Consequently, habitat loss from such occurrences indirectly impacts the regions fishing economy (Good 1999).

- Puget Sound—The inland waters of Puget Sound exemplify a wide range of habitat that extend from upland to subtidal areas (PSAT 2000). Numerous threatened or endangered species inhabit the Puget Sound Estuary including green, leatherback, loggerhead, and olive ridley sea turtles, Aleutian Canada goose; bald eagle; brown pelican; marbled murrelet; northern spotted owl; peregrine falcon; and western snowy plover.[42] Program priorities include those associated with protecting water quality and natural resources that become jeopardized with human population growth, foreign species introductions, and contamination (PSAT 2000).

5.4 STATE MARINE MANAGED AREAS

NOAA and the DoI are working with state agencies to collect data on sites included in the national MMA Inventory. A State Advisory Group was established with regional representatives to guide the development of the state data collection process. As of July 2005, states have identified over 1,400 MMAs within 35 coastal states, commonwealths, and territories, although various levels of data analysis and GIS compilation exist throughout the nation (NOAA 2005). In comparison to federal-level MMAs, state-level sites are generally more diverse and complex in regards to programs and policies. This complexity requires an organized and detailed network of sites and authorities to allow for coordination among all levels of government involvement (Davis et al. 2004).

5.4.1 State of California Marine Managed Areas

The Marine Life Protection Act (MLPA; Assembly Bill 993) was introduced in February 1999, and is included in Chapter 10.5 of the California Fish and Game Code, Sections 2850 to 2863. “The purpose of the MLPA was to improve the array of MPAs existing in California waters through the adoption of a Marine Life Protection Program and a comprehensive master plan.”[43] The MLPA states that "marine life reserves" (defined as no-take areas) are essential elements of an MPA system because they "protect habitat and ecosystems, conserve biological diversity, provide a sanctuary for fish and other sea life, enhance recreational and educational opportunities, provide a reference point against which scientists can measure changes elsewhere in the marine environment, and may help rebuild depleted fisheries." The CDFG is the lead agency responsible for implementing the provisions of the MLPA.[43]

There are six goals of the MLPA established in California Fish and Game Code Section 2853(b). They are 1) protect the natural diversity and abundance of marine life and the structure, function, and integrity of marine ecosystems, 2) help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted, 3) improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance and to

manage these uses in a manner consistent with protecting biodiversity, 4) protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value, 5) ensure that California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement and are based on sound scientific guidelines, and 6) ensure that the state's MPAs are designed and managed, as a network.[43]

For California, informational and GIS data have been received and are currently in review for 121 sites, six of which are located in the Pacific Northwest OPAREA and vicinity (**Table 5-3**; **Figure 5-5**).[15]

5.4.1.1 Areas of Special Biological Significance

Areas of Special Biological Significance (ASBS), also referred to as State Water Quality Protection Areas, are designated by the State Water Resources Control Board (SWRCB; SWRCB 2003). The state of California adopted the Ocean Plan in 1972 and has since revised the legislation seven times with the last review in 2005. The SWRCB is responsible for addressing potential amendments to the Ocean Plan to assure beneficial water quality standards in marine environments along the California coast. ASBS are defined by California legislation as "those areas designated by the State Board requiring protection of species of biological communities to the extent that alteration of natural water quality is undesirable".[44] The California Ocean Plan set forth regulations that prohibit discharges into designated marine ASBS; the SWRCB may grant special permission that allows discharge in ASBS, provided that the beneficial uses of the ocean waters are not compromised (SWRCB 2001; Gladstone 2005; CEPA[44]). Of the thirty-four ASBS statewide, the following three areas lie within the vicinity of the Pacific Northwest OPAREA. More detailed information regarding the exact extents of protected ocean waters can be found in SWRCB (2001).

- Kelp Beds at Trinidad Head—Trinidad Head, a large rocky prominence that steeply rises to a height of 116 m above the sea level, lies off the coast of northern California and remains landlocked only on its northern coast to the mainland of California. The ASBS encompasses 1.18 km^2 of kelp beds in the ocean waters surrounded by rocky shore and offshore rocks, sand beaches, and hard and soft bottom habitats.[15]

- Kings Range National Conservation Area—The northern portion of the California coast which Kings Range National Conservation Area falls along is also referred to as the "Lost Coast" due to the lack of civilization and industrial developments. Discharges are prohibited along 45.7 km of coastline, as well as in ocean waters extending seaward 305 m or to the 30 m isobath, whichever is the greater distance from shore (SWRCB 2003). Marine mammals and birds utilize the coastal tidepools, kelp beds, and rocky offshore habitat.[15]

- Redwood National Park—Located along the northern California coast, this 249.67 km^2 area extends from the mean high tide line to the 30 m isobath and spans north to south approximately 55 km. The ASBS provides nearshore and open water habitat for several species of marine mammals, seabirds, and invertebrates.[15]

5.4.1.2 Coastal Sanctuary

- California Coastal Sanctuary—Covering approximately 13,566 km^2, the sanctuary spans the entire coast of California from Oregon to Mexico. The sanctuary protects all state waters (mean high tide line to 3 NM) from the potentially harmful risk of oil and gas extractions to the marine environment. All offshore islands and rocks are also protected with the same regulations as that of the mainland coast.[15]

5.4.1.3 State Marine Reserves

Per the requirements of the Marine Resources Protection Act of 1990, the Fish and Game Commission are required to establish four marine ecological reserves along the California coast with the purpose "to provide for scientific research related to the management and enhancement of marine resources" (CDFG 2002c; Barry and Lasko 2004). Marine Reserves are awarded complete protection from all extractive and

destructive activities, including human activities, barring those related to scientific research with prior approval and authorization (14 CCR 630.5; Palumbi 2002). Enforcement on these reserves is the responsibility of the CDFG (see CDFG 2002 for more details). There is one State Marine Reserve within the state of California and the Pacific Northwest OPAREA.

- Kings Range Marine Reserve—Established in 1994 as the Kings Range (Punta Gorda) Marine Resources Protection Act Ecological Reserve, the site was officially renamed a State Marine Reserve in 2002 as a result of the Marine Managed Areas Improvement Act (MMAI; McArdle 2002). Spanning approximately 3.2 km of the northern California coastline in a strong upwelling zone, the reserve primarily consists of sand with some hardbottom that provides for a unique assortment of invertebrates (McArdle 2002; NOAA[6]).

5.4.1.4 State Parks

The California State Park system protects over 450 km of coastline, 1006 km of freshwater frontage, wetlands, beaches, estuaries, and dune systems, totaling approximately half a million ha of coverage (RAC 2000). State Parks are designated to preserve and protect the natural, scenic, cultural, marine and terrestrial environments and ecosystems for the enjoyment of future generations. Within the Pacific Northwest OPAREA, one state park is located along the Pacific coast of California (see CDFG 2002 for more details).[15]

- Tolowa Dunes State Park—Located 3.2 km north of Crescent City, Tolowa Dunes is the northernmost MMA in the state of California. The 2,023 ha park contains a diverse array of habitat ranging from ocean coastline and wetlands to sand dunes and wooded ridges. Several marine mammal species such as harbor seals and gray whales, migrating birds, and fish frequent the area.[15,45] Enforcement on this park is the responsibility of the CDFG and California Department of Parks and Recreation.

5.4.2 State of Oregon Marine Managed Areas

In 1973, Oregon drafted a statewide program outlining the states' land use policies in a set of 19 Statewide Planning Goals. The program establishes the importance of designating and properly managing MPAs in Oregon to conserve, sustain, and properly manage renewable marine resources and critical ecosystems (Taylor 2004). Goals 16 and 19 elucidate development limitations and protection measures for estuarine and ocean resources. More specifically, the purpose of Goal 16 is to "recognize and protect the unique environmental, economic and social values of each estuary and associated wetlands, and to protect, maintain, where appropriate develop and restore long-term environmental, economic, and social values, diversity and benefits of Oregon's estuaries."[46] The objective of Goal 19 is to enhance awareness and increase the priority of protecting and sustaining renewable marine resources, such as living marine organisms, rather than focusing on the development of non-renewable ocean resources.[46]

Although nine federal sites in Oregon are included in the MMA Inventory, no state sites have been incorporated due to ongoing data analysis; data collection for 17 sites is complete and undergoing review (**Table 5-3**). GIS information is also being compiled in order to identify and map the boundaries of each site (Didier 1998; NOAA[6]). All state sites are currently managed by the Oregon Department of Fish and Wildlife. Seven out of the 17 state sites are designated Research Reserves wherein all human-influenced activities, barring those concerned with collecting or observing for various types of marine scientific research, are prohibited. Oregon protects five areas as Marine Gardens. These areas are protected from potential human disturbance and threat of overuse of species' and habitat. Shellfish reserves prohibit the removal of clams from designated areas. More information on Oregon protected state-level sites may be found at the Oregon Coastal Atlas website.[47]

5.4.3 Washington State Marine Managed Areas

The MMA Inventory currently contains complete registers for two states (Washington State and Massachusetts) and one territory (CNMI). Data collection and final approval was granted in March 2005 to the assembled catalog of state protected areas in Washington State. Final datasets for 60 sites across the state, together with GIS boundary data for 54 of the locals, has been compiled in the Inventory. Information regarding the status of individual sites is available to the public at www.mpa.gov. Additional protected areas are classified at state and local levels and enforcement is provided by environmental agencies, as well as public outreach volunteers.

Upon federal approval in 1976, Washington State became the first state to have an established coastal zone management program (NOAA and WSDE 2001). The state's Department of Ecology administers the Washington Coastal Zone Management Program which includes two constituents, the federal CZMA and the state Shoreline Management Act (SMA). The national standpoint states that "It is the national policy to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations." Cooperation between federal, state, and local affiliates is encouraged and the relationships improve effective implementation of coastal zone management and development.

Organizationally, the document discusses state controlled areas of Washington State separately by their inclusion in the Pacific Northwest OPAREA or Puget Sound Study Area (**Table 5-3**, **Figure 5-5**, and **Figure 5-6**).

5.4.3.1 Washington State: Pacific Northwest OPAREA Sites

All nine protected areas located along the west coast of Washington State are managed by Washington Department of Natural Resources (WDNR) and categorized as either Natural Area Preserves (NAP) or Natural Resources Conservation Areas (NRCA; **Figure 5-5**). The passage of the Natural Areas Preserve Act in 1972 allowed for the establishment of a statewide system in which natural areas are identified and protected to conserve valued ecosystems of a particular region (WSDNR 2003). Habitat loss and degradation of habitat are the two major concerns prompting the creation of the conservation system in which WDNR carries out ecologically sound land management practices (WSDNR 2003).

5.4.3.1.1 Natural Area Preserve

Nature Area Preserves (NAPs) are managed specifically for their ecological value and represent important natural ecosystems of the state and include rare plant and animal habitat (WSDNR 2003; WSDNR[47]). In several areas, WDNR, Washington State Parks and Recreation Commission (WSP&RC) and WDFW work in committed cooperation to ensure proper management of NAPs (WSDNR 2005). NAPs are designed to "provide for the protection of natural lands, together with the plants and animals living thereon in natural ecological systems, which are valuable for the purpose of scientific research, teaching, as habitats of rare and vanishing species, as places of natural historic and natural interest and scenic beauty, and as living museums of the original heritage of the state" (RCW 79.79.010).

- Bone River NAP—Located on the easternmost coast of Wallapa Bay in southern Washington State, Bone River NAP includes 1,038 ha of wetland and conifer forest habitat. Terrestrial features also include tidal flats, sloughs, mudflats, salt marshes, and freshwater streams that provide essential habitat for waterfowl and bald eagles (WSDNR 2005; WSDNR[48]).

- Gunpowder Island NAP—Covering approximately 62 ha on the Pacific side of Wallapa Bay in southern Washington State, Gunpowder Island NAP includes ecological communities such as salt marshes, transition zone wetland, estuarine sandy beach, and dunes. Dune vegetations and the sandy beach attract nesting seabirds such as caspian terns and the rare snowy plover (WSDNR 2005; WSDNR[48]).

- Niawiakum River NAP—The preserve occupies 339 ha of intact tidal river system south of Bone River NAP on the inland coast of Willapa Bay. The area provides pristine salt marsh vegetation and wetland habitat for a variety of wildlife including bald eagles, blue heron, and kingfishers (WSDNR 2005; WSDNR[48]).

- North Bay NAP—Located in northern Grays Harbor on the west coast of Washington State, North Bay NAP protects one of the highest quality freshwater sphagnum bogs in the state. This 444 ha area also protects five well-preserved wetland plant communities that support insect and endangered butterfly species (WSDNR 2005; WSDNR[48]).

- Sand and Goose Islands NAP—The areas are referred to collectively due to their close proximity along the coast of Grays Harbor. In 1973, Sand and Goose Islands became the first designated NAPs for Washington State (WSDNR 2003). Together, the two sand islands support 8 ha that protect nesting seabirds and provide haulout sites for seals (WSDNR 2005; WSDNR[48]).

- Whitcomb Flats NAP—This preserve is a very small, 2 ha island in the southern portion of Grays Harbor that provides nesting habitat for seabirds and is also utilized by pinnipeds as a haulout site (WSDNR 2005; WSDNR[48]).

5.4.3.1.2 Natural Resources Conservation Area

The NAP Act did not recognize natural resources conservation areas (NRCAs) in the statewide system of natural areas until its amendment to do so in 2003. Prior to the amendment, the areas were unique designations of WDNR (WSDNR 2005). Designation procedures, implementation, and management criteria are currently being refined and processes are expected to be finalized by 2007 (WSDNR 2005). However, the passage of the NRCA Act in 1987, has since allowed for the establishment of 24 NRCAs representing more than 20,000 ha in Washington State (Murray 2000). The purpose of these conservation areas is to protect "(1) Lands identified as having high priority for conservation, natural systems, wildlife, and dispersed recreational values; (2) prime natural features of the Washington landscape or portions thereof, inland or coastal wetlands, significant littoral, estuarine, or aquatic sites or important geological features; (3) examples of native ecological communities; and (4) environmentally significant sites threatened with conversion to incompatible or ecologically irreversible uses" (WSDNR 2005). Two NRCA are located along the outer coast of Washington State.

- Elk River NRCA—Located in the southern region of Grays Harbor, this 6.9 ha preserve represents the largest and highest quality estuarine system in Washington State.[49] The area provides essential habitat ranging from salt marsh to forested uplands for waterfowl, shorebirds, nesting bald eagles, and terrestrial mammals (WSDNR 2005; WSDNR[49]).

- Teal Slough NRCA—Totaling 3.4 ha, the coastal forest ecosystem is the southernmost NRCA along Washington State's Pacific coast. The forest habitat contains remnants of ancient cedars, Sitka spruce and western hemlock that support marbled murrelet, spotted owl, pileated woodpecker, and salamander populations.[49]

5.4.3.2 Washington State: Puget Sound Study Area Sites

The Puget Sound Study Area contains shared nearshore waters of Washington State and British Columbia where a mix of agencies and organizations play significant roles in the management and establishment of protected areas. Although the development of MPAs and refuge networks throughout the Puget Sound Study Area and Washington State are still in their infancy, measures are being taken to protect biological diversity (Palsson 2001). The Environmental Cooperation Agreement was signed by the two nations in 1992 with the purpose of addressing mutual environmental matters within the region (EPA et al. 1994). The Agreement prompted the formation of the Environmental Cooperation Council (ECC) in 1994, who then established the Marine Science Panel that consisted of scientists from both Washington State and British Columbia (EPA et al. 1994; Murray 2000). The Panel's primary objective was to create an inventory of recommendations to improve existing and potential environmental concerns. With high

priority, the Panel suggested the development of a system of recognizing and establishing MPAs to protect marine habitat and resource populations (Murray and Ferguson 1998).

In response to the Marine Sciences Panel report, the Puget Sound-Georgia Basin International Task Force was formed by the ECC to prioritize and implement the recommendations of the Panel and to create work groups in Washington State and British Columbia to address the goals of establishing MPAs to improve the living resources and biodiversity of the region (Mills 1998, 1999). The Washington MPA Work Group came together in 1995 with additional state agencies such as the WDFW, WDNR, Department of Ecology, and the University of Friday Harbor Laboratories and began to develop a common strategy in defining, developing and establishing MPAs (Mills 1998, 1999; Murray 2000). At this time, an interagency group in British Columbia had formerly been created to address the MPA goals; therefore, this team represented the Work Group for British Columbia (Mills 1998).

Protected areas are located throughout the multiple-estuarine system and management varies at each site ranging from year-round, on-site management to sites where oversight is only conducted more infrequently during particular seasons or exclusively for maintenance related issues (Palsson 2001). Management responsibilities are undertaken by several state and local agencies such as the marine resources division of the WDFW, WSP&R, San Juan County Marine Resources Committee (SJCMRC), and the University of Washington Friday Harbor Laboratories.

For the purpose of this report, the majority of the Washington State MPAs that lie among the nearshore waters of the Puget Sound Study Area follow with brief descriptions (**Table 5-3**).

5.4.3.2.1 State Parks

Approximately 80 State Parks are located along the shorelines of Washington State. All parks contain intertidal, subtidal, and/or saltwater frontage, spanning 3,336,630 m of shoreline. WSP&RC acquires, operates, manage and protects the diverse system of natural sites.[15]

Additionally, Underwater Parks (UPs) are managed by WSP&RC within the Washington State park system. Beginning in 1970, these subtidal MPAs were delineated adjacent to existing upland parks with the purpose of preserving and promoting underwater marine life through the establishment of harvest restrictions, construction of beneficial artificial habitats, and the maintenance of high quality dive sites (Murray 2000). Nine UPs are located within the Puget Sound Study Area (**Figure 5-6**).

5.4.3.2.2 Marine Preserve

Marine Preserves (MPs) are designated and managed by the WDFW with the purpose of promoting depressed and over-harvested stocks of fish, shellfish, and wildlife.[15] This network of sites is granted partial-protection and enhanced with the establishment of year-round harvest closures for one or more species (Murray 2000; NOAA[6]; **Figure 5-6**).

- Admiralty Head MP—WDFW established the site in 2002 to manage rocky habitat species. Rocks, boulders, and coarse sediments extend offshore to depths of 12 m from the extreme low water mark and create favorable conditions for the proliferation of kelp, fish, and invertebrate species. Sea urchin and sea cucumber fisheries use the area extensively.[15]

- Colvos Passage MP—This small marine area, also known as Sunrise Beach, occupies 0.01 km^2 of rocky benthic habitat and coarse shoreline substrate. Rocky outcroppings, boulders, and fractured bedrock provide habitat and protection for bladed kelp, foliose red algae, eelgrass, bull kelp, rockfishes, and macro invertebrates.[15]

- Titlow Beach MP—Established in 1994, WDFW and Metropolitan Park District of Tacoma act to preserve tidelands, beaches and banks, and protect the marine life within. With few exceptions, it is unlawful to fish or possess fish, wildlife, and shellfish or to damage or remove submerged aquatic vegetation.[15] Rocky habitat species such as flatfish, rockfish, eelgrass, bladed kelp, and

red algae are protected within the 22.5 ha reserve (Murray 2000; NOAA[6]). Educational outreach and scientific research are supported within the boundaries of the reserve (Murray 2000).

- Zee's Reef MP—This rock reef features a natural rocky outcropping that lies approximately 183 m offshore. Together with large stacked boulders and fractured bedrock, the site provides protection and shelter to sparse fields of kelp and algae, rockfishes, and encrusting marine organisms.[15]

- San Juan County/Cypress Island Marine Biological Preserve—The large reserve (1,132 km^2) was established in 1923 by WDFW and the University of Washington, Friday Harbor Laboratories with the purpose of protecting the biological marine resources surrounding Cypress Island (Murray 2000; NOAA[6]). The majority of potentially threatening human activities are prohibited without some degree of restriction or permit requirement (Murray 2000). Unique features that include pollution-free waters, quiet lagoons and bays, and swift tideways are ideal for oceanographic and marine flora and fauna research.[15]

5.4.3.2.3 Recreational Marine Preserve

Recreational Marine Preserves (RMPs) are typically established in areas of aesthetic beauty or superior recreational value with the purpose of protecting non-consumptive uses of marine resources (Smukler 2001). Two RMPs are located in the Puget Sound Study Area and lie in close proximity of each other (**Figure 5-6**).

- Brackett's Landing Shoreline Sanctuary Conservation Area and Edmond's Underwater Park—Collectively, Edmond's UP and Brackett's Landing Shoreline Sanctuary Conservation Area span 196 m of shoreline and include subtidal, intertidal, and upland areas (Murray 2000). The conservation area consists of sandy beach and sand flat that are divided by a jetty. The UP encompasses 11 ha of high quality recreational diving sites featuring underwater trails and artificial habitats that promote abundant assemblages of marine life. The city of Edmonds and WDFW currently manage and uphold 1970 city ordinances prohibiting the taking of all marine organisms.

5.4.3.2.4 Research and Educational Marine Preserve

Research and Educational MPs are established to protect natural resources and support educational outreach programs, monitoring activities, and scientific research (Murray 2000). The sites are partially-protected by WDFW and harvest restrictions may or may not be enforced.[15] All five Research and Educational MPs in the Puget Sound Study Area, located throughout the San Juan Island archipelago, were established in 1990 to provide protection to University of Washington research areas that investigate the interaction of native species and ecosystems (Murray 2000; **Figure 5-6**).

- Argyle Lagoon San Juan Islands MP—The small intertidal embayment reserve (0.06 km^2) is owned and co-managed by the University of Washington Friday Harbor Laboratories and WDFW. Upland shores, mudflats, and emergent wetlands provide habitat for riparian vegetation, flatfish, sculpins, and marine invertebrates.[15]

- False Bay San Juan Islands MP—This large, shallow, intertidal bay is located along the southwest shore of San Juan Island and provides habitat for invertebrates, migrating shorebirds, killer whales, and harbor seals.[15] The bay completely drains at low tide allowing for extensive soft sediment research (Murray 2000). Fishing restrictions prohibit the removal or consumption of specified shellfish, food fish, and bottomfish species (Murray 2000).

- Yellow and Low Islands San Juan Islands MP—The 0.74 km^2 reserve includes all nearshore and offshore habitat to a distance of 274 m. Rocky outcroppings, assorted bottom sediments and vegetation, protect invertebrates and rocky-habitat fish species.[15]

- Shaw Island San Juan Islands MP—Within the reserve boundaries (1.81 km^2), varying degrees of rocky habitat extend from the shoreline to a depth of 122 m and include outcroppings, boulder fields, walls of bedrock, and coarse sediments. Kelp greenling, rockfish, and lingcod utilize the rock reef and intertidal environments.[15]

- Friday Harbor San Juan Islands MP—The preserve contains valuable study sites for investigating, evaluating, and monitoring biological diversity. Rocky shore habitat extends offshore to unconsolidated sediments, influencing the nature of species that inhabit each strata. The site contains a high diversity of marine invertebrates and vegetation, macro-invertebrates, rockfish, and pinnipeds.[15]

5.4.3.2.5 Marine Species Preserve

Marine Species Preserves primarily function as conservation tools to help meet fishery management goals (Smukler 2001). Various restrictions are placed on commercial and recreational fisheries with the purpose of replenishing stock biomass, maintaining genetic diversity, and improving overall marine health (Murray 2000). Palsson and colleagues compared the effects of ecosystem management on Puget Sound rocky habitat fish species in no-take refuges to populations in more unrestricted areas and found greater density and size responses among individuals reared with harvest restrictions (Palsson and Pacunski 1995; Palsson 1998).

Voluntary No-take Bottomfish Recovery Areas (VNTBRA) and Special Management Fishery Areas (SMFA) are located within the Puget Sound Study Area to promote depressed and over-harvested marine stocks. Eight VNTBRA were established in 1997 after an assembly of local fishermen, civilians, and legislative officials agreed upon locations of depleted bottomfish populations (**Table 5-3**). These sites are currently managed by SJCMRC and range in size from 0.14 to 4.27 km^2.[15] Fishermen are encouraged to avoid designated no-take areas and fish elsewhere. Two SMFA are located among the San Juan and Upright Channels off the coast of northern Washington State. Restrictions prohibit commercial harvest of sea urchin and sea cucumber populations. These sites differ from the voluntary sites in that they include intertidal and subtidal habitats and are under the authority of WDFW.

5.4.3.2.6 Marine Conservation Area

Marine conservation areas (CA) are designated and managed by the WDFW with the purpose of protecting declining and over-harvested stocks of fish, shellfish, and wildlife.[15] These communities are granted full-protection and enhanced with the establishment of non-consumptive recreation regulations and non-harvest zones (**Figure 5-6**).[15]

- City of Des Moines Park CA—The 0.04 km^2 area is co-managed by the city of Des Moines and WDFW with the primary purpose of protecting non-consumptive recreation uses. The predominately rocky intertidal substrate provides habitat for numerous invertebrates and marine flora.[15]

- Keystone CA—Established in 2002, the 0.05 km^2 area is managed as a fully-protected marine reserve by WDFW to protect fish, shellfish, and recreational activities that occur within intertidal depths at the high water mark, waterward to depths of 21 m. Commonly observed species include rocky habitat fish, pelagic fish species, floating bull kelp and other macroalgae assemblages, and invertebrate communities.[15]

- Octopus Hole CA—This area is located along Hood Canal in southern Puget Sound and encompasses 0.11 km^2 of rocky habitat that extends from depths of 5 to 20 m. Subtidal bedrock outcroppings create fissures and grooves that provide suitable habitat for kelp, invertebrates, and other various forms of marine life, including octopuses.[15]

- Orchard Rocks CA—WDFW established the 0.41 km^2 reserve in 1998 and currently manages the area with the purpose of perpetuating declining bottomfish and shellfish populations. Marine

vegetation covers exposed bedrock, cobble, and rubble; Harbor seals and California sea lions utilize the substrate and navigational buoys as haulout sites.[15]

- Saltar's Point Beach CA—This conservation area was designated in 2000, to protect non-consumptive recreation uses within intertidal boundaries. Together, WDFW and the Town of Steilacoom manage the small site that encompasses only 0.02 km^2 of intertidal habitat.[15]

- South 239th Street Park CA—This site consists of intertidal habitat including tidelands, the water column, and associated bottom substrate and features. The site was designated a conservation area in 1998, to protect non-consumptive recreation uses. The city of Des Moines limits species harvest to ensure proliferation of beach flora and fauna (Murray 2000).

- Sund Rock CA—The purpose of this small marine area (0.28 km^2) is to protect bottomfish populations and to maintain recreational scuba diving areas (Murray 2000; NOAA[6]). WDFW manages the subtidal and intertidal zones, as well as the unique rocky substrate that extends to a depth of 27 m and creates exceptional diving settings and habitat for invertebrate, fish, and algal assemblages.[15]

- Waketickeh Creek CA—The site was established in 2000 to protect the fish and shellfish species that reside in the complex rocky habitat. Waketickeh Creek CA is the most expansive conservation area in Hood Canal, covering 0.58 km^2 of subtidal and intertidal habitat that contain a mosaic of differing rock layers and formations at various water depths. The area is a source of biological diversity, providing habitat to seabirds, invertebrates, and fish species.[15]

5.4.3.2.7 Aquatic Reserve

WDNR has the authority to designate aquatic lands to secure them as areas for educational and scientific purposes and to protect aquatic lands of environmental importance (Davis and Lopez 2004). The purpose of the aquatic reserve (AR) program is to "ensure environmental protection, preservation and enhancement of state-owned aquatic lands that will provide direct and indirect benefits to aquatic resources in the state of Washington" (Davis and Lopez 2004; **Figure 5-6**).

- Cherry Point AR—Established in 2000, the reserve lies in north Washington State, facing the Strait of Georgia, and was designated to prevent further decline of herring populations. The 1,214 ha site includes tidelands and bedlands that provide habitat to herring spawning and migrating Chinook salmon and waterfowl.[15]

- Cypress Island AR—This reserve surrounds Cypress Island and includes the intertidal and subtidal rocky reef habitats, beginning at the tidelands and continuing half a mile waterward or to a depth of 21 m, whichever comes first. As the most undeveloped island in the San Juan archipelago, the reserve protects mostly undisturbed kelp and eelgrass beds that provide refuge for a variety of invertebrates, fish, and wildlife.[15]

- Fidalgo Bay AR—Located near the city of Anacortes in northern Washington State, the 2.72 km^2 reserve was designated by WDNR to protect eelgrass beds and other habitat utilized by forage fish, migrating waterfowl, and a diverse array of marine flora and fauna.[15]

- Maury Island AR—The 22.01 km^2 reserve was designated in 2000 to protect ideal aquatic habitat by reducing or eliminating future development and related concerns. The area provides important habitat for marine species, such as rearing and spawning juvenile salmon and herring, sea urchins, and assorted aquatic plants in southern Puget Sound.[15]

5.4.3.2.8 Natural Area Preserve

WDNR and other governing agencies such as WDFW work together in committed cooperation set forth by the NAP Act of 1972 to ensure the protection of natural lands. See section 5.3.6.1.1 for more information regarding these areas. DNR has designated approximately 50 NAPs within Washington State; six are located in the Puget Sound Study Area and contain a marine component (**Figure 5-6**).

- Cypress Highlands NAP—Located within the San Juan Islands archipelago, this 434 ha reserve consists of rare wetlands, grasslands, rock flats, Douglas-fir, lodgepole pine, western red cedar, and Rocky Mountain juniper.[48]

- Dabob Bay NAP—This 76 ha preserve was established in 1987 to protect its exceptional intertidal salt marsh vegetation and coastal spit bionetwork (Murray 2000; NOAA[6]). WDNR manages the area in the northern end of Hood Canal and prohibits all human activity, barring that of approved scientific research, ecological monitoring, and survey procedures (Murray 2000).

- Kennedy Creek NAP—Located near Olympia in the southern Puget Sound Study Area, the 97 ha intertidal natural area was established in 1990 by WDNR to protect priority wetland communities (Murray 2000). The area includes a marine setting that extends from the tidal flats to the upper tidal boundary of Schneider and Kennedy Creeks.[15] The site provides important habitat for a genetically divergent population of coho salmon, as well as for shorebirds and other spawning and foraging fish species.[15]

- Lummi Island NAP—Lummi Island NAP was established to protect five priority bird species and five important regional habitats that include old growth forest, rock and gravel beach, cliffs, caves, and snag-rich areas (Murray 2000). Within the 287 ha site, only a small portion of steep and narrow intertidal habitat is located along the shoreline. The site is managed by WDFW and protection is primarily focused on the nesting bird populations rather than any particular subtidal or intertidal marine resources (Murray 2000).

- Point Doughty NAP—The 23 ha preserve is located along the coast of Orcas Island and protects the natural forest and marine communities that provide habitat to bald eagles and haulout sites for pinnipeds.[48]

- Skookum Inlet NAP—This protected area is located in the southern Puget Sound Study Area and contains both upland and intertidal components that are collectively managed by WDNR (Murray 2000). The site was designated in 1986 to protect characteristic examples of the Puget Trough wetland ecoregion that provides important foraging areas for native chum and coastal cutthroat trout.[15]

5.4.3.2.9 Natural Resources Conservation Areas

NRCAs are established to protect and conserve outstanding examples of natural ecosystems through resource protection goals, limited community use, and public environmental education (Murray 2000). See section 5.3.6.1.2 of this report for further information. Six NRCAs are located within the vicinity of the Puget Sound Study Area (**Figure 5-6**).

- Cattle Point NRCA—The 45 ha conservation area is located on the southern tip of San Juan Island and includes the shoreline along the Strait of Juan de Fuca. The notable research site is surrounded by diverse habitat such as conifer forest, steep bluffs, freshwater wetlands, and grasslands in which an abundance of wildlife resides.[49]

- Cypress Island NRCA—This area occupies the majority of Cypress Island, spanning 1,452 ha of the largest undeveloped island in the San Juan Island archipelago, and includes the tidelands to the extreme low tide line (Murray 2000; WSDNR48). Biodiversity is sustained within the wetland,

forest, and marine environments of the island through NRCA designation (Murray 2000; WSDNR[49]).

- Hat Island NRCA—Located in the eastern region of the San Juan archipelago, this 37 ha conservation area provides habitat for bald eagles, seabirds, and shorebirds along its shoreline and terrestrial domains.[49] Its primary purpose is to provide research and education opportunities to conserve the area's diverse habitat.

- Lummi Island NRCA—The 267 ha area is a shoreline site that includes mixed forest in northern Puget Sound.[49] Since its designation in 1991, the expanse has sustained the upland habitat and diverse species within (Murray 2000).

- Shipwreck Point NRCA—This 191 ha conservation area consists of shoreline and upland habitat along the northern coast of Washington State along the Strait of Juan de Fuca. The purpose of the site is to preserve the diverse habitat and species therein.[49]

- Woodward Bay NRCA— Established in 1987, the 263 ha area represents relatively undisturbed ecosystems that are dominated by upland habitat with some intertidal estuarine habitat. The area provides haulout sites for pinnipeds, as well as important nesting habitat for seabirds and waterfowl (Murray 2000; WSDNR[49]).

5.4.3.2.10 Wildlife Area

WDFW establishes and manages Wildlife Areas (WAs) in Washington State with the purpose of optimizing and sustaining wildlife populations in land and aquatic habitats. Although Washington State contains 25 wildlife areas, only two lie within the Puget Sound Study Area.

- South Puget Sound WA—Established in 1988, the area is comprised of five satellite areas that occupy 1,851 ha (Murray 2000). The majority of the acreage lies on McNeil, Gertrude, and Pitt islands. Gertrude Island possesses the largest haulout site for harbor seals in southern Puget Sound; therefore, habitat protection is in place for marine life along the shores and within the intertidal lands (Murray 2000). Overall, the area consists of bald eagle, great blue heron, harbor seal, cliff, estuary, and intertidal management zones (Murray 2000; NOAA[6]; **Figure 5-6**).

- Skagit WA—Approximately 5,200 ha of primarily intertidal land was acquired from 1948 to 1992 and are predominately located between the mouths of the north and south forks of the Skagit River (Murray 2000). The purpose of the WA is to protect the upland and intertidal habitats to ensure the integrity of natural ecosystems and to preserve and perpetuate wildlife and fish populations (Murray 2000).

5.4.3.2.11 Nature Preserve

Nature preserves are typically established to preserve assemblages of marine and/or terrestrial species within an ecosystem (Smukler 2001). Two preserves are located in the Puget Sound Study Area (**Figure 5-6**).

- Tongue Point Marine Life Sanctuary—Spanning approximately 1.6 km of shoreline, Tongue Point Marine Life Sanctuary (MLS) is located on the northern coast of Washington in the Strait of Juan de Fuca and extends seaward 16 km (Murray 2000). In collaboration with WDNR, Clallam County Parks and Fair Department established and currently manage the site with the purpose of preventing human activities from damaging or removing intertidal marine life or driftwood (Murray 2000; Smukler 2001). The surrounding habitat is primarily open coast rocky intertidal with sandy beach and tidepools (Murray 2000).

- Zella M. Schultz Seabird Sanctuary—Established in 1975, the 19 ha preserve is located on the western tip of Protection Island at the mouth of Discovery Bay in Puget Sound. The island is notable for its nesting seabird populations and haulout and pupping areas for harbor seals (Murray 2000). Under cooperative agreement, WDFW and USFWS manage the sanctuary and enforce a no-access marine buffer zone of approximately 183 m offshore that provides indirect protection to the marine resources surrounding the island (Murray 2000).

5.5 CANADIAN PROTECTED AREAS

Enactment of the Environmental Cooperation Agreement in 1992 prompted the formation of the ECC and identification of five task forces to address cross-border environmental issues. To coordinate bilateral environmental efforts, representatives of U.S. EPA; USFWS; WDNR; WDFW; Northwest Fisheries Science Center; Washington Department of Ecology; Fisheries and Oceans, Canada (DFO); Environment Canada; Puget Sound Action Team; British Columbia Ministry of Water, Land, and Air Protection; the Northwest Straits Commission; the Coast Salish Sea Council; and Northwest Indian Fisheries Commission collaborate to prioritize recommendations related to preventing habitat loss, maintaining and establishing MPAs, and addressing exotic marine species introductions in shared waters (Murray 2000; MoE49). For more information, see Section 5.4.3.2 of this MRA.

In addition, the Canadian government has established policies and management strategies that address protected area concerns throughout the country. Upon passage of the Ocean's Act in 1997, DFO, Parks Canada, and Environment Canada coordinate the responsibilities of maintaining coastal, estuarine, and marine waters (Jamieson and Lessard 2000). The Ocean's Act shifted Canada's conservation focus from species concerns to ecosystem management and encouraged a scientific approach in the identification and categorization of natural areas in need of protection (Henwood et al. 1998). Protected areas include sponge reef complexes, marine parks, fishery closures, marine conservation areas, bird sanctuaries, ecological reserves, and wildlife management areas; however, DFO has authority over all areas that contain a marine component (Jamieson and Lessard 2000; Jamieson and Levings 2001; Jamieson and Chew 2002; **Table 5-3**; **Figure 5-6**). Although the number of recognized federal protected areas changes over time, baseline data from 1997 documented the existence of 125 legislative protected areas and 597 federal fishery closures in British Columbia (Jamieson and Lessard 2000). Furthermore, human activity restrictions are dependent upon classification and location; however, all MPAs share minimum protection standards that include the prohibition of ocean dumping; dredging; and the exploration for, or development of, non-renewable resources (Jamieson and Lessard 2000).

Canadian federal fishery closures are abundant throughout the nearshore waters of the Puget Sound Study Area and are designed to prevent declining fish stocks that occur in response to both recreational and commercial harvesters. Rockfish Conservation Areas (RCAs) protect inshore rockfish and lingcod populations from incidental fisheries and operate with the intention of allowing fish stocks the opportunity to rebuild. Thirty-eight RCAs are located in the Puget Sound Study Area (**Table 5-3**; **Figure 5-7**).

5.6 SCUBA AND FREE DIVING SITES

The waters of the northeast Pacific Ocean, also known as the Emerald Seas, offer some of the best diving in the world; few areas can match the dense sea life populations (Bliss 1997). Divers all over the Pacific Northwest enjoy the natural formations, pristine marine preserves, and diverse marine life that are so common in this environment. The cool waters and strong currents of the Puget Sound move from Alaska and British Columbia and flow in and out twice a day with the tide, providing nutrients, oxygen, and food for the diverse sea life ranging from vibrantly colored anemones, sponges, and soft corals to wolf eels and tiny whelks to giant Pacific octopuses and sixgill sharks (Bliss 1997).

Recreational dive sites (**Figure 5-8**) in the vicinity of the Pacific Northwest OPAREA and Puget Sound Study Area are very diverse Washington's outer coast characterized by heavy surge, strong currents, and high wave action; whereas, the Puget Sound Study Area is protected, creating an environment of unique,

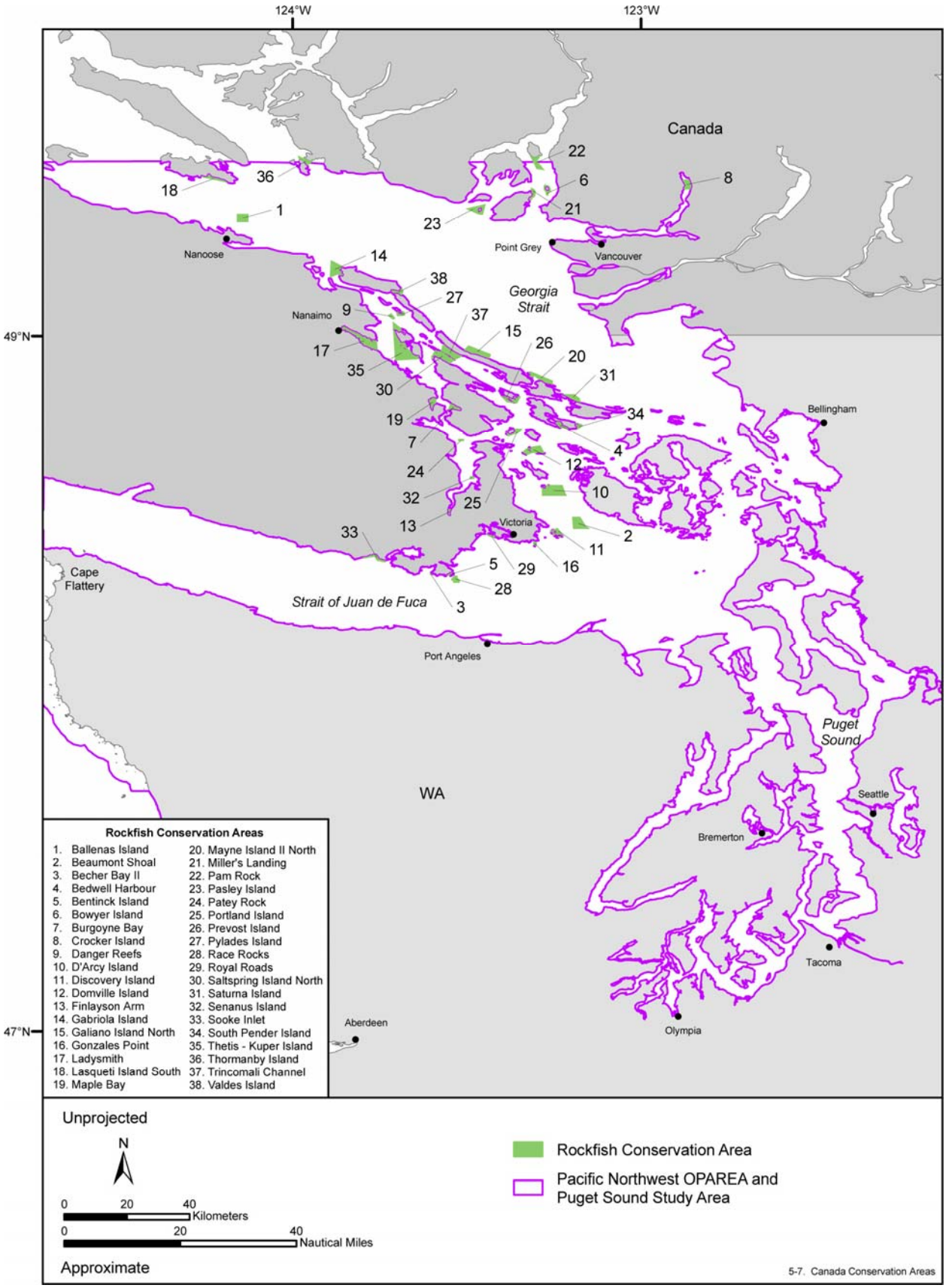

Figure 5-7. Canadian rockfish conservation areas within the Puget Sound Study Area. Map adapted from: DFO[16] and DFO.[17]

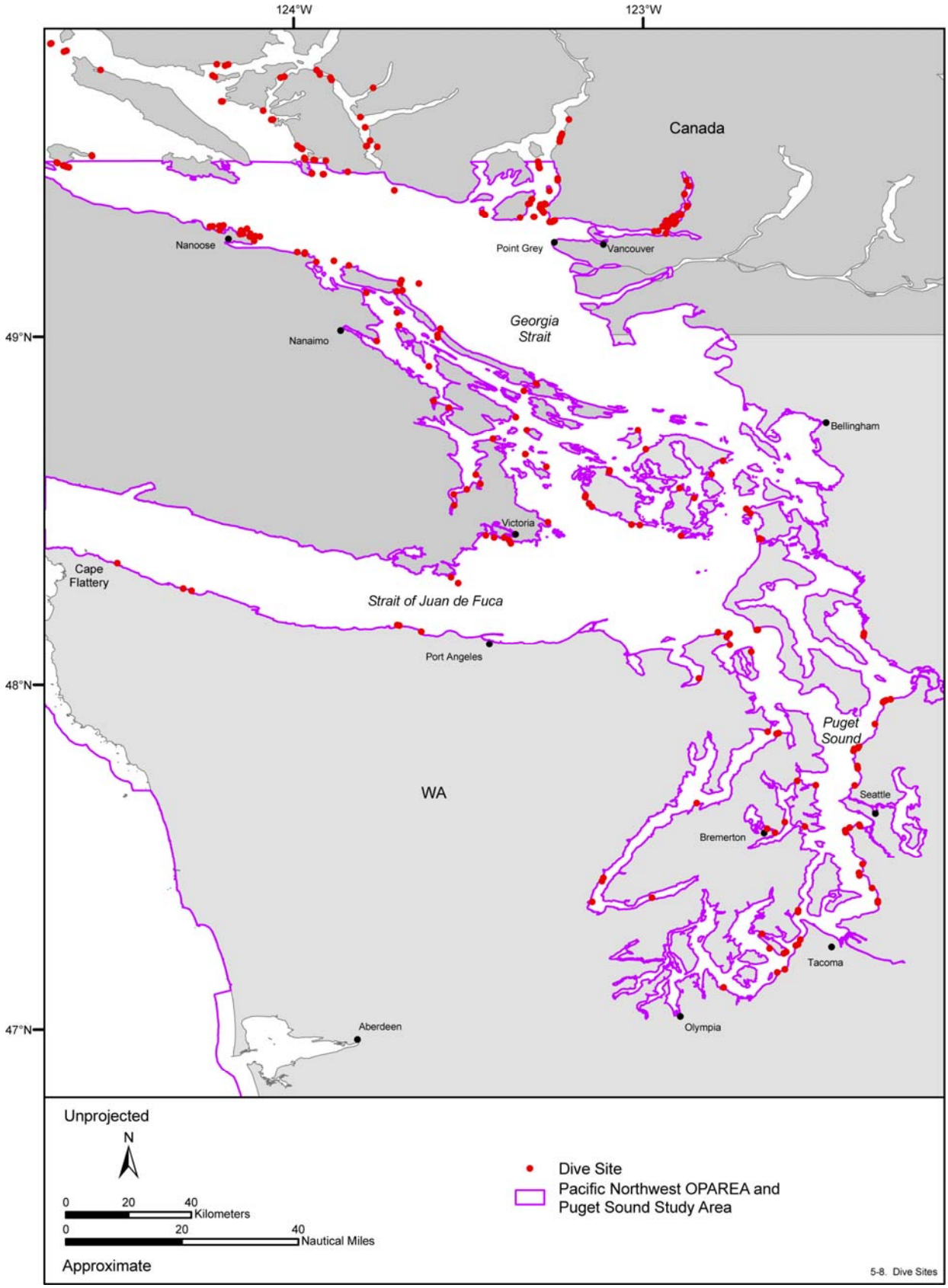

Figure 5-8. Recreational dive sites located within the nearshore regions of the Pacific Northwest OPAREA and Puget Sound Study Area and vicinity. Source data: Bliss (1997), Province of British Columbia[8], and Shorediving.com.[50] Source maps (scanned): Fischnaller (2000) and DiveBC.[51]

long, shallow inland passages that showcase many animal species that are normally restricted to deeper waters. In the Puget Sound Study Area, deep, nutrient-laden water is constantly upwelled as water passes back and forth over nine major submerged ridges. This mixing results in a constant supply of nutrients to the surface waters. In early spring and summer, plankton populations, algae, and kelp dramatically increase. In fall and winter, the huge growth of kelp present after each summer is detached by winter storm waves and, due to the decreased hours of sunlight, plankton also die off (Fischnaller 2000). The Pacific Northwest can be subject 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 Divers Alert Network (DAN) helps divers in need with medical emergency assistance and promotes diving safety through research, education, products and services. It is a nonprofit organization that exists to provide expert information and advice for the benefit of the diving public.[54]

Puget Sound Study Area—Within the Puget Sound Study Area, dive sites are almost ubiquitous. Recreational diving takes place at specified dive sites, but these sites are many, and few areas of the Sound, within SCUBA depth constraints, are left uncharted by recreational divers. Generally, diving occurs in every season, but divers tend to stay away from heavy fishing seasons and areas where boat traffic and fishery equipment can cause hazardous and dangerous situations.

Because the Puget Sound Study Area is diverse in bathymetry, substrate, hydrology, and biota, the dive sites are also diverse. For example, the Strait of Juan de Fuca, contains rocky reefs full of channels and crevices, sandy shallows full of eelgrass, and shipwrecks engulfed in marine life (Bliss 1997). In the northern Puget Sound, it is common to see the demarcation of kelp forests at the shelf of near vertical walls and fingers, or ridges. These walls, consisting of jagged rock, countless caves, small walls, ledges, and overhangs, have been carved by the unrelenting currents and jut out in different directions, forming small shelves at various and inconsistent depths. Central Puget Sound features moderately sloping mudflats, such as those found in Elliot Bay near Seattle (Bliss 1997). The runoff from Seattle causes poor water quality; however, this is a location of an artificial reef consisting of large boulder piles that provide cracks, crevices, crannies, and fissures for excellent marine life habitat. Southern Puget Sound is characterized by strong currents and eddies, a moderately sloping bottom, some rocky substrate, and an upper ledge colonized by kelp, sandstone formations, extensive walls consisting predominately of clay with cave-like indentations, large boulders, and artificial reefs interspersed among the silty bottom.[53] Hood Canal does not experience substantial currents and tidal exchange and is fed by many rivers from the Olympic Mountains; this causes cold surface waters and distinctive thermoclines to form, especially in winter. Hood Canal features spectacular rock formations with large, rugged protruding rocks, walls, ledges, boulders, and pinnacles with countless dark holes, cracks, and gaps for inhabiting marine life. Eventually, the rocky structure of Hood Canal gives way to a silty substrate to the north towards southern and central Puget Sound.[52]

British Columbia—British Columbia waters feed an incredible assortment and variety of marine life and provide many dive sites. British Columbia waters have the same features as the Puget Sound, including walls, ledges with kelp, pinnacles, rocky reefs, and ridges with overhangs, caves, and crevices.[53] However, the British Columbia waters are generally exposed to high surge, wave action, and currents as well as more abundant and diverse marine life than the U.S. waters of the Puget Sound. Plankton blooms tend to occur more often in the summer season; therefore, visibility is diminished during this time (Bliss 1997). During spring or fall, visibility and water temperature is reasonable, and the abundant marine life is apparent; these are the most popular seasons to dive British Columbia waters.

Pacific Northwest OPAREA—The outer coast of the Pacific Northwest has better visibility and stronger currents than the Puget Sound. The strong currents have formed a dynamic topography that consists of volcanic formations of boulders, rock structures, caves, crevices, and ledges.[53] The unyielding currents have cut sheer channels through rocky ridges to form dramatic canyons over 6 m deep. This rocky and rugged substrate provides prime habitat for the majority of the common northwest species (i.e., attachment sites for large kelp forests, sponges, and soft corals) and some not so common species.[53] There are many dive sites located along the outer Pacific coast; however there are no documented sites

within the OPAREA (i.e., within the nearshore waters of the W-237A region of the Whidbey Island Complex).

Marine Life—Divers of the Pacific Northwest have documented a comprehensive representation of many northwest species. The invertebrate life is rich and includes such organisms as crabs (i.e, sharpnose, decorator, umbrella, red-rock, Dungeness, and Puget Sound King), urchins, limpets, sea cucumbers, giant barnacles, chitons, sponges (i.e., huge vase and cloud sponges), corals (hard and soft), anemones (i.e., crimson, tube, and giant plumose anemones), a variety of nudibranchs (i.e., red, orange spotted, giant, sea lemons, white-lined dironas, yellow-edged cadlinas, and Hudson dorids), sea stars (i.e, sunflower, pink short spined, feather, morning sun, cushion, and Vermilion stars), and clams (e.g., piddock clams). The Pacific Northwest is famous for its Giant Pacific Octopus, Wolf eels, and schools of assorted and diverse rockfish (e.g., black, yellowtail, copper, brown, canary, blue, vermilion, quillback, tiger, and china rockfish). In addition, lingcod, red irish lord, sculpins (grunt and buffalo), greenlings (kelp and painted), cabezon, and perch (striped seaperch, shiner, and pile perch) are common.[52]

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6.0 RECOMMENDATIONS

The waters of the Pacific Northwest OPAREA and Puget Sound Study Area are well studied and surveyed, due to the importance of the habitat to marine mammals and the contribution of the commercial fishing industry to the regional economy. Scientists know a great deal about the inshore and nearshore waters of the region, with less being known about waters further offshore (i.e., beyond the 2,000 m isobath). Despite the resulting wealth of information and data that are available for most regions of the study area, several data gaps became evident during the preparation of this MRA.

The following recommendations, conceived by the MRA authors, are designed to improve our understanding of the marine resources in the Pacific Northwest Region, 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 as 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 below are grouped into those related to the production and evaluation of the MRA and those needed to adequately complete environmental documentation for the MRA.

6.1 MARINE RESOURCES ASSESSMENTS

Revise the Pacific Northwest MRA once every five years. The MRA would need a full revision of the text, data, GIS maps, and other informational components so that newly available data sets and published literature can be incorporated. The Navy needs the best (i.e., most recent, most complete, and most accurate) available information to evaluate future actions and consider adjustments to training exercises or operations in order to mitigate any potential impacts to protected marine resources. Periodic updates would be of moderate cost relative to the initial MRA. Cost: High. Priority: 1.

Subject the Pacific Northwest MRA to peer review. Peer-review by regulatory agencies (e.g., NMFS and USFWS), the general scientific community, and potential government users (e.g., MMS and USMC) would increase the effectiveness of this MRA. Biologists from universities and government agencies (such as those listed in **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 Pacific Northwest MRA.

Name	Affiliation	Expertise	Address	Email
Brent Norberg	NMFS-NWR	Marine mammals & sea turtles	NMFS-NWR 22622 61st Ave SE Bothell , WA 98021	brent.norberg@noaa.gov
Brian Hatfield	USGS-Western Ecological Research Center	Sea Otters	USGS - Western Ecological Research Center PO Box 70 San Simeon , CA 93452	brian_hatfield@usgs.gov
David Irons	USFWS	Birds	USFWS - Region 7 1011 East Tudor Road Anchorage, AK 99503	david_irons@fws.gov

Table 6-1. Continued.

Name	Affiliation	Expertise	Address	Email
Donald McAlpine, Ph.D.	New Brunswick Museum	Sea turtles	New Brunswick Museum 277 Douglas Ave. St. John, New Brunswick E2K 1E5	dmcalpin@nb.aibn.com
Greg Bargmann	WDFW	Forage fish	WDFW 600 Capitol Way North Olympia, WA 98501-1091	gbargmann@dfw.wa.gov
Jay Barlow, Ph.D.	NMFS-SWFSC	Cetaceans	NMFS-SWFSC 8604 La Jolla Shores Dr La Jolla, CA 92037	jay.barlow@noaa.gov
Jeff Laake	NMFS-NMML	Cetaceans	NMFS-NMML 7600 Sand Point Way NE Seattle, WA 98115	jeff.laake@noaa.gov
Jen Burnaford, Ph.D.	University of Puget Sound	Habitats	University of Puget Sound Department of Biology 1500 N. Warner St. Tacoma, WA 98416	jburnaford@ups.edu
Jim Watson	WDFW	Bald eagle	WDFW-Wildlife Program 600 Capitol Way N Olympia, WA 98501-1091	wildthing@dfw.wa.gov
John Calambokidis	Cascadia Research Collective	Marine Mammals	Cascadia Research 218 1/2 W Fourth Ave Olympia , WA 98501	calambokidis@cascadiaresearch.org
John Ford, Ph.D.	Canada DFO	Marine Mammals	Pacific Biological Station Department of Fisheries and Oceans Canada 3190 Hammond Bay Rd Nanaimo , BC V9T 6N7	fordjo@pac.dfo-mpo.gc.ca
Joseph Uravitch	National MPA Center	Marine managed areas	National MPA Center NOS, NOAA 1305 East-West Hwy., SSMC4 Silver Spring, MD 20910-3281	joseph.uravitch@noaa.gov
Kent Wohl	USFWS	Birds	USFWS Migratory Bird Office, 1011 E. Tudor Rd. Anchorage, AK 99503-6199	kent_wohl@fws.gov
Lyman Thorsteinson	USGS-Western Fisheries Research Center	Fish and fisheries	USGS - Western Fisheries Research Center 6505 NE 65th St. Seattle, WA 98115	lyman_thorsteinson@usgs.gov
Monique Lance	WDFW	Marine mammals	WDFW Marine Mammal Investigations 7801 Phillips Road SW Tacoma, Washington 98498	lancemml@dfw.wa.gov

Table 6-1. Continued.

Name	Affiliation	Expertise	Address	Email
Paul Wade, Ph.D.	NMFS-NMML	Cetaceans	NMFS-NMML 7600 Sand Point Way NE Seattle, WA 98115	paul.wade@noaa.gov
Peter Dutton, Ph.D.	NMFS-SWFSC	Sea turtles	NMFS-SWFSC 8604 La Jolla Shores La Jolla, CA 92037	peter.dutton@noaa.gov
Phillip Clapham, Ph.D.	NMFS-NMML	Large cetaceans	NMFS-NMML 7600 Sand Point Way NE Seattle, WA 98115	phillip.clapham@noaa.gov
Rob Suryan, Ph.D.	Oregon State University	Albatross	Hatfield Marine Science Center, 2030 SE Marine Science Dr. Newport, Oregon 97365	rob.suryan@oregonstate.edu
Robert DeLong, Ph.D.	NMFS-NMML	Pinnipeds	NMFS-NMML 7600 Sand Point Way NE Seattle, WA 98115	robert.delong@noaa.gov
Sally Mizroch, Ph.D.	NMFS-NMML	Large cetaceans	NMFS-NMML 7600 Sand Point Way NE Seattle, WA 98115	sally.mizroch@noaa.gov
Scott Benson	NMFS-SWFSC	Sea turtles	NMFS-SWFSC Marine Turtle Research Program c/o MLML Norte 7544 Sandholdt Rd. Moss Landing, CA 95039	Scott.Benson@noaa.gov
Steve Jeffries	WDFW	Marine Mammals	WDFW 7801 Phillips Rd SW Tacoma , WA 98498	jeffrsjj@dfw.wa.gov

Obtain marine mammal and sea turtle data sets for the Pacific Northwest OPAREA and Puget Sound Study Area that may not have been available for inclusion in this assessment. While all available comprehensive data have been included (**Table A-1**), acquiring the following data sets may ensure more complete data coverage:

- NMFS ship strike database (contact: Greg Silber, Ph.D., NMFS-Silver Spring)
- Updated North Pacific right whale database (contact: Paul Wade, Ph.D., NMFS-NMML)
- Oregon pinniped data (contact: Robin Brown, ODFW)
- GLOBEC survey data (contact: Cynthia Tynan, Woods Hole Oceanographic Institute)

Acquisition and analysis of existing data is less expensive than physically collecting new marine mammal and sea turtle survey data. The potential contribution of these data sets to our understanding of the distribution of these protected species is high. Cost: Moderate. Priority: 1

6.2 ENVIRONMENTAL DOCUMENTATION

- Fund dedicated marine mammal and sea turtle aerial and/or shipboard surveys in portions of the Pacific Northwest OPAREA and Puget Sound Study Area designated as areas of "no systematic survey effort" (**Figures 6-1** and **6-2**). While it is essential that the NMFS-SWFSC and NMFS-NMML continue surveying in previously studied areas to account for seasonal and inter-annual variations in the distribution and abundance of protected species stocks, it is also critical to gather data for areas where survey effort has not taken place (or has occurred at lower levels). By focusing attention on these areas, a more complete picture of marine mammal and sea turtle distribution may emerge. Given the high-profile status of these protected species, it would be beneficial to learn as much as possible about them, especially their distribution. Additionally, further funding by the Navy will provide the NMFS-SWFSC and NMFS-NMML the means to provide greater focus on data collection and thereby greatly improve the ability to estimate species densities within the region. These surveys should include:

  - Upwelling period shipboard surveys in regions of the OPAREA where there is a lack of systematic survey effort; specifically, offshore waters in the northwest corner (**Figure 6-1**). Warning Areas W-237E, W-237F, and W-237H have been surveyed infrequently from April to September. Due to the distance of these areas from shore, shipboard surveys would be the most feasible survey method. Since these waters are located within the Canadian EEZ, it is suggested that the Navy encourage and fund a collaborative effort between U.S. and Canadian resource management agencies to survey these waters. Cost: High. Priority: 1.

  - Relaxed period aerial or shipboard surveys throughout the entire Puget Sound Study Area (including the Nanoose and Dabob Ranges) as well as shipboard surveys in Warning Areas W-237E, W-237F, W-237G, W-237H, and W-237J (**Figure 6-2**). The central portion of the Pacific Northwest OPAREA, west of Warning Areas W-570 and W-93, should also be surveyed more intensely from October to March. Shipboard surveys would be necessary for each of the Warning Areas due to their distance from shore. Either aerial or shipboard surveys could be conducted within the Puget Sound Region, depending upon the species being targeted and the preferred survey platform. Again, it is recommended that the Navy encourage U.S. and Canadian agencies to work together to survey areas in close proximity to the U.S.-Canada border. Cost: High. Priority: 1.

- Support onboard specialists to collect marine mammal and sea turtle sighting data during dedicated oceanographic or fisheries surveys within the OPAREA and Puget Sound Study Area. This can be done at a relatively low cost (primarily the salaries of the observers) since the monitoring would occur simultaneously with ongoing cruises. An interagency agreement may facilitate this effort. The cruise tracks of existing surveys are usually predetermined to address concerns of the group conducting the survey and may not necessarily address those areas of particular concern to the Navy. Nevertheless, existing research cruises are valuable opportunities to collect a suite of data of interest to the Navy (the alternative, dedicated cruises, offer the benefit of controlling survey design and focus, but are very expensive). Cost: Low. Priority: 1.

- Continue to conduct acoustic surveys for marine mammals by towing passive acoustic arrays behind research ships. Acoustic surveys have been conducted in conjunction with some sighting surveys and are particularly useful for vocal, deep-diving species such as sperm whales, which spend less time at the surface and are often missed during visual sighting surveys. Acoustic equipment and ship costs make this program potentially expensive. Cost: Moderate to High. Priority: 1.

- Assist the NMFS-SWFSC in funding an expansion of the aerial survey pilot study for sea turtles off Oregon and Washington State that was led by Scott Benson in 2004. The NMFS-SWFSC has been unsuccessful in obtaining the necessary funding to continue these surveys, but would like to so that sea turtle occurrence patterns in the Pacific Northwest Region can be better understood (Dutton, P.H., NMFS-SWFSC, pers. comm., 5 October 2005). Cost: High. Priority: 1.

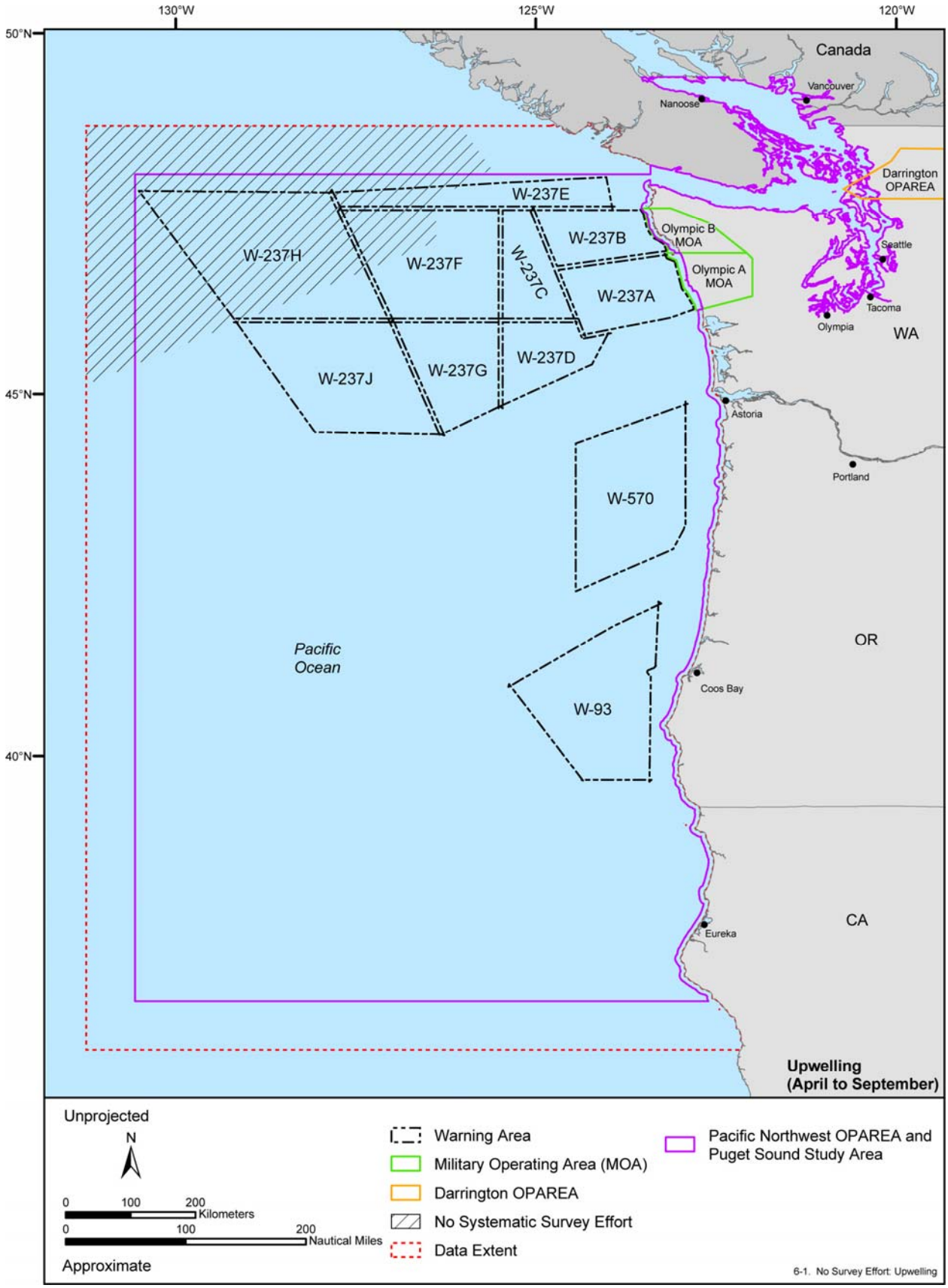

Figure 6-1. Areas of no systematic survey effort in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity during the upwelling season (April through September).

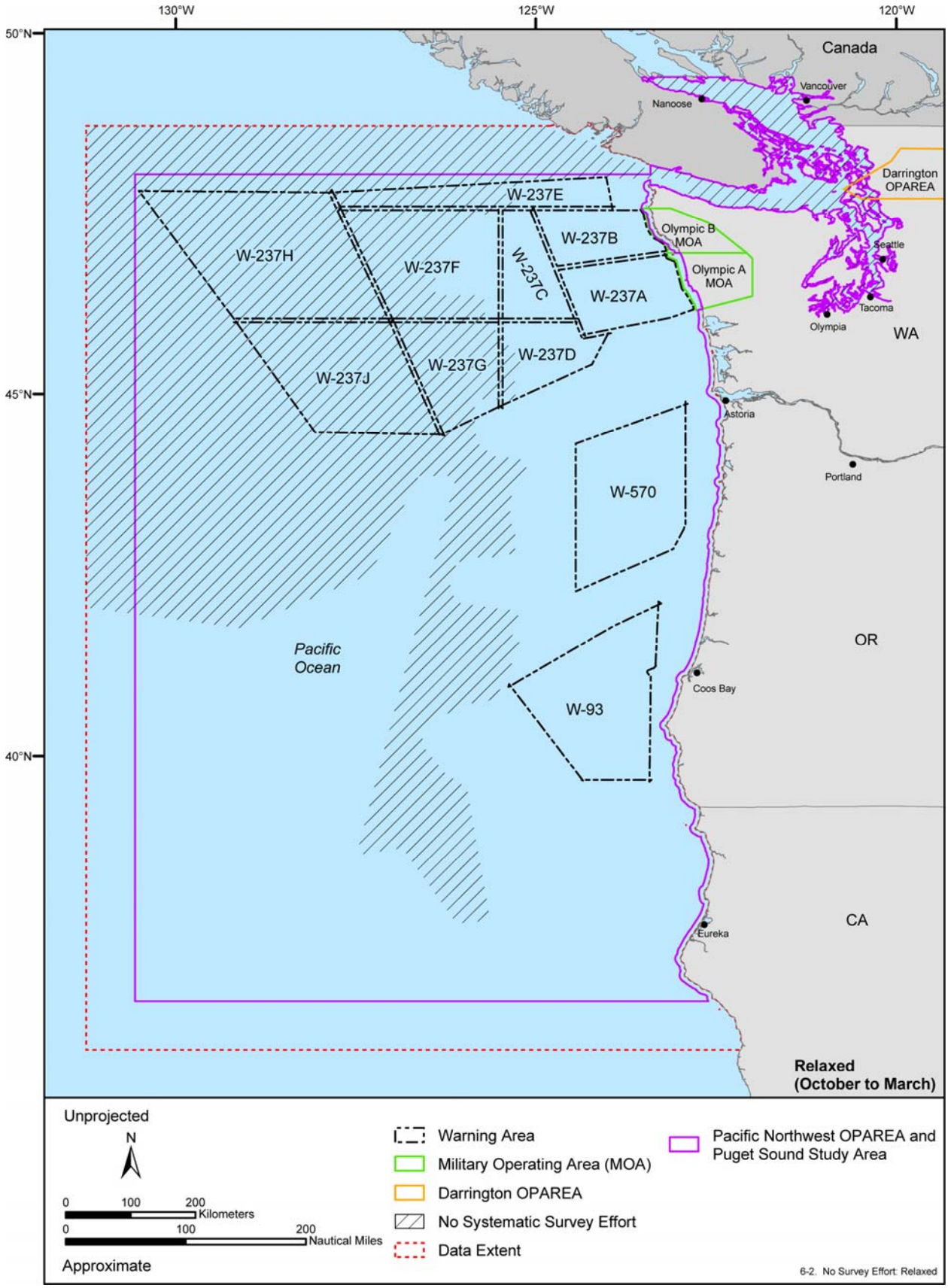

Figure 6-2. Areas of no systematic survey effort in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity during the relaxed season (October through March).

- Support research to update the Stinson (1984) report on the biology and distribution of sea turtles in the eastern North Pacific Ocean. A vast amount of information on sea turtles in this region has been collected over the past 20 years. This information should be synthesized and presented in a single document, rather than scattered among journal articles, recovery plans, sighting/stranding databases, and gray literature. Cost: Low to Moderate. Priority: 2.

- Support the utilization of satellite-tracking technology to monitor the movements of species of special interest. Several species of endangered cetaceans and sea turtles occur in the Pacific Northwest, 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.

- Support the marine mammal and sea turtle stranding networks, particularly with analyses of their collected data. For the hard-shelled sea turtles, strandings represent a large percentage of known occurrences in the Pacific Northwest OPAREA and Puget Sound Study Area (Green, G.A., Tetra Tech EC, Inc., pers. comm., 2 December 2005). 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. Photographs of individual whales can supplement aerial surveys in the determination of movement patterns and stock structure for those species with photo-identification catalogs. Cost: Low. Priority: 3.

- Support a survey of the Pacific Northwest to obtain accurate, high-resolution bathymetry data. High-resolution bathymetry that spans the region will allow for an accurate assessment of shelf bathymetry and hardbottom habitats. Cost: High. Priority: 2.

- Support research to identify the seasonal distribution of essential habitats that affect marine mammals, fisheries, water quality, and shoreline erosion. A significant amount of research is necessary to analyze the present state and sensitivity of these areas and their present locations. Habitat distribution information in the Puget Sound Region and along the outer coast of the Pacific Northwest is essential for predicting consequences of habitat destruction/reduction. The distributions of the following habitats are needed:

  - Seagrass beds and potential seagrass mitigation/transplantation sites, as well as distressed areas that can benefit from restoration activities. Cost: High. Priority: 1.

  - Live/hardbottom communities. There is sufficient data for kelp bed distributions and a certain amount of live/hardbottom assemblages can be inferred to be associated with kelp beds. There are, however, many other live/hardbottom communities that are not located in the depth range of kelp forests and locations are unknown. Cost: High. Priority: 1.

  - Wetlands and estuaries. A significant amount of data has already been collected through the National Wetlands Inventory (NWI); however, the data is often inaccurate. Fund a survey of marine and estuarine habitat occurrence in the nearshore areas of Puget Sound. Cost: High. Priority: 1.

- Support the funding of studies to determine hearing capabilities of Pacific salmonids. As noted by Hastings and Popper (2005), such data would be of particular value if it were for animals of different lifestages and sizes since it is possible that hearing capabilities change with age and/or size of the fish. Cost: Moderate. Priority: 2.

- Update EFH identifications/descriptions/habitat suitability maps, HAPCs, and ecologically important closure areas as revised or additional amendments and/or plans become available from the FMCs

and NMFS (e.g., Pacific Coast Groundfish FMP EFH Designation and Minimization of Adverse Effects Final EIS/Record of Decision [ROD]). Cost: Moderate. Priority: 1.

- Support the development of a database containing all the Pacific Northwest MRA EFH data and information, which would provide user-friendly access to all the EFH data and maps. Cost: Low to Moderate. Priority: 1.

- Support the development of a custom GIS-based application designed to provide functionality to the use of EFH data and use the EFH database proposed in the above recommendation as its base. This custom, stand-alone application would not require the purchase of any additional software or hardware and would allow for easy use of the EFH data in many different environments. Cost: Moderate. Priority: 2.

- Update the map and information relevant to MMAs (**Figure 5-4**). When this MRA report was prepared, the criteria for MPA designation were in development by the National MPA Center, with 2005 as the estimated time of completion. Both state and federal site information and GIS data are currently being analyzed and incorporated into the MMA Inventory. Federal, state, territory, local, and tribal management authorities and programs influence the designation, development, and implementation of MPA sites into the MMA Inventory. Cost: Low. Priority: 1.

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9.0 GLOSSARY

Abalones—large marine mollusks of the class Gastropoda with single, oval, shallow shell containing beautifully colored interior

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

Adhesive—sticky

Adjudicated fishing rights—fishing rights of federally-recognized Indian tribes that have been established pursuant to court decree

Adult—developmental stage characterized by sexual or physical (full size and strength) maturity

Advection—differential motion within a fluid; changes in properties (e.g., temperature, salinity) that take place in the presence of horizontal or vertical flows of seawater (i.e., currents) represent advective changes

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

Alaska Gyre System—dominant circulation feature in the Gulf of Alaska formed by the counterclockwise flow of the Subarctic Current and its continuation as the Alaska Current

Alcid—diving seabirds represented by 16 species that inhabit the nearshore and offshore zones of the Pacific Northwest coastal states

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

Alpha male—the dominant male

Alevin—developmental life stage of young salmonids and trout that are between the egg and fry stage. The alevin has not absorbed its yolk sac and has not emerged from the spawning gravels

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

Anadromous species—referring to the life cycle of fishes, such as salmon, in which adults travel upriver from the sea to breed, usually returning to the area where they were born

Anaerobic—life or biological processes that occur in the absence of oxygen

Anchovies—a small herring-like schooling saltwater plankton-feeding marine fish of the family Engraulidae

Annelid worms—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

Anomurans—small to medium sized malacostracans, mainly with a distinct head and thoracic body regions shielded dorsally and laterally with a carapace, a distinct abdomen, and a pair of well-developed chelae (claws). Predator and/or scavenger which burrows into intertidal or subtidal sediments and resembles small lobsters and/or crabs

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

Area of primary occurrence—for the MRA, it is the areas and habitats where the marine mammal or sea turtle species is primarily found

Area of rare occurrence—for the MRA, it is the areas and habitats where the marine mammal or sea turtle species is not expected to be found regularly

Area of secondary occurrence—for the MRA, it is the areas and habitats where the marine mammal or sea turtle species may be found, especially during "anomalous" environmental conditions

Arribada—a large aggregation of female sea turtles exiting the ocean together to nest at the same time and the same place

Arrow worms—known as Chaetognaths, these torpedo-shaped, 2-120 mm long, chordata are found in marine plankton

Artificial habitat—a human-made, estuarine/marine habitat (shipwrecks, dedicated artificial reefs: rubble, concrete igloos, trains, tanks, ships, 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, reef habitat (sunken ships, trains, tanks, 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

Audiogram—a hearing sensitivity curve drawn as a function of frequency and sound pressure level; describes the hearing ability of an animal

Auditory-evoked potential study—an electrophysiological far-field recording of the auditory nerve and its associated accessory auditory nuclei in response to a sound stimuli

Baleen—the interleaved, hard, fibrous plates made of keratin (protein in fingernails and hair) that hang side by side in rows from the roof of the mouth of mysticete whales; baleen takes the place of teeth and serves to filter the whale's food from the water

Bank—a topographic feature on a continental (or island) shelf and over which the depth of water is relatively shallow (20 to 200m)

Barnacles—a collective name for various marine crustaceans of the subclass Cirripedia; the adults form a hard outer shell and attach to hard substrates such as rocks and ships, as well as to certain whales

Baseline—the line from which maritime boundaries (EEZ, contiguous zone, territorial waters) are measured; in the U.S., the baseline is the low tide line except at the mouths of inland water bodies (bays) where a closing line (straight line) is drawn

Basking—an activity performed by pinnipeds and sea turtles while on land in which they expose themselves to pleasant warmth

Batch spawner—species that spawns repeatedly, releasing batches of eggs and sperm into the sea for external fertilization and development

Bathyal—of or relating to the region of the ocean bottom between the sublittoral and abyssal zones, from depths of 200 to 4,000 m (660 to 13,000 ft)

Bathybenthal—intermediate and lower continental slope usually at depths of 50 to 2,500 m in the Northeast Pacific Ocean

Bathymetry—the topography of the ocean floor; study and mapping of the ocean depths

Bay—a body of water partly enclosed by land but with a wide outlet to the sea

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

Bight—an inward bend or bow in the coastline

Billfish—giant warm-water fish of tropical and subtropical seas having a prolonged and rounded toothless upper jaw of the family Xiphidae

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

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

Bottlenose dolphin—the former common name for *Tursiops truncatus,* now called the common bottlenose dolphin

Brachyuran crabs—a group of crustaceans including the true crab characterized by a short abdomen concealed under the cephalothorax

Brackish—having a salinity between that of fresh and sea water

Braided (meandering) channel—ever-changing smaller channels that together constitute the course of an entire river

Brail net—consists of a small net used to scoop out portions of catch from the main net and haul these portions aboard; used in the market squid fishery

Brittlestar—starfishlike echinoderm belonging to class Ophiuroidea that has five to eight elongate, slender, cylindrical arms distinctly radiating from a flat central disc

Broadcast spawner—organism which releases its gametes into the water, where fertilization occurs; without parental care

Brood—young of an animal cared for at one time

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 in relatively shallow water in the intertidal and subtidal zones along the coast, in estuaries, and muddy bottoms of slat marshes

Bryozoans—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

Calcareous—composed of calcium or calcium carbonate

Calf—a young animal dependent on its mother

California Current—ocean current that flows southward along the west coast of the U.S. to the northern part of Baja California; formed by parts of the North Pacific Current and the Subarctic Current

Callosity—a patch of thickened, keratinized tissue on the head of a right whale, inhabited by large numbers of whale lice

Calving interval—the period of time from one birth to the next, generally applicable to cetaceans

Calving—the process of giving birth by a whale, dolphin, porpoise, or manatee

Cancroid crabs—a family of crabs, Cancroidea, including the genus Cancer

Candidate species—a species 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

Canopy—the cover produced by the intermingling of upper branches of trees in a forest. Analogous cover can be formed by algae and octocorals.

Carangids—burrowing shrimp

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

Carnivora—an order of living and extinct mammals that includes such species as pinnipeds and otters

Carnivore—an animal that feeds exclusively on another animal's tissue

Carrying capacity—the maximum population of a particular species a particular region can support without hindering future generations' ability to maintain the same population. The carrying capacity of an environment will vary for different species in different habitats, and can change over time due to a species' impact on its environment, as well as other environmental factors

Catch per unit effort (CPUE)—measure of a species relative abundance

Category 1 fishery—exploited species that can not be placed on any of the subsequent categories, because of lack of data

Category 2 fishery—species pursued in directed fisheries, and/or regularly found in bycatch, whose catches have not decreased historically, probably due to their higher reproductive potential

Category 3 fishery—species that are exploited by directed fisheries or bycatch, and have a limited reproductive potential, and/or other life history characteristics that make them especially vulnerable to overfishing, and/or that are being fished in their nursery areas

Category 4 fishery—species in this category show substantial historical declines in catches and/or have become locally extinct

Category 5 fishery—Species that have become rare throughout the ranges where they were formerly abundant, based on historical records, catch statistics, or expert's reports

Cephalopods—any marine mollusk of the class Cephalopoda, with the mouth and head surrounded by tentacles (squid, octopus, cuttlefish)

Cere—fleshy area at the base of the bird's beak

Ceremonial—salmon is a traditional food of Washington State Native American tribes. Examples of ceremonies that require traditional meals, including salmon are: winter ceremonials, naming ceremonials, giveaways and feasts, and funerals

Cetaceans—whales, dolphins, and porpoises

Chaetognaths—known as arrow worms that are active elongated, transparent predators in marine plankton

Charter fishing—fishing from a vessel carrying a passenger for hire (as defined in Section 2101(21a) of Title 45, U.S. Code) who is engaged in recreational fishing

Cheloniidae—the family of hard-shelled sea turtles that includes the green turtle, loggerhead turtle, hawksbill turtle, Kemp's ridley turtle, olive ridley turtle, and flatback turtle

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—ranging all the way around the world

Circumpolar—ranging all the way around high northern or southern latitudes

Cladocerns—order of microscopic crustaceans with trunk limbs enclosed in a carapace used for feeding and antennae used for swimming; called water fleas

Clan—one or more killer whale pods that share a related dialect; pods within a clan have probably descended from a common ancestral group and therefore are probably more closely related to each other than to pods from other clans

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

Coastal water—water that is along, near, or relating to a coast

Coast—the boundary where land and water meet

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 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

Cods—any of various marine fishes of the family Gadidae, especially the Pacific hake

Cold-core ring—an eddy or circular current of warm water; in the North Atlantic Ocean, the water in cold-core rings circulates cyclonically (counterclockwise)

Cold-temperate—a latitudinal zone extending between 45 degrees and 58 degrees in both northern and southern hemispheres

Colonial—nesting in groups or colonies rather than in isolated pairs

Colony—highly integrated group of animals; herein refers specially to birds and land-breeding pinnipeds

Columbia River Plume—a large, shallow freshwater plume with strong frontal regions and currents jets near its edges and eddy-like, retentive regions within its body that affects coastal and shelf circulation and cross-shelf transport; frequently present up to 150 km north of the river mouth on the Washington shelf from spring to fall even during periods of upwelling

Commercial fishing—fishing in which the fish is harvested, either in whole or part, are intended to enter commerce through sale, barter, or trade

Common—in the case of sea turtles, common means that sea turtles have been recorded in all, or nearly all, proper habitats, but some areas of the presumed habitat are occupied sparsely or not at all and/or the region regularly hosts large numbers of the species

Community—killer whales that can be linked together through associations form a community. Although all whales in a community may not have been observed to mix, all can be linked together through intermediate associations

Conspecific—member of the same species, and in many cases, the same age or even sex

Continental Divide—the line of summits in the Rocky Mountains that separate streams flowing toward the Gulf of California and Pacific from those flowing toward the Gulf of Mexico, Hudson Bay and the Arctic Ocean

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 break—the area where the slope of the continental shelf rapidly changes from gently sloping to steeply sloping; where the continental shelf gives way to the continental slope

Continental shelf—the province of the continental margin with a gently seaward-sloping seabed (1:1000 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 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 (about 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

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 reef—a massive, wave-resistant structure built largely by colonial, stony coral via deposition of calcium carbonate

Cosmopolitan—having a broad, wide-ranging distribution

Cottids—see sculpin

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

Crèches—a group of young animals all around the same age that herd together

Crepuscular—most active at low light levels during dusk and dawn

Crinoids—class of sessile echinoderms commonly called sea lilies and feather stars; these animals have a cup-shaped body that attaches to the substratum by a stalk (sea lilies) and have feathery arms; class Crinoidea of the phylum Echinodermata

Critical habitats—the portion (minimum) of the habitat that is essential for the survival for certain protected (threatened and endangered) species (whales or sea turtles) and may include areas essential for feeding or reproduction by those species

Croakers—member of the abundant and varied family Sciaenidae, carnivorous, spiny-finned fishes including the weakfishes, drums, and whitings

Crustaceans—arthropods that have two pairs of antennae and a hard exoskeleton (shell); lobster, shrimp, and crabs are the most familiar examples

Cumaceans—sediment-dwelling invertebrate with a carapace that encloses the anterior thoracic segments, which form a gill chamber

Curved carapace length (CCL)—the length of a sea turtle's carapace as measured by researchers working on nesting beaches with a flexible tape measure

Cusk eels—elongate compressed somewhat eel-shaped fishes

Cuttlefish—marine mollusk of the class Cephalopoda that has 10 arms including two long tentacles it can draw back into its body

Cyclonic—counterclockwise circulation in the Northern Hemisphere or clockwise in the Southern Hemisphere; in oceanography, synonymous with cold-core ring

Damselfish—group of fish species of the family Pomacentridae with thin, compressed bodies and circular outlines

Davidson Current—coastal countercurrent setting north inshore of California Current along west coast of U.S. (from northern California to Washington to at least 48 degrees north) during winter months

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 with a reference level; in air, the reference pressure is 20 uPa and the reference range is 1 m, while for underwater sound, the reference is 1 uPa 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

Demosponges—largest and most complex group of siliceous and horny sponges; includes forms with needle-shaped or four-branched siliceous spicules, which may or may not be sported by spongin

Density—physical property measured by mass per unit volume; in biology, the number of organisms per unit of distance

Dermochelyidae—the family of leatherback sea turtles

Desiccation—removal of water; the process of drying

Determined spawner—all eggs to be spawned are developed at the same time

Detritus—a mass of dissolved organic waste material from decomposing dead plants or animals

Diadromous—migrating between fresh water and sea water

Dialect—refers to killer whales; a unique set of discrete calls made by an individual whale and its fellow group or pod members; dialects differ among resident pods, but individuals and groups within the west coast transient community share generally the same distinctive set of discrete calls and have little dialect variation

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

Diffusion—intermixing of particles as a result of movement caused by thermal agitation

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 blooms in freshwater and marine habitats

Dipnet—consists of a small net attached to the end of a long shaft; is used in the harvest of chub mackerel

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

Diurnal—active or occurring during daylight hours; having a daily cycle

Dive gear—is used to take sea urchins, abalone, or sea cucumbers. Divers use “hookah” systems consisting of a long air hose connected to an air compressor on the deck of a boat

Dominant species—species most prevalent in a particular community, or at a given period

Dorsal—relating to the upper surface of an animal

Drift algae—detached intertidal and subtidal kelp forming floating mats

Drift gillnets—gillnets attached to the stern of a fishing boat and allowed to drift below the ocean surface; sharks and swordfish are among some of the targeted species

Drum seines—are purse seines that are hauled into drums requiring less people to operate; species commonly targeted include sardines, anchovy, and mackerel

East Australian Current—forming the western boundary of the South Pacific subtropical gyre, this largest ocean current moves a substantial volume of low-nutrient tropical water south down the Australian coastline towards the temperate regions with ocean eddies peeling off into the Tasman Sea

Ebb tide—outgoing or falling tide

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)

Echinoid—referring to echinoderms, e.g., sea urchins and sand dollars

Echiurid proboscis—known as spoonworms; are sediment dwellers that extend their proboscis onto the sediment surface

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

Eelpout—elongate, tapering marine fish commonly found in the North Pacific

El Niño—wind-driven reversal of the Pacific equatorial currents resulting in the movement of warm water towards the coasts of the Americas, considered a natural cyclical atmospheric/oceanic phenomenon; El Niño is often termed the El Niño/Southern Oscillation, or "ENSO"

Elasmobranch—fishes of the class Chondrichthyes that are characterized by having a cartilaginous skeleton; includes sharks, skates, and rays

Electroreception—the ability to detect magnetic fields radiated by marine animals

Embayment—an indentation in the shoreline that forms a bay

Embryogenesis—development of an embryo

Emigration—a movement out of an area by members of a population

Endangered species—any animal or plant species in danger of extinction throughout all or a significant portion of its range; the authority to list a species is shared by the USFWS (plants and animals on land) and NMFS (most marine species) under provisions of the ESA

Endemic—occurring in a specific area

Environmental impact statement (EIS)—a detailed written statement that helps public officials make decisions that are based on understanding of environmental consequences and to take actions that protect, restore, and enhance the environment

Epibenthic—refers to organisms living on the ocean floor

Epifauna—animals living on the surface of the ocean floor; any encrusting fauna

Epi-mesopelagic—zone of marine waters between epipelagic and mesopelagic

Epipelagic—the oceanic zone from the surface to 200 m

Equidistant line or equidistance—a median line, every point of which is the same distance from the nearest points on the baselines of two countries

Essential fish habitat (EFH)—those habitats necessary to fish for spawning, breeding, feeding, or growth to maturity; designated by the NMFS

Estuary—area of the mouth of a river where river water meets and mixes with seawater; often an area of high biological productivity and important as nursery areas for many marine species

Euhaline—water with salt concentrations of 30 to 40 ppt

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

Eutrophication—the process by which nutrient-rich water promotes a rapid growth of algae and phytoplankton, which reduces the water's dissolved oxygen content

Evolutionary significant unit (ESU)—refers to salmonids; a population that is substantially reproductively isolated from conspecific populations and represents an important component in the evolutionary legacy of the species

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

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

Eye patch—the elliptically-shaped white patch located above and behind a killer whale's eye

Eyrie—nest or dwelling made by a bird of prey, usually elevated in a tree or on a cliff

Falcate—sickle-shaped and curved (refers to the dorsal fin of some cetaceans)

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)

Federally-recognized tribes—any Indian or Alaska Native tribe, band, nation, pueblo, village or community that the Secretary of the Interior acknowledges to exist as an Indian tribe. The Secretary of the Interior is required to publish an annual list of such tribes in the Federal Register (25 USC sections 479a and 479a-1)

Fingerlings—juvenile salmonids up to nine months of age, generally two to four inches in total length. Also called parr, typically referred to as hatchery juveniles

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 Management Plan (FMP)—plan prepared by a Regional Fishery Management Council or by NMFS (if a Secretarial plan) to manage fisheries

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 glacially over deepened valley, usually narrow and steep-sided, extending below sea level and filled with salt water

Flabelliferan isopod—member of the suborder Flabellifera with a flatten body, some abdominal segments fused together, and last segment fused with telson; uropods are fan-shaped forming a tail fan together with telson. Most common shallow-water marine species

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

Flood tide—incoming or rising tide

Flora—all the plant species of a given area

Flotsam—wreckage or cargo left floating on the sea surface after a shipwreck

Flounder—see flatfish

Flukes—the horizontally spread tail of a cetacean

Flying fish—tropical marine fishes of the genus *Exocoetus* having enlarged winglike fins used for brief gliding flight

Flying gurnard—a species of gurnard of the genus *Cephalacanthus* or *Dactylopterus* with very large pectoral fins; able to fly like the flying fish, but not for great distances

Forage fish—any fish eaten by larger predatory fish, seabirds, or marine mammals, usually swimming in large schools

Forage—the act of searching for food or provisions

Fork length—length of a fish measured from the tip of the snout to the fork of the tail

Front or frontal—see ocean front

Fry—newly hatched or born fish

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

Gametes—mature egg or sperm, capable of reproduction after fertilization with sperm or egg from same species

Gammarid amphipods—amphipods commonly associated with sediments

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 of development in the uterus from conception until birth (pregnancy)

Gillnet—a type of fishing gear made of rectangular mesh panels that are set more or less vertically in the water so that fish swimming into it are entangled by their gills; they can be set to fish at the surface, midwater, or on the bottom of the water column

Gonadal—pertaining to reproductive organs, ovaries or testicles

Gonochoristic—referring to a species that has separate sexes (i.e., male and female individuals)

Greenlings—small cold-water fishes of the family Hexagrammidae found only on the Pacific coast

Gregarious—used to describe animals that form social groups

Groundfish—group of fishes that spend most of their life on or near the ocean floor (e.g., rockfish, flatfish, roundfish, skates, sharks, chimeras); also known as demersal species

Gullies—trough or lengthy, narrow, depression in the sea floor extending into a continental shelf or toward a seacoast

Gyre—circular movement of waters, larger than an eddy; usually applied to oceanic systems

Habitat area of particular concern (HAPC)—discrete areas within essential fish habitat (EFH) that either play especially important ecological roles in the life cycles of federally managed fish species or are especially vulnerable to degradation from fishing or other human activities

Habitat preference—the choice by an organism of a particular habitat in preference to others

Habitat—the place where an organism is found temporarily or permantley and that provides sustenance, shelter, and space

Hake—any of various marine food fishes of the genus Merluccius and Urophycis, relater to and resembling the cod

Hard bottom 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

Harvestable rate—total fishing mortality in a fishery expressed as a proportion of the total fish abundance available (standing stock) in a given fishing area at the start of a time period

Harvest—fish killed as a result of encounters with fishing gear

Hatchling—a newly hatched bird, amphibian, fish, or reptile

Haul out—the process by which pinnipeds crawl or pull themselves out of the water onto land

Haulout site—intertidal rock outcrops, sandbars, shoals, mudflats, or sandy beaches where marine animals, such as pinnipeds, periodically and purposefully come ashore

Headlands—high, steep-faced promontory extending into the sea

Herbivore—an animal that eats plants as its main source of energy

Hermit crab—marine crustacean living in cast-off shells of gastropods

Herring—any of various marine fishes of the family Clupeidae, especially a commercially important food fish (*Clupea harengus*) of the Pacific and Atlantic waters

Heterogeneous—having a non-uniform structure or composition

Histioteuthid squids—deep water squids without a transparent corneal membrane but with eyelids of the suborder Oegopsida

Holdfast—the algal equivalent of roots that attaches the organism to a surface or the seafloor

Holding area—an area in which prior to spawning, ripening adult Pacific herring congregate and hold in a region usually adjacent to the spawning grounds

Homing—orienting or directing homeward or to a destination

Hook and line gear—includes pelagic longlines used to target tuna and swordfish

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

Hyperiid amphipods—family and suborder of Amphipoda with very large head and eyes, five abdominal segments and seven pairs of thoracic legs

Hypersaline—water with a high concentration of dissolved mineral salts present

Hypoxia—waters with a low oxygen concentration, usually less than 2 parts per million; hypoxic waters are considered oxygen-depleted

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—refers to bird; one hatched in the spring of the same year

In situ—in the natural or original position

Incidental fisheries bycatch—the catch of additional species, such as fishes, turtles, or marine mammals, that are not targeted by a fishery but are harvested in addition to the target or sought after species

Incubation—the act of keeping an egg warm so that development is possible

Infaunal—invertebrates living in the sediment of the seafloor

Infrasonic—sound at frequencies too low to be audible to humans, generally below 20 Hz

Inshore—lying close to the shore or coast

Insular—geographically isolated; pertaining to an island

Inter-nesting interval—the amount of time between successive sea turtle nesting events during the nesting season

Interpolate—extrapolation to predict values for a parameter between limited data points

Interstitial—pertaining to, or occurring within, the pore spaces (interstices) between sediment particles

Intertidal—marine or estuarine environment that lies between the area of shore exposed between high and low tide

Irruptive—entering an area where not characteristically seen

Isobath—bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isohaline—contour of equal salinity, usually shown as a line connecting points of the same salinity

Isopods—shrimp-like animals of the order Isopoda that have their body flattened dorso-ventrally

Isopondylous fish—herring-like fishes with simplified anterior vertebrate

Isotherm—contour of equal temperature; usually shown as a line linking points of the same temperature

Iteroparity—reproductive strategy where individuals reproduce several times throughout their life

Iteroparous—an organism that reproduces several times during its lifespan (i.e., does not die after spawning)

IUCN Red List—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

Jellyfish—any various free-swimming coelenterates having disc or bell-shaped body of jellylike consistency having long tentacles with nematocysts of the classes Scyphozoa and Hydrozoa of the phylum Cnidaria

Jetsam—cargo or equipment deliberately thrown overboard from a ship and which either sink or wash ashore.

Jetties—structure use at inlets to stabilize the position of the navigation channel, to shield vessels from wave forces, and to control the movement of sand along the adjacent beaches so as to minimize the movement of sand into the channel

Juvenile—mostly similar in form to adult but not yet sexually mature; a smaller replica of the adult

Kelp holdfast—a branched, modified stem that attaches kelp to rocks or other hard substrata

Kelp sporophyll—a leaf structure that bears sporangea (a spore-bearing structure)

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.)

Kilopascal (kPa)—a standard unit of pressure in the International System of measurements

Kleptoparasitism—food theft from another animal

Kogia—the genus comprised of the pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*Kogia sima*)

Krill—see euphausiids

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)

Lactation—secretion or formation of milk by the mammary glands for the purpose of nursing offspring

Lair—a resting place used by an animal; often for giving birth, nursing young, or hibernating; den

Laminarian—pertaining to seaweeds of the genus *Laminaria* or to that zone of the sea (from two to ten fathoms in depth) where the seaweeds of this genus grows

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

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

Longline gear—lines that are deployed horizontally to which gangions and hooks or pots are attached; can be stationary, anchored, or buoyed lines that may be hauled manually, electrically, or hydraulically; gear is most often used to catch rockfish and sablefish

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

Longshore transport—sediment transport down the beach (parallel to the shoreline) caused by longshore currents and/or waves approaching obliquely to the shoreline

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-frequency sound—sound having frequencies below 1,000 Hz

Lumpsuckers—small scorpaeniform marine fish of the family Cyclopteridae whose pelvic fins have evolved into adhesive discs which allows the fish to attach itself to substrate

Macrofauna—small to moderate sized invertebrates living on and in bottom sediments

Macrophyte—macroscopic plant in an aquatic environment

Macroplanktonic—large planktonic organisms 20 to 200 mm in diameter

Macroscopic algae—large algae, commonly referred to as seaweed

Macrourids—common and abundant deep-sea fishes; also known as rattails or grenadiers of the family Macrouridae

Map projection—a mathematical formulation that transforms feature locations on the Earth's curved surface (three-dimensional) to a map's flat surface (two dimensions)

Masking—obscuring of sounds of interest by interfering sounds, generally at similar frequencies

Matriarch—the eldest female in a matrilineal group, pod, or subpod

Matriline—the basic social unit of resident killer whales, comprised of a mature female and her immediate descendants; descendants may include mature males and mature daughters and their offspring

Maturation—process of becoming mature

Maximum sustained (sustainable) yield (MSY)—largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions

Mean higher high water (MHHW)—average height of all daily higher high waters recorder over 19-year period, or computed equivalent period

Mean lower low water (MLLW)—arithmetic mean of the lower low water heights of a mixed tide over a specific 19-year Metonic cycle (National Tidal Datum Epoch); only the lower low water of each tidal day is included in the mean

Mean—(arithmetic) average

Median—(arithmetic) the middle number in a set of data when it is calculated from lowest to highest; it is an indicator of central location in a dataset

Melon—a fatty cushion forming a bulbous "forehead" in toothed whales; may act to focus sound for echolocation

Mesobenthal—pertaining to the upper continental slope (depths of 200 to 500 m) in the Northeast Pacific

Mesohaline—water with a salt concentration of 5 to 18 ppt

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

Mesoscale—large scale

Metabolism—all biochemical reactions that take place in an organism

Metadata—information about a geographic information system (GIS) shapefile or coverage file that describes the source of the data or information, the creation date, the data format, the projection, the scale, the accuracy, and the reliability of the GIS file with regard to some standard

Metamorphosis—process of transforming from one body form to another form during development (e.g., tadpole changing to a frog)

Microhabitat—a smaller part of a habitat that has some internal interactions allowing it to function self-sufficiently within a generally larger habitat

Midshipmen—any of various fishes of the genus *Porichthys*, having several rows of light-producing organs along their bodies

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

Morphology—the form and structure of an organism considered as a whole; appearance

Morphometric—the study of comparative morphological measurements

Mudflat—muddy or sandy coastal strip usually submerged by high tide

Multiple brooders—species which releases multiple batches of larvae over the course of a spawning

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

Natal—of or associated with the time or place of one's birth

Nasal septum—the wall of flexible cartilage dividing the nasal cavity into halves

Nauplii—earliest stage of crustacean larvae

Nautical mile (NM)—a distance unit used in the marine environment that is equal to one minute of latitude or 1.85 km

Nearshore—an indefinite zone that extends seaward from the shoreline

Nekton—actively swimming pelagic organisms that are able to move independently of water currents; typically within the size range of 20 mm to 20 m

Neonate—a newborn

Neritic zone—the shallow portion of pelagic ocean waters; ocean waters that lie over the continental shelf, usually no deeper than 200 m

Neustonic—organisms living on or just under the water surface, often dependent on surface tension for support

Nocturnal—applied to events that occur during nighttime hours

North Pacific Transition Zone (NPTZ)—an oceanwide feature associated with the oceanic and atmospheric gyre scale circulations and air-sea energy exchange process; bounded on the north and south by the subarctic and subtropical frontal zones; region where rapid changes occur in thermohaline structure, hydrostatic stability structure, and biological species composition; extends from Japan to North America flowing eastward and fed by the Kuroshio and Oyashio currents

North Pacific—the part of the Pacific Ocean found north of the Equator

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)

Nutrification—process by which saltwater or freshwater systems develop high nutrient concentrations

Occurrence record—a marine mammal or sea turtle sighting (aerial or shipboard survey), stranding, incidental fisheries bycatch, nesting, or tagging data record for which location information is available. An occurrence record, especially sighting occurrence records, may represent the occurrence of one or multiple animals of a particular species; for instance, one occurrence record from a marine mammal sighting survey may indicate that 34 short-finned pilot whales were observed at a location but this information would be plotted on a MRA map figure as one occurrence record

Ocean front—a boundary between two water or air masses that have different densities; water density differences are caused by differences in temperature or salinity

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

Odontoceti—the suborder of cetaceans comprised of toothed whales (e.g., beaked whales, dolphins, porpoises, sperm whale)

Offshore killer whales—a little-known population of killer whales, found mostly in offshore waters off British Columbia but also identified in California, Washington, and southeastern Alaska; more closely related genetically to residents than transients; appear to travel in generally larger groups than residents or transients

Offshore—open ocean waters over the continental slope that are deeper than 200 m; water beyond the continental shelf break

Olfactory—relating to the sense of smell

Oligotrophic—water that is lacking in nutrients, which results in low primary production

Omnivore—an animal that feeds on both plant and animal tissue

Ontogenetic migration—occupation by an animal of different habitats at different stages of development

Oophagous—feeds on eggs

Opalescent squid—market squid which occurs in open coastal waters from the ocean surface to the bottom

Ophuiroid—echinoderms known as basket stars or brittle stars that have long, slender, jointed arms distinctly separated from the body

Opisthobranchs—gastropods with a well-developed shell and a single gill

Opportunistic—used to describe organisms that take advantage of all feeding opportunities and do not prey on a few specific items

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

Osmoregulatory—maintenance of an optimal, constant osmotic pressure in the body of a living organism

Ostracods—crustacean like crabs and lobsters that have thicker ornamented valves

Otariids—the eared seals (sea lions and fur seals), which use their foreflippers for propulsion; from the family Otariidae

Overfish—a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis

Overwinter—staying the winter in one area

Oviparous—producing eggs that develop and hatch outside the maternal body (i.e., externally)

Ovoviviparous—giving birth to live young which have developed from eggs that hatched within the mother's body

Oxygen minimum zone (OMZ)—a layer in which the descending food material that's passing through the water column has been degraded by bacterial activity. As the food is degraded, a lot of oxygen is used by the bacteria, resulting in a minimal amount left in the water column

Pacific Northwest Operating Area (OPAREA)—the Pacific Northwest Ocean Surface/Subsurface Operating Area which encompasses all waters offshore (greater than 3 NM) of Washington, Oregon and Northern California, as well as the nearshore areas (to the mean higher high tide line) of W237-A

Pack ice—sea ice, especially that which is unattached to land and usually moving and shift to same extent

Pandalid shrimp—coldwater "true shrimp" are commercially important nearshore and offshore members of the infraorder Caridea

Parademersal—referring to a species or animal that occupies a vertical zone somewhat intermediate between those that are clearly associated with the bottom and those usually observed well up in the water column

Paralarvae—planktonic lifestage of cephalopods

Parr—see fingerlings

Parturition—act of giving birth

Pathogen—an biological agent that cause disease or illness to its host

Pectoral fin—flipper; flattened fore-limb of a cetacean (supported by bone)

Pelage—the fur or hair covering a mammal

Pelagic—open ocean; the primary division or zone in the open ocean that encompasses the entire water column and is subdivided into the neritic (shallow) and oceanic (deep) zones

Pelecypod—bivalved mollusks inhabiting marine and freshwater soft bottom sediments ranging in size from a few millimeters to 1.2 meters in length; may be burrowing, mobile, or sedentary types

Peru Current—northerly extension of the cold Humboldt current off the Peruvian coast; divided into an inner coastal current and an outer oceanic current by a tongue of warm water from the South Equatorial countercurrent

Phaeophyte—brown algae

Phenology—The study of the relationship between climate and the timing of periodic natural phenomena such as migration of birds, bud bursting, or flowering of plants

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

Physiographic—pertaining to geographic features of the earth's surface

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

Pinnacles—sharp pyramidal or cone-shaped rock partly or completely covered by water

Pinnipeds—seals, sea lions, fur seals, and walruses

Pipefish—fish with long tubular snout and slim body covered with bony plates

Piscivorous—a carnivorous animal that eats fish

Pistol shrimp—symbiosis or snapping shrimp of the family Alpheidae consisting of very short eye stalks and one much larger pistol claw

Planktivore—an animal that eats phytoplankton and/or zooplankton

Plankton—organisms (plant or animal) that drift in the water column and cannot propel or move themselves

Pleopods—one of paired abdominal appendages among crustaceans; may be used in swimming, fanning water, respiration or reproduction

Plumage—the feathers worn by a bird at any given time

Plume—a feather; a moving or expanding body of water

Pod—in resident killer whales, a group of maternally related individuals that tend to travel together; in transient killer whales, the term 'group' is used in preference to 'pod' because groups are not necessarily made up of related animals

Polar—in latitudes near one of the poles (North or South), typified by cold and ice-infested waters

Pollock—important food and game fish of the northern seas, related to cod

Polychaete—class of soft-bodied, metamerically segmented coelomate worms that bears bristles and fleshy appendages on most segments; marine; may be free-swimming, errant, burrowing or tube dwelling

Polyhaline—water with a salt concentration between 18 and 30 ppt

Pompanos—any one of several marine food fishes of the genus Trachynotus

Population—a group of individuals of the same species occupying the same area

Posterior—situated near or toward the back of an animal's body

Post-flexion—larvae beginning transformation into juvenile

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

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

Proboscis—a flexible, elongated snout of certain animals

Protogynous hermaphrodite—Sequential hermaphrodite in which the fish functions first as a female and then changes to a male

Protracted spawning—a longer spawning period

Psycho-acoustic study—a behavior study used to measure the hearing ability of an organism (e.g., operant conditioning where an animal is behaviorally trained using positive reinforcement to respond to sound stimuli)

Pteropod—small, free-swimming, shelled mollusks which swims near the surface by means of a modified foot with wing-like appendages; related distantly to oysters and mussels

Puget Sound Study Area—inshore waters located between Washington State and British Columbia, including the Strait of Juan de Fuca, the Strait of Georgia, the water area surrounding the San Juan Islands, Hood Canal, and Puget Sound

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"

Pycnocline—a zone of marked water density gradient that is usually associated with depth

Pyrosomas—blue-green bioluminescent, pelagic, tunicates that form thimble-shaped colonies of the genus *Pyrosoma*

Rafeedie decision—popular term for United States versus Washington No. 9213, subproceeding 89-3, a federal district court decision regarding treaty tribal rights to shellfish, including geoducks.

Range—the maximum extent of geographic area used by a species

Rare—a plant or animal restricted in distribution or number; in the case of sea turtles, rare means that a species occurs, or probably occurs, regularly within the region but in very small numbers; in the case of marine mammals, rare means a species that only occurs in the area sporadically

Ratfish—a fish of Pacific waters having a long narrow tail

Ratify—to affirm or approve; in the case of a treaty, to agree to be bound by the treaty

Recreational fishing—fishing for sport or pleasure

Redd—nest made in gravel consisting of a depression dug by a fish for egg deposition (and then filled) and associated gravel mounds

Refugia—an area that has escaped ecological changes occurring elsewhere and so provides a suitable habitat relict species

Regular—in the case of marine mammals, a species that occurs as a regular or normal part of the fauna of the area, regardless of how abundant or common it is

Relaxed season—occurs off the Pacific Northwest coast from October through March when winds are light and variable and the seas can remain calm for extended periods

Relief—the inequalities (elevations and depressions) of the sea bottom

Remigration interval—the amount of time between successive sea turtle nesting seasons

Resident killer whales—a form of killer whales that feeds preferentially on fish, especially salmon, and has a very stable social structure

Rhodophyte—red algae

Riffle—shallow area of a stream in which water flows rapidly over a rocky gravelly stream bed

Riparian vegetation—plants that grow rooted in the water table of a nearby wetland such as a river, stream, etc.

Robust—powerfully built

Rock crab—any one of several species of large crabs of the genus *Cancer*

Rockfish—marine food and game fish of the genus *Sebastes* found along the northern coasts of America and Europe

Rookery—an animal's breeding ground; it is the specific beach on which they nest (turtle) or pup (pinniped)

Roost—sleeping; refers to birds

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

Roundfish—an ordinary market fish exclusive of flounders, soles, halibut, and other flatfishes

Rufous—Reddish-brown

Saddle—a light-colored patch behind the dorsal fin of some cetaceans

Sagittal crest—prominence on top of the 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)

Salmonid—a member of the Salmonidae family of fishes

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 lances—known as sand eels, this common forage fish of the family Ammodytidae has a narrow, elongate, subcylindrical body with a pointed snout and long dorsal and anal fins

Sand spit—type of bar or beach that develops where a re-entrant occurs, such as at a cove, bay, or river mouth. Spits are formed by the movement of sediment (typically sand) along a shore by longshore drift

Sanddabs—any of various important marine food flatfishes of the family Paralichthyidae

Sardines—any of various small or half-grown edible herrings or related fishes of the family Clupeidae

Saury—a slender long beaked fish of the family Scombersocidae

Scaphopod—a member of the phylum Mollusca and class Scaphopoda which have an elongate conical shell and live buried within the sediment feeding on foraminiferans and other small animals

Scarp—a line of cliffs produced by faulting or erosion

School—a social group of fish, drawn together by social attraction, whose members are usually of the same species, size, and age; the members of a school move in unison along parallel paths in the same direction

Scleractinian—hard or stony corals (class Anthozoa, subclass Hexacorallia, order Scleractinia) known as true corals that dominate reef ecosystems; they have a compact calcareous skeleton and polyps with no siphonoglyphs (grooves)

Scorpionfish—marine fishes of the family Scorpaenidae having a tapering body with an armored head and venomous spines

Sculpin—any of numerous spiny large-headed broad-mouthed usually scaleless scorpaenoid fishes

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 lilies—class of sessile echinoderms referred to as crinoids; these animals have a cup-shaped body that attaches to the substratum by a stalk and has feathery arms; filters food particles from the currents flowing past them

Sea stars—one of the class Asteroidea of echinoderms having flat, usually fine-armed body containing embedded calcareous plates bearing spines or tubercles

Sea surface temperatures (SST)—the temperature of the layer of seawater (approximately 0.5 m deep) nearest the atmosphere

Sea urchins—one of the class (Echinoidea) of echinoderms in which the body is covered by hard shell (test) composed of fitted immovable plates with often large and sharp spines that are articulated at bases; may be of various sizes - spherical, depressed spherical, discoid, or round

Seamount—an undersea mountain rising more than 914 m from the sea floor, but having a summit at least 305 m below sea level (in contrast to an island)

Seaweed—any macroscopic marine alga or sea grass

Sedentary—organism that spends the majority of its time in one place

Sediment—solid fragmented material, either mineral or organic, that is deposited by ice, water, or air

Semelparous—animals that have a single reproductive period during their lifespan

Semi-demersal—refers to species found in water column a few meters above the bottom

Semi-pelagic—fish that spend part of their life on the bottom and part in the water column above

Sergestid shrimp—several species of non-commercial shrimp of the decapod crustacean family Sergestidae

Sessile—used to describe an animal that is attached to something rather than free moving

Set gillnets—gillnets that are anchored to the seafloor and may be fished on the ocean bottom or floating above the anchors; used to catch California halibut, sharks, white seabass, barracuda, white croaker, flying fish, and rockfish

Sexual maturity—the state in which an animal is physiologically capable of reproducing

Sexually dimorphic—differences in the appearance of the sexes of a species; size differences are a primary difference where males are generally larger than females; other differences may be in body shape and color

Shallow water—water that is between the shore and the continental shelf break or shallower than 200 m

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

Siphon—an opening in mollusks or in urochordates (tunicates) which draws water into the body cavity

Site fidelity—the tendency to return to the same site repeatedly

Slough—a shallow inlet or backwater whose bottom may be exposed at low tide; sloughs often border estuaries and typically have a stream passing through them

Slump—a landslide where the underlying rock masses tilt back as they slide from a cliff or escarpment

Smelt—family of saltwater small streamlined fish superficially like herring but possessing an adipose fin like salmon and trout that enters streams and ponds to spawn

Smolt—a young Salmonidae (e.g., salmon or trout) which has developed silvery coloring on its sides, obscuring the parr marks, and which is about to migrate or has just migrated into the marine environment

Smoltification—process of transforming a Salmonidae species (e.g., trout or salmon) from a parr to a smolt in preparation to leave the freshwater environment and enter the marine environment; during this transformation, the functioning of the gills and kidneys must be reversed

Snag—a standing dead or dying tree that has lost most of its branches and provides cavities for nesting, perches, and feeding sites for wildlife

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

Spawn—the release of eggs and sperm during mating

Species diversity—the number of different species in a given area

Species of concern—a species 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

Species—a population or series of populations of organisms that can interbreed freely with each other but not with members of the other species

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)

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

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

Subpopulations—an identifiable fraction or subdivision of a population

Subsistence—ways in which indigenous people use the environment and the resources it provides (e.g., salmon) to meet the nutritional needs of the members of the society

Substrata—layer or base on which animal or plant lives

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 on by the underwater surface and become breakers

Surf zone—area of the water from the surf line to the beach

Surfperches—short deep bodied fish with continuous, long dorsal fins of the family Embiotocidae; inhabit surf zone along sandy shores

Sympatric—species or subspecies occurring together; having overlapping areas of distribution

Talon—claw of a bird of prey

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

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

Thermohaline circulation—density-driven water circulation caused by differences in temperature and/or salinity

Thermoregulatory—an organism's ability to maintain a specific body temperature regardless of the environmental temperature

Thornyhead—marine fish of the genus *Sebastolobus* found along the Pacific coast of America

Threatened species—any plant or animal species likely to become endangered within the foreseeable future throughout all or a part of its range; the authority to designate a species as threatened is shared by the U.S. Fish and Wildlife Service (terrestrial species, sea turtles on land, manatees) and National Marine Fisheries Service (most marine species) under provisions of the Endangered Species Act

Tidepools—pool of waters remaining on beach or reef after recession of tide

Tidewater—low-lying coastal land drained by tidal streams

Tintinnids—suborder (Tintinnidea) of microscopic, planktonic Protozoa which possess a lorica or vase-like shell with tentacle-like organelles; often covered by diatoms, sponge spicules or other small particles; widely distributed in open seas and coastal waters

Topography—physical features of the ocean floor, such as mounds or ridges

Topsmelt—small, schooling surface-dwelling fish of the family Atherinopsidae having silver side along each side

Total allowable catch—number or weight of fish which may be harvested in a specific unit of time

Total length—the longest measurable distance from the outermost portion of a fish's snout lengthwise to the outermost portion of the tail fin

Traffic separation scheme—a plan, generally internationally agreed on, by which vessels in congested areas use one-way lanes to lessen the danger of collisions

Trammel net—consists of three layers of net: a slack, small mesh, inner panel of netting sandwiched between two outer layers of netting, which are taught and have a larger mesh size

Transboundary—across borders

Transient killer whales—a form of killer whales that feeds preferentially on marine mammals and has a looser social structure than that of residents; transients also differ from residents in dorsal fin shape, group size, behavior, vocalizations, and genetics

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

Trans-oceanic—on or from the other side of the ocean

Trans-Pacific—spanning or crossing the Pacific Ocean

Trap or pot—generally constructed of galvanized wire that may or may not be vinyl coated; usually distributed throughout shallow water in the spring and summer and moved into deeper waters as winter arrives; used to target spot prawns, spiny lobster, and rock crabs

Trawl net—a towed fishing gear or net that consists of a cod-end or bag for collecting the fish or other target species; trawls can be towed at any depth of the water column

Troll gear—consists of up to six stainless steel lines running from hydraulic spools to outrigger poles from which they are spread and suspended from the boat. Baited hooks are then attached to the stainless steel mainlines at regular intervals using monofilament leaders. The lines are then pulled slowly through the water (trolling). Used to target both salmon and albacore tuna

Trophic level—a step in the transfer of food or energy within a chain

Tropical—the geographic region found in the low latitudes (30° north of the equator to 30° south of the equator) characterized by a warm climate

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*)

U.S. versus Washington—commonly referred to as “The Bodlt decision”, this on-going federal court proceeding that enforced and implemented reserved treaty fishing rights with regard to salmon and steelhead returning to western Washington State

Ulvoid—characteristic of the green algal family Ulvaceae; most species have broadly expanded, membranous, green blades

Underwing—the underside of the wing

Unknown—for the MRA occurrence polygons, it is the area and habitats for which insufficient information is available to establish occurrence due to lack of survey effort (best judgment follows then whether the area would be anticipated to be of primary or secondary occurrence)

Upwelling—movement of dense, cold, nutrient-rich water up from ocean depths to the surface

Upwelling season—occurs off the Pacific Northwest coast from April through September when upwelling conditions are high

Urochordates—a subphylum of Chordata distinguished by having a notochord, a dorsal hollow nerve cord, gill slits, and a post-anal tail; sea squirts

Uro-genital area—portion of ventral surface around and near the excretory and genital orifices

Usual and accustomed fishing areas—traditional Indian fishing grounds and stations of treaty Indian tribes in the Pacific Northwest so designated through judicial process. Defined in the Boldt Decision (383 Federal Supplement 312: 313) as "every fishing location where members of an Indian tribe customarily fished from time to time at and before treaty times, however distant the then-usual habitat of the tribe, and whether or not other tribes then also fished in the same waters"

Vagrant—a wanderer, in the same sense of an animal moving outside the usual limits of distribution for its species or population

Veliger—the larval stage of various invertebrates (e.g., white abalone) having one or two ciliated membranes for swimming

Ventral—relating to the underside (or belly side) of an animal

Vertebrates—animals with a backbone

Viviparous—type of development in which the young are born alive after having been nourished in the uterus by blood from the placenta

Warm-core ring—an eddy or circular current of warm water; in the North Atlantic Ocean, the water in warm-core rings circulates anticyclonically (clockwise) and the rings are formed when meanders pinch off the northern side of the warm Gulf Stream

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 and salinity

Watershed—region draining into a river, river system or other body of water

Weaning—the end of the lactation period; the process of changing from milk to a solid diet in juvenile mammals

Wetland—an area inundated by water frequently enough to support vegetation that requires saturated soil conditions for growth and reproduction; generally includes swamps, marshes, springs, seeps, or wet meadows; they can be freshwater or saltwater

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

Worm tubes—usually of calcium carbonate or particles of mud or sand built on submerged surface by polychaete worm

Wrasses—predominately warm-water fish represented by 20 species of the family Labridae on the Pacific west coast

Yolk-sac larvae—fish larvae which has already hatched from the egg but has not started feeding yet and still absorbs the yolk in the ventrally attached sac

Young-of- the-year (YOY)—a juvenile fish less than one year old

Zoea—an early larval stage of crabs and shrimp

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

APPENDIX A: INTRODUCTION

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Appendix A-1. Data confidence and Pacific Northwest OPAREA and Puget Sound Study Area geographic information system (GIS) maps.

The level of data confidence is dependent upon three factors: precision, accuracy, and currency. Each of these three factors are in turn affected by all the variables involved in obtaining data and putting the data into a GIS in order to display the data on a map. Following is a brief description of the three main factors and some of the subsequent variables that figure into overall level of confidence.

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

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

Pacific Northwest OPAREA and Puget Sound Study Area Map Examples	Description of Map Data	Confidence Level
Bathymetry, Sea Surface Temperature, Chlorophyll, Benthic Habitats, Critical Habitat maps, Marine Mammal and Sea Turtle Occurrence maps, Maritime Boundaries	Data from original/reliable sources. Provided in a digital format with geographic coordinates given. Identified as "*source data*" in map captions.	**High** 101 maps (81% of total number of maps)
Circulation, Ferry Routes, Marine Managed Areas, Dive Sites, EFH maps (majority)	First- or second-hand data sources. Locations obtained through scanning geo-referenced* maps. Identified as "*source map(s) scanned*" in map captions.	**Medium** 17 maps (14% of total number of maps)
Migration maps, Fisheries, EFH maps (minority)	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** 7 maps (5% of total number of maps)

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

Appendix A-2. Map projections.

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

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

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

Appendix A-3. Overview of research efforts that provide occurrence information for marine mammals and sea turtles in the Pacific Northwest OPAREA and Puget Sound Study Area.

To subjectively determine the areas of occurrence for marine mammals and sea turtles in the Pacific Northwest OPAREA and Puget Sound Study Area, attempts were made to compile available records from aerial and shipboard survey sightings, strandings, incidental fisheries bycatch, taggings, pinniped haulout sites, and miscellaneous/opportunistic encounters. The following is intended to be a review of the many comprehensive research efforts conducted and/or sponsored by federal, state, and academic institutions directed to the marine mammal and sea turtle species in the region. For a variety of reasons, it was not possible to obtain every data source in existence; however, a large number of data sets were collected (**Table A-1**). Comprehensive data sources that were available for inclusion in this MRA are described below. The occurrence polygons were based on both the aerial and shipboard survey (on-effort) data as well as known habitat preferences of individual species in the Pacific Northwest.

Although research on marine mammals was limited until the passage of the Marine Mammal Protection Act (MMPA) of 1972, systematic surveys of the Pacific Northwest have been conducted since the early 1900s (Everitt et al. 1979). Following passage of the MMPA, numerous studies were initiated to survey the marine mammals of the northeast Pacific Ocean and inland waters of the Pacific Northwest (e.g., Johnson 1974). For a complete history of the earlier survey efforts of the region, refer to Everitt et al. (1979).

Aerial and Shipboard Surveys

Aerial and shipboard surveys constitute a majority of the marine mammal data collected for this MRA. Henwood and Epperly (1999) and Forney (2002) provide brief descriptions of how aerial and shipboard surveys are conducted. Aerial or shipboard observers collect line-transect data during daylight hours, weather permitting (i.e., no rain, Beaufort sea state <5). Surveys are conducted along pre-designated transect lines following established sampling methods that allow for abundance estimates in an area of interest. Any animal sightings that occur while the observation platform (e.g., ship or plane) is traveling along the transect line and observers are actively searching for animals are noted as “on-effort” sightings, and can be included when estimating abundances and/or densities in an area. Any animal sightings that occur while the observation platform is diverted from or in transit to the transect line are recorded as “off-effort” sightings. It should be noted that aerial and shipboard surveys have been conducted throughout the Pacific Northwest OPAREA and Puget Sound Study Area, although survey effort is non-existent in waters of the OPAREA that are furthest offshore (**Figures A-1** and **A-2**). In addition, very few offshore surveys have been conducted in British Columbia waters just north of the Pacific Northwest OPAREA, which likely accounts for the small number of sightings reported for the region (Willis and Baird 1998). The Pacific Northwest OPAREA has been surveyed much more intensely during the upwelling period (April to September; **Figure A-1**) than during the relaxed period (October to March; **Figure A-2**).

➢ Aerial Surveys

The typical goal of an aerial survey is to estimate the overall density or abundance of a given marine mammal or sea turtle population. Aerial surveys are appropriate when little is known about the distribution and abundance of a population or species over relatively large areas. Such surveys help identify “hot spots” for future studies. Surveys can then be conducted to monitor trends in seasonal or annual variations in distribution and abundance patterns. Aircraft are also used in fine-scale surveys over a subregion of a study area.

- Aerial line transect surveys have been conducted from late summer and early autumn beginning in 1986 by **NMFS-SWFSC**. In each survey year, 26 transects from Point Conception, CA to the Russian River, CA were replicated as often as permissible by the local weather to monitor harbor seals in central California. Beginning in 1989, 17 additional transects, running from the Russian

Table A-1. Inventory of the marine mammal and sea turtle data sources included in the MRA for the Pacific Northwest OPAREA and Puget Sound Study Area.

DATA SOURCE	RECORD DATES
Aerial Surveys	
NMFS-SWFSC California coastal cetacean surveys	1991-1992
NMFS-NMML Delphinid aerial surveys in Oregon and Washington offshore waters	1992
NMFS-NMML Marine mammal aerial surveys off OR, WA, and southern BC	1997, 2002-2003
NMFS-NMML coastal cetacean aerial surveys off northern Washington	1998-1999
OSPR surveys	1994-1997
Shipboard Surveys	
NMFS-SWFSC California marine mammal survey (CAMMS)	1991
NMFS-SWFSC Population of *Delphinus* stocks (PODS) surveys	1992-1993
NMFS-SWFSC Oregon, California, and Washington line-transect expeditions (ORCAWALE)	1996, 2001
NMFS-NMML Marine mammal small boat surveys off OR, WA, and southern BC	2002-2003
Oregon/Washington *Miller Freeman* cruise	1989
Marine mammal abundance in the Olympic Coast National Marine Sanctuary	1995-1998, 2000, 2002
Cascadia USGS ship surveys	1998-2003
Harbor porpoise surveys in the Juan de Fuca and Haro Straits	2001-2002
Aerial and Shipboard Surveys	
Oregon/Washington marine mammal surveys	1989-1990
Strandings	
NMFS-SWR California marine mammal stranding network database	1994-2004
NMFS Oregon and Washington stranding database	1994-2004
NMFS-SWR sea turtle stranding records	1994-2004
NMFS-NWR sea turtle stranding records	
Incidental Fisheries Bycatch Records	
California/Oregon drift gillnet fishery	1990-2003
California set gillnet fishery	1990-2000
Mixed/Miscellaneous Data Sources	
North Pacific right whale database	1900-1999
NMFS platforms of opportunity (POP) database	1989-1997
British Columbia cetacean sightings network	1956-2005
Central/northern California low-altitude birds and marine mammals surveys	1980-1983
Central/northern California high-altitude marine mammal surveys	1980-1983
Cascadia Photo-ID database of Humpback whales	1986-2005
Cascadia Photo-ID database of Gray whales	1991-2005
USGS sea otter occurrence records	1995-2005
Structure of populations, levels of abundance and status of humpback whales (SPLASH)	2004
Published Literature and Reports	
Anonymous[1]	2005
Baird and Stacey	1988
Baird and Stacey	1989
Baird and Stacey	1991
Baird and Stacey	1993
Balcomb	1973
Braham	1983
Calambokidis and Osmek	1998
Dawson et al.	1998

Table A-1. Continued.

DATA SOURCE	RECORD DATES
Published Literature and Reports (continued)	
Ferrero and Tsunoda	1989
Ferrero et al.	1994
Fiscus and Niggol	1965
Ford et al.	2005
Jeffries et al.	2000
Joyce et al.	1982
Keple	2002
Lamont-Doherty	2004
Lance et al.	2004
Leatherwood and Walker	1979
Leatherwood et al.	1989
MacLean and Koski	2005
McAlpine et al.	2002
McAlpine et al.	2004
Mitchell[2]	2005
Mitchell and Houck	1967
Miyashita	1993
Osborne and Ransom	1988
Osborne et al.	1988
Pike and MacAskie	1969
Pitman and Dutton	2004
Reeves and Mitchell	1993
Rice	1968
Rice et al.	1986
Roest et al.	1953
Shepherd	1932
Slipp and Wilke	1953
Stacey and Baird	1991
Stacey and Baird	1997
Stinson	1984
Stroud	1968
Sullivan and Houck	1979
Willis and Baird	1998

River north to the California-Oregon border were surveyed up to three times each field season to monitor more northern populations (Forney 1999). Transects followed a zigzag pattern to systematically survey the area from the coast to the 92 m isobath (Barlow 1988). Total transect length was 916 km and could be covered over a period of two days, weather permitting (Forney 1999).

- During March through April 1991 and February through April 1992, the **NMFS-SWFSC** conducted line-transect **California coastal cetacean surveys** (Carretta and Forney 1993; Forney and Barlow 1993; Forney et al. 1995; Forney and Barlow 1998). The study area was bounded by the U.S./Mexico border in the south and extended out to approximately 280 km offshore off southern California. These aerial surveys were conducted in conjunction with shipboard surveys to obtain winter abundance estimates for cetacean species commonly found in California's coastal waters.

- In 1992 **NMFS-NMML** conducted a follow up to the general **Delphinid Aerial Surveys in Oregon and Washington Offshore Waters** from 1989 to 1992 (see Brueggeman 1992). This follow up survey was conducted to obtain sufficient data to estimate the population size of Pacific white-sided and Risso's dolphins in the region (Green et al. 1993). Aerial surveys were conducted in a

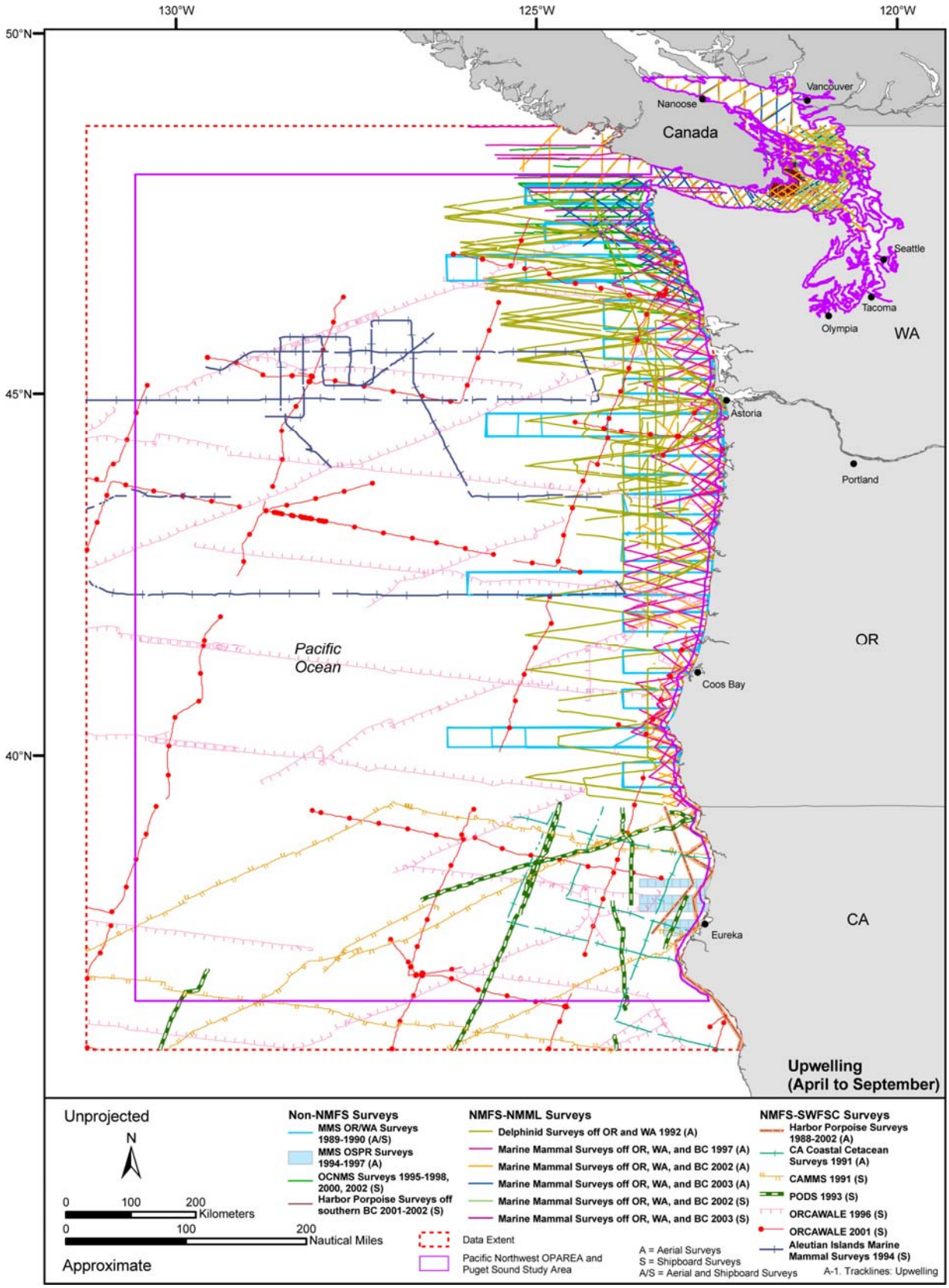

Figure A-1. On-effort tracklines and survey grid blocks for aerial and shipboard surveys conducted in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity during the upwelling season (April through September). Source data: refer to Table A-1.

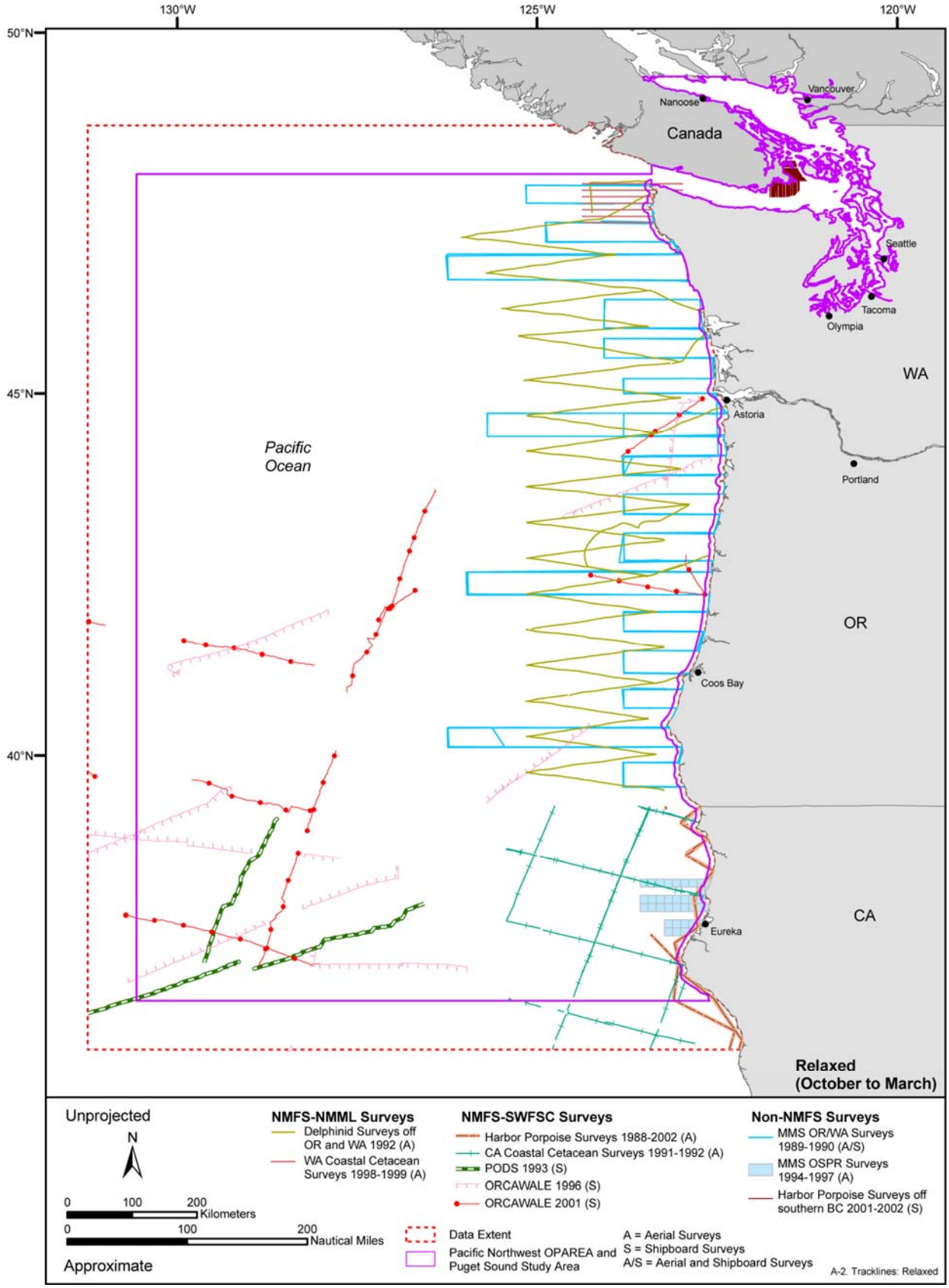

Figure A-2. On-effort tracklines and survey grid blocks for aerial and shipboard surveys conducted in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity during the relaxed season (October through March). Source data: refer to Table A-1.

sawtooth pattern from Cape-Flattery, WA to the Oregon-California border between the 200 m isobath and 111 km offshore of the 200 m isobath.

- In 1997, 2002, and 2003, the **NMFS-NMML contracted Cascadia Research** to fly marine mammal aerial surveys off the coasts of Oregon, Washington State, and southern British Columbia (from roughly 47 to 50.5°N). The purpose of these line transects was to determine the abundance of harbor porpoise and other marine mammals and to compare results with small boat surveys performed concurrently in the area (Chandler and Calambokidis 2003a, 2003b).

- From November 1998 through January 1999, the **NMFS-NMML** conducted aerial surveys off the northern Washington coast in response to questions about the location and times of the southbound migration of gray whales through the region (Shelden et al. 2000). The survey covered eight transects spanning from Cape Flattery to Carroll Island with each transect running from the shore to a distance of 55.6 km offshore.

- Patterns of leatherback turtle abundance and distribution off central California were recorded on aerial line-transect surveys conducted by **NMFS-SWFSC** during the late summer and fall months of 1990 to 2001 from Point Conception to the California-Oregon Border (Benson et al. 2003). Attempts to obtain this data were unsuccessful.

- A pilot study to survey sea turtles off the coast of Washington State and Oregon was conducted by Scott Benson **NMFS-SWFSC**. Only one leatherback was encountered off the coast during the month of October (Dutton, P.H., NMFS-SWFSC, pers. comm., 5 October 2005)

- The **Oil Spill Prevention and Response (OSPR) Surveys** were conducted as part of a larger program funded by the California Department of Fish and Game (CDFG) and California Office of Spill Prevention and Response (OSPR). These surveys were initiated to maintain readiness for oil spill response.[1,2] Aerial surveys were conducted throughout the year to ensure that trained and experienced aerial observers were available should an oil spill occur in the offshore waters of California. Surveys were flown at an altitude of 60 m above ground level and at a typical air speed of 90 knots. Two observers searched a corridor of 50 m on each side of the aircraft. Species, numbers, behavior and other information was described, and date, time, and position of the aircraft were recorded. Data collected from surveys conducted between 1994 and 1997 were provided by the **MMS** for inclusion in this report.[1]

➢ **Shipboard Surveys**

Shipboard surveys are designed to collect data to address many informational needs. To meet the mandate established in Section 117 of the MMPA, the NMFS must prepare, in consultation with regional Scientific Review Groups, stock assessment reports for each marine mammal stock that occurs in U.S. waters. These stock assessment reports contain a description of the stock, information on its distribution, as well as a minimum population estimate (Wade and Angliss 1997). One of the primary ways the NMFS collects marine mammal population data to use in stock assessment reports is from shipboard surveys.

The NMFS is also responsible for assessing and monitoring sea turtle stocks, which requires distribution and population estimates for determination of the status of stocks in relation to past and future human activities. While shipboard surveys are not the optimal survey technique to estimate sea turtle population sixes, sighting records from shipboard surveys often provide valuable information that can be used to determine distribution and life history patterns.

- From 1965 through 1975, **NOSC shipboard surveys** covered the area from Point Conception south to the tip of Baja California, sampling each quarter of the year; and from San Diego to Kodiak, Alaska in April (Dahlheim et al. 1982; Leatherwood et al. 1984). Cruises were conducted year round, but principal effort was during the winter and spring within 185 km of the coast

(Leatherwood et al. 1984). Northern right whale dolphin data from these surveys were listed in Leatherwood and Walker (1979) and are included in this report.

- During 1967 and 1968, the **Pacific Ocean Biological Survey Program of the Smithsonian Institution** conducted at least 45 ship surveys in various portions of the North Pacific (Leatherwood and Walker 1979). Of those cruises, 19 surveyed some portion of the area from the Mexican border to waters off British Columbia. Surveys covering some portion of the waters from 25°N to 40°N and up to 741 km offshore were conducted at least once every quarter and almost every month of the year (Leatherwood and Walker 1979). Northern right whale dolphin data from these surveys were listed in Leatherwood and Walker (1979) and are included in this report.

- A vessel-based survey was conducted from the NOAA ship ***Miller Freeman*** in August of 1989 in an attempt to compare the assessments of marine fauna distribution and abundance in shelf waters with those collected via aerial surveys. Thirty-nine east west transects (18.5 km apart) extended from the 55 m isobath to just beyond the continental shelf edge (200 m isobath). Surveys were conducted from the flying bridge, 12 m above the surface, and spanned from central California to Vancouver Island, British Columbia (Brueggeman 1992; Green et al. 1992).

- From 28 July to 5 November 1991, the **NMFS-SWFSC** conducted the **California Marine Mammal Survey (CAMMS)**, a three-month shipboard survey of cetaceans in waters off the coast of California. This survey was performed aboard the NOAA ship *McArthur* (Cruise AR-91-02, SWFSC Observer Cruise 1426) and was an attempt to determine the abundance and distribution of cetacean species that were commonly captured by drift and set gillnet fisheries in the region. The *McArthur* traversed a grid of predetermined tracklines uniformly covering California's coastal waters out to a distance of approximately 555 km offshore. A secondary set of survey tracklines encircled each of the Channel Islands at a distance of 1.85 km from shore (Hill and Barlow 1992; Barlow and Gerrodette 1996).

- Between 28 July and 6 November 1993, the **NMFS-SWFSC** conducted the **Population of *Delphinus* Stocks (PODS)** surveys along the U.S. and Mexican west coasts. The NMFS-SWFSC utilized the NOAA ships *David Starr Jordan* (Cruise DS-93-08, SWFSC Cruise Number 1509) and *McArthur* (Cruise AR-93-02, SWFSC Cruise Number 1508) for these surveys. The study area ranged from the California/Oregon border to Cabo Corrientes, Jalisco, Mexico and also included the Gulf of California. The primary purpose of these surveys was to estimate the abundance of the central stock of common dolphin. Aerial photogrammetry, photo-identification, vocalization, and genetic studies of cetaceans and pinnipeds were conducted as well (Mangels and Gerrodette 1994).

- The **NMFS-SWFSC** conducted the 1993 **Population of *Delphinus* Stocks (PODS)** surveys from the California/Oregon border southward to Cabo Corrientes, Jalisco, Mexico, extending from the coast to approximately 300 nm offshore. These surveys were conducted aboard the NOAA ships *David Starr Jordan* (Cruise DS-93-08, SWFSC Cruise Number 1509) and *McArthur* (Cruise AR-33-02, SWFSC Cruise Number 1508). The primary purpose of these surveys was to estimate the abundance of the northern stock of common dolphin and to make an estimate of its absolute abundance.

- In 1994, **NMFS-NMML** performed shipboard surveys of marine mammals on the first leg of the *Surveyor* cruise (21 July to 1 August) in an attempt to combine acoustic data with visual sightings of marine mammals (Thomason et al. 1997). Approximately 2,400 km were surveyed off the coasts of Oregon and Washington State spanning the area from the continental shelf to 400 km offshore. Data related to the visual sightings of marine mammals encountered throughout the cruise are included in the MRA. These data were provided by Jay Barlow of the **NMFS-SWFSC**.

- Ship surveys were conducted over a two-week period in late-June and July 1995, 1996, 1997, and 1998 aboard the NOAA ship ***McArthur*** and in 2000 aboard the naval ship ***Agate Passage*** to

understand marine mammal distribution and abundance in the newly designated Olympic Coast National Marine Sanctuary, as well as to collect information on seabirds, oceanographic conditions, and juvenile fish. In mid-June 2002, a shorter, one-week survey was done. These cruises followed tracklines originally established by the NOAA ship *Miller Freeman* in 1989 (Calambokidis et al. 2004).

- During 1996 and 2001, the **NMFS-SWFSC** performed the **Oregon, California, and Washington Line-Transect Expeditions (ORCAWALE)**. These surveys were conducted off the coasts of California, Oregon, and Washington State to a distance of approximately 556 km offshore. The purpose of these surveys was to determine the distribution and estimate the abundance of cetaceans commonly found off the U.S. west coast. In addition, biological and oceanographic data were collected to better characterize the animals' environment. The 1996 cruise consisted of two 30-day legs aboard the NOAA ship *David Starr Jordan* and three 30-day legs aboard the NOAA ship *McArthur* (Von Saunder and Barlow 1999). In 2001, the first five legs of the cruise were conducted on the *David Starr Jordan* while the final leg was conducted on the *McArthur* (Appler et al. 2004).

    - **ORCAWALE 1996**: *David Starr Jordan* – 4 September to 4 November, Cruise DS-96-10, SWFSC Cruise Number 1605; *McArthur* – 18 July to 14 October, Cruise AR-96-07, SWFSC Cruise Number 1604

    - **ORCAWALE 2001**: *David Starr Jordan* – 30 July to 10 November, Cruise DS-01-05, SWFSC Cruise Number 1617; *McArthur* – 15 November to 8 December, Cruise AR-01-05, SWFSC Cruise Number 1619

- In 2002 and 2003, the **NMFS-NMML** conducted shipboard line transects in an attempt to coordinate shipboard sightings with ongoing aerial surveys in the offshore and inland regions of the Pacific Northwest. Unfortunately, inclement weather often prevented clean overlap. For example, observers from the NMML were on site attempting vessel surveys in the Strait of Juan de Fuca at various times from 12 to 29 August 2003 and in the San Juan Islands from 19 to 28 August 2003. Aerial surveys in the eastern Strait of Juan de Fuca occurred from 7 to 10 August 2003 and in the San Juan Islands from 13 to 19 August 2003 (Chandler and Calambokidis 2003a, 2003b).

- The ***Oshoro Maru IV*** is a ship utilized by Hokkaido University for the training of cadets and scientific expeditions in the North Pacific. The vessel, along with its predecessors, has made several travels into the waters off of Washington State, Oregon, and Alaska (Bower 2001). No attempts were made to obtain data of samples collected in U.S. waters by Japanese research vessels.

- Acoustic and visual surveys of southern resident killer whales along the outer coast was conducted during February and March 2004 aboard the NOAA ship *Surveyor* to determine the winter distribution and behavior of these whales (Norris et al. 2004). Attempts to obtain this data from the individual researchers were unsuccessful.

- The **U.S. Geological Survey** conducted seismic-reflection surveys in the waters within Puget Sound in March 1998. As a part of this project, **Cascadia Research** was contracted by the USGS to monitor marine mammals from the survey platform. The primary objective of these marine mammal surveys were to (1) help mitigate the impacts on marine mammals by providing information on the presence of any marine mammals close to the sound source (2) document the presence and number of marine mammals present in the vicinity of USGS survey operations, and (3) document reactions of marine mammals to the survey ship and sound sources (Calambokidis and Osmek 1998; Bain et al. 1999; Calambokidis et al. 2002a).

- **Aerial and Shipboard Surveys**

  - Aerial and shipboard surveys were conducted off the coastlines of Oregon and Washington State as part of the **Oregon/Washington marine mammal surveys** to determine the distribution, abundance, and habitat preferences of cetaceans, pinnipeds, sea birds, sea otters, and sea turtles. Twelve aerial surveys were conducted along over 40,000 km of systematic tracklines between April 1989 and September 1990. One additional aerial survey, targeting gray whales, was conducted in May 1990 along 2,555 km of trackline (Brueggeman 1992). A concurrent shipboard survey, conducted on the NOAA vessel *Miller Freeman* during August 1989, was undertaken to survey the coastal regions off the coastline of Oregon and Washington State.

Strandings

- Marine mammal stranding networks are under the jurisdiction of the NMFS and are nominally based on the administrative regions of the NMFS (Geraci and Lounsbury 1993). Wilkinson and Worthy (1999) discuss the genesis of marine mammal stranding networks in the U.S. Legal authority for U.S. stranding networks is contained in the MMPA. In the Marine Mammal Health and Stranding Response Act (in the 1992 Amendments to the MMPA), Congress made it a national policy to monitor the various factors affecting the health of marine mammal populations. Collection and analyses of stranded marine mammals have contributed much to what is known about each species (Becker et al. 1994).

  - The California Marine Mammal Stranding Network (CMMSN), which is coordinated and managed by the **NMFS-SWR**, responds to all cetacean and pinniped strandings in the state of California (Seagars 1991). The **California Marine Mammal Stranding Network Database** was received from Mr. Joe Cordaro, Southwest Regional Stranding Coordinator with the NMFS-SWR. Over 560 stranding records for the northern California area during 1994 through 2004 were included in this data set. Approximately half of the stranding locations were available in coordinate (latitude/longitude) form; the remaining strandings were provided as locality descriptions (e.g., beach, street, or landmark location).

  - Strandings from Oregon and Washington State (the Northwest Region Marine Mammal Stranding Network) are also compiled in a National Stranding Database managed by **NMFS**. Strandings of marine mammals were received from Dr. Stephanie Norman, **NMFS-NWR**. Approximately 4,000 stranding records for the Oregon and Washington State regions during 1994 through 2004 were included in this data set. Only 3% of the stranding locations were available in coordinate (latitude/longitude) form; the remaining strandings were provided as locality descriptions (e.g., beach, street, or landmark location).

- Sea turtle strandings in California are reported to the California Sea Turtle Stranding Network, which is under the administration of the **NMFS-SWR**. Mr. Joe Cordaro, who also maintains the NMFS-SWR stranding database for marine mammals, provided **sea turtle stranding records** from 1994 to 2004. A total of 3 sea turtle strandings occurred in northern California over this time span. Stranding locations were available as locality descriptions.

- Strandings of sea turtles in Oregon and Washington State were provided by the **NMFS-NWR** strandings coordinator, Mr. Brent Norberg. Of the 62 sea turtle strandings reported from 1958 to 2004, 51 provided sufficient geographical detail to accurately depict the location of the stranding in this MRA.

Incidental Fisheries Bycatch

The NMFS has been using observers to record catch and incidental bycatch data aboard U.S. commercial fishing and processing vessels since 1972. The National Observer Program (NOP), which

collects information on incidental bycatch of marine mammals, sea turtles, and seabirds, was established under the authority of the Marine Mammal Protection Act of 1972, the Endangered Species Act of 1973, and the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (Carretta et al. 2005). Observers employed under this program have monitored fishing activities along all U.S. coasts and have collected data for a range of conservation, management, compliance, and economic issues.[3] Observers are required to complete sighting forms, document the circumstances of capture, and obtain biological data (e.g., measurements) on incidentally captured marine mammals and sea turtles.

A number of studies have been undertaken to reduce fishery bycatch along the Pacific Northwest. These studies involve equipping fishing nets with acoustic alarms in an attempt to prevent marine mammals (primarily harbor porpoise) from becoming entangled (Gearin et al. 1994; Gearin et al. 2000).

Included in this MRA are bycatch records from the California/Oregon drift gillnet fishery and the California set gillnet fishery for both marine mammals and sea turtles. These data were received from the NMFS-SWFSC, which uses data collected by the NOP to estimate amount of bycatch and produce technical reports.

- In July 1990, the NMFS-SWR Fisheries Observer Branch began fielding mandatory observers aboard drift gillnet fishing vessels that were targeting swordfish and thresher sharks off the coasts of California and Oregon. Incidental bycatch records of cetaceans and pinnipeds from the **California/Oregon drift gillnet fishery** span 1990 to 2003.

- In July 1990, the NMFS-SWR Fisheries Observer Branch also began placing mandatory observers on vessels in the set gillnet fishery that were targeting California halibut, angel shark, white seabass, soupfin shark, and yellowtail. Incidental bycatch records of pinnipeds and cetaceans from the **California set gillnet fishery** were available for the years of 1990 to 2000, which is when the observer program for this fishery was suspended.

Native tribes also collect and report any fisheries bycatch. However, due to the sensitive relations between the U.S. government and the tribal nations, this data could not be pursued for inclusion in the MRA.

Mixed/ Miscellaneous Data Sources

- The **North Pacific Right Whale Database** is a review of all available 20th and 21st century records of this species in the North Pacific Ocean. There have been a total of 1,965 recorded sightings since 1900; of these 988 came from the western North Pacific, 693 from the eastern North Pacific, and 284 had no location specified. Thirteen strandings (all but one from the western North Pacific) were recorded. Known catches for commercial or scientific purposes totaled 742 (331 in the western North Pacific, 411 in the eastern North Pacific). Overall, the data support the hypothesis that at least two stocks of right whales exist in the North Pacific (Brownell et al. 2001). This database was provided by Ms. Caroline Good (Duke University) with the permission of Dr. Phillip Clapham (NMFS-Alaska Fisheries Science Center). An updated database has been prepared, but was not received for inclusion in the report.

- In collaboration with the **Minerals Management Service**, the **Center for Marine Studies** of the University of California, Santa Cruz conducted monthly aerial transect surveys of offshore waters from 1980 to 1983 to describe pinniped, sea otter, seabird, and sea turtle occurrence from Point Conception, CA to the California-Oregon border (Bonnell et al. 1983; Center for Marine Studies 1983b, 1983a). The purpose of this study was to collect and analyze data that could be applied to the process of assessing, predicting, and mitigating the impact upon these animals which might result from oil and gas development in the central and northern California outer continental shelf (Bonnell et al. 1983). Both low-altitude (61 m above sea level) and high-altitude (300 m above sea level) aerial transect surveys, were conducted on a monthly basis (Bonnell et al. 1983; Dohl et al. 1983); 36 surveys were completed over the three-year period.

- Sightings were collected onboard British Columbia ferry vessels from April 2000 through May 2001 as research for the Masters thesis of Alison Keple (Keple 2002). During these surveys, harbor seals, California sea lions, Dall's porpoise, Steller sea lions, Pacific white-sided dolphins, harbor porpoise, killer whales, gray whales, and a minke whale were reported. Raw data received from Ms. Keple could not be decoded and attempts to obtain alternate data sets from Ms. Keple and NMFS-NMML were unsuccessful. Graphical representations of data in Ms. Keple's thesis were not of a scale that could be used for precise locations in the MRA.

- The objective of the Structure **of Populations, Levels of Abundance, and Status of Humpback whales (SPLASH)** 2004 cruise was to locate, collect data on and understand the distribution of humpback whales in the waters of western Canada, the Gulf of Alaska, Aleutian Islands, and Bering Sea (NMFS-SWFSC 2005). The project was a portion of a large international project (SPLASH) designed to estimate the abundance and determine the population structure for humpback whales throughout the North Pacific involving the governments of Canada and Mexico as well as multiple agencies within the government of the U.S. The primary study methods were photo-identification and biopsy sampling. Passive acoustics were used to aid in finding aggregations of whales. In addition, biological and oceanographic data were collected to better characterize the whale's environment, and survey data were collected for all other cetacean and pinniped species observed (NMFS-SWFSC 2005).

- The **U.S. Global ocean Ecosystems dynamics** (**GLOBEC) program** seeks to determine how climate change and climate variability affect abundances, distributions and productivity of animals in key ecosystems of the coastal ocean. Locations of these ecosystems included the California Current System of the U.S. Pacific coast and the Gulf of Alaska (Batchelder et al. 2002; Strub and Batchelder 2002). Attempts to obtain marine mammal data collected in collaboration with the GLOBEC program (e.g., Tynan and Ainley 2004; Tynan 2005) were unsuccessful.

- The **NMFS Platforms of Opportunity Program (POP)** collects data on opportunistic sightings of marine mammals throughout the world (particularly in the North Pacific Ocean). POP sighting data are opportunistically collected aboard NOAA, Navy, and U.S. Coast Guard vessels as well as aboard commercial fishing and tourist boats.[4] The National Marine Mammal Laboratory (NMML), a branch of the **NMFS-AFSC**, assigns a species identification as either "sure," "likely," "unsure" or "not possible." Dr. Robyn Angliss of the NMML provided POP sighting data used in this MRA; these data only represent confirmed (i.e., "sure") sightings.

- A map displaying the distribution of killer whales along the Pacific coast and Puget Sound regions from 1975 to the spring of 2005 was obtained from **NMFS-NWFSC**. The scale of the map did not allow for an accurate depiction of the distribution of killer whales with respect to season. Additional attempts to obtain more precise geographical and seasonal data were unsuccessful.

- The U.S. Navy documents acoustic detections and has been recording ''biologicals,'' including blue whale calls, on their **Sound Surveillance System (SOSUS)** arrays since the system was established to track submarines in the mid-1950s (Nishimura and Conlon 2001). Since 1991 the SOSUS system has been used by **NOAA-PMEL** to investigate underwater earthquakes, volcanoes, and whale calls (Stafford et al. 1998). SOSUS data received from Dr. Kate Stafford at **NMFS-NMML** did not plot in the OPAREA and was not included in the MRA.

- Brad Hanson of the **NMFS-NWFSC** has conducted tagging surveys of Dall's porpoise of the coasts of British Columbia and Washington State (Hanson and Baird 1998; Hanson et al. 1998). Attempts to obtain raw data of these surveys were unsuccessful.

- Over the past ten years, two **sea otter occurrence records** were documented for the northern California region of the Pacific Northwest OPAREA. Mr. Brian Hatfield of the **U.S. Geological Survey (USGS)**, Western Ecological Research Center provided the locations of these records for inclusion in this MRA.

- The **Oregon Department of Fish and Wildlife (ODFW)** retain records of pinniped haul out sites along the Oregon coast. Attempts to obtain this data from ODFW were unsuccessful.

- Marine mammal research is conducted by the **Washington Department of Fish and Wildlife** (WDFW) for Washington State waters. Attempts to obtain tagging and small boat survey data were unsuccessful. Pinniped haul out data was purchased from the WDFW (WDFW 2005). Sea otter sighting data were obtained directly from the Washington State sea otter recovery plan where only total animal numbers were recorded per year with broad geographic locations (Lance et al. 2004). Additionally, records provided for Washington State and Oregon received from Deanna Lynch at USFWS were at too gross a scale for inclusion on the maps and did not include record type or seasonality information.

- The **British Columbia Cetacean Sightings Network**, a joint project of the Vancouver Aquarium and Fisheries and Oceans Canada, collects sightings of whales, dolphins, porpoises, and sea turtles from citizens along the coast. Records of strandings that occurred along the coastline from 1956 through 2005 were received from Mr. Doug Sandilands, Coordinator of the B.C. Cetacean Sightings Network.

- The **Orca Network** has been collecting and distributing individual accounts of marine mammal sightings in the Salish Sea, Puget Sound, Strait of Juan de Fuca, and Georgia Strait since 2001.[5] These data were not available electronically and were not further pursued for inclusion in this MRA.

- The **Center for Whale Research** has helped to keep tabs on three pods of killer whales in the Pacific Northwest and look for warning signs of environmental deterioration in the top predators of Puget Sound. Data from the center were not available in an electronic format and not pursued for inclusion in the MRA.

- The **West Coast Whale Research Foundation (WCWRF)** was founded in 1980 to administer, support and conduct whale research and education programs and has become instrumental in the logistics of many pioneering studies of gray whales, humpback whales and orcas on the Pacific Coast of Canada. In 2003, the Foundation changed its name to the **Pacific Wildlife Foundation**. Sighting data for gray whales in the Pacific Northwest was requested from Dr. Jim Darling; however, sighting information was not in a format compatible for inclusion in the MRA and was not further pursued.

- The **Whale Museum** has played a vital role in the Southern Resident killer whales. Data collected, compiled, and archived by the Museum has been used in several governmental studies to determine if the killer whales should receive federal protection. Rick Osborne was contacted for sighting data for inclusion in the MRA; however, data was not in a format compatible for inclusion.

- From September 2001 to August 2002, harbor porpoise distribution was surveyed in the Juan de Fuca and Haro Straits (Hall 2004). All surveys were conducted in Canadian waters only and were based out of Victoria, British Columbia. This data was obtained from Ms. Anna Hall for inclusion in the MRA.

- **Cascadia Research** scientists conduct photo-identification surveys of humpback, gray, and blue whales along the U.S. west coast. Databases identifying humback and gray whales in the region were obtained from Dr. John Calambokidis, co-founder of Cascadia Research and included in the maps produced for these species. In addition data from Cascadia Research published reports (Calambokidis et al. 2001; Calambokidis et al. 2002b; Calambokidis and Barlow 2004; Calambokidis et al. 2004) were used in this MRA.

- Commercial whaling from permanent shore stations operated in British Columbia from 1905 to 1967, and information about historic populations of large whales in B.C. waters is contained in the records from this period. Although catch records from the years 1905, 1906 and 1907 were not located, those from the years 1908 to 1967 document a catch of 24,427 whales. An intensive attempt in 1987 by the **Pacific Biological Station** to locate, compile, and electronically archive these records resulted in the development of the **B.C. Historical Whaling Database (HWD)** is an electronic resource documenting

where and when whales were caught along with biological details about these whales (Nichol et al. 2002). In this report, whaling data was added to the occurrence maps as sightings as it was reasoned that a whale must be seen prior to harvest.

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APPENDIX B: MARINE MAMMALS

LIST OF FIGURES

Figure	Title
B-1	Areas of occurrence for threatened and endangered cetaceans, excluding the SRKW, in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
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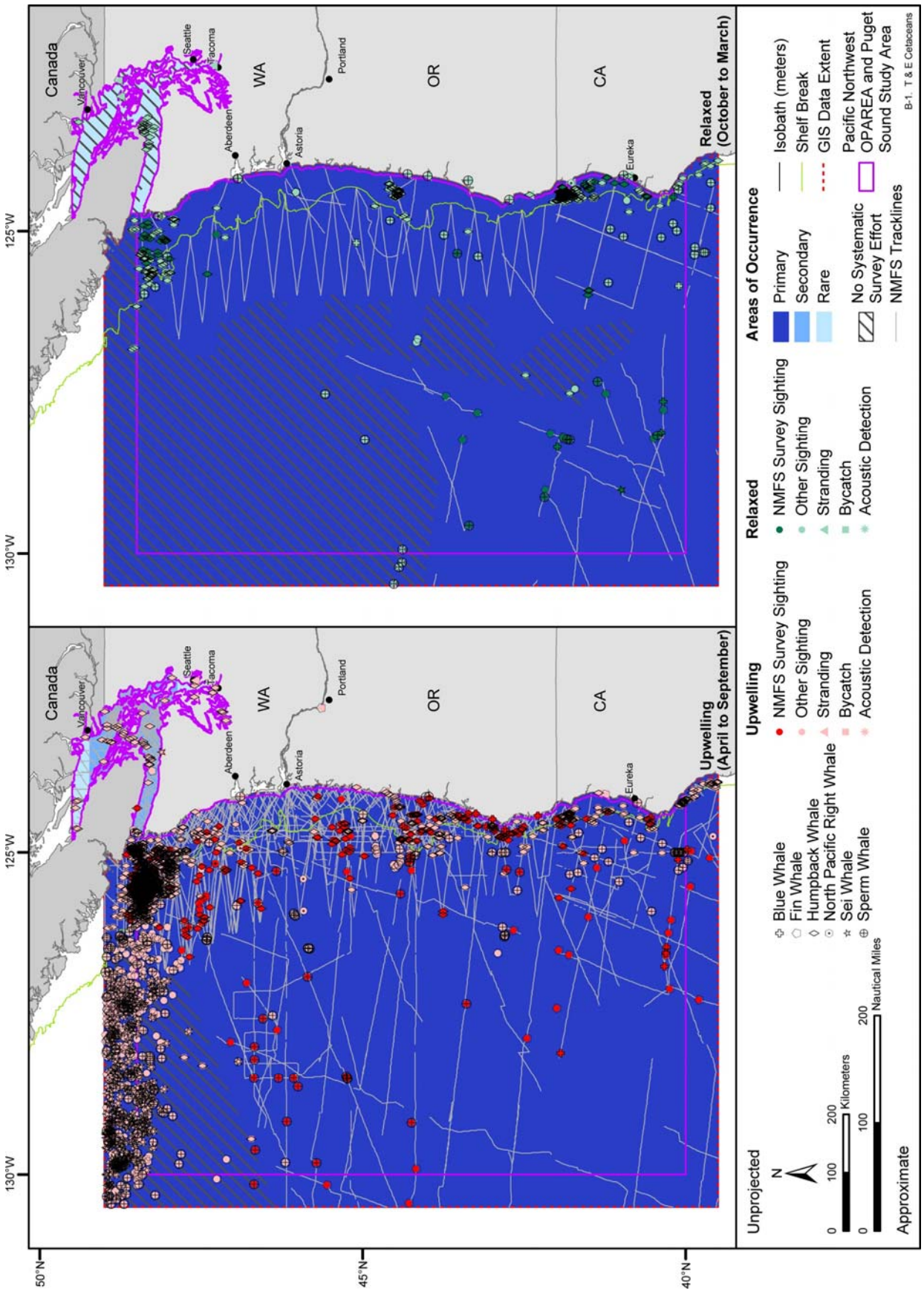

Figure B-1. Areas of occurrence for threatened and endangered cetaceans, excluding the SRKW, in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

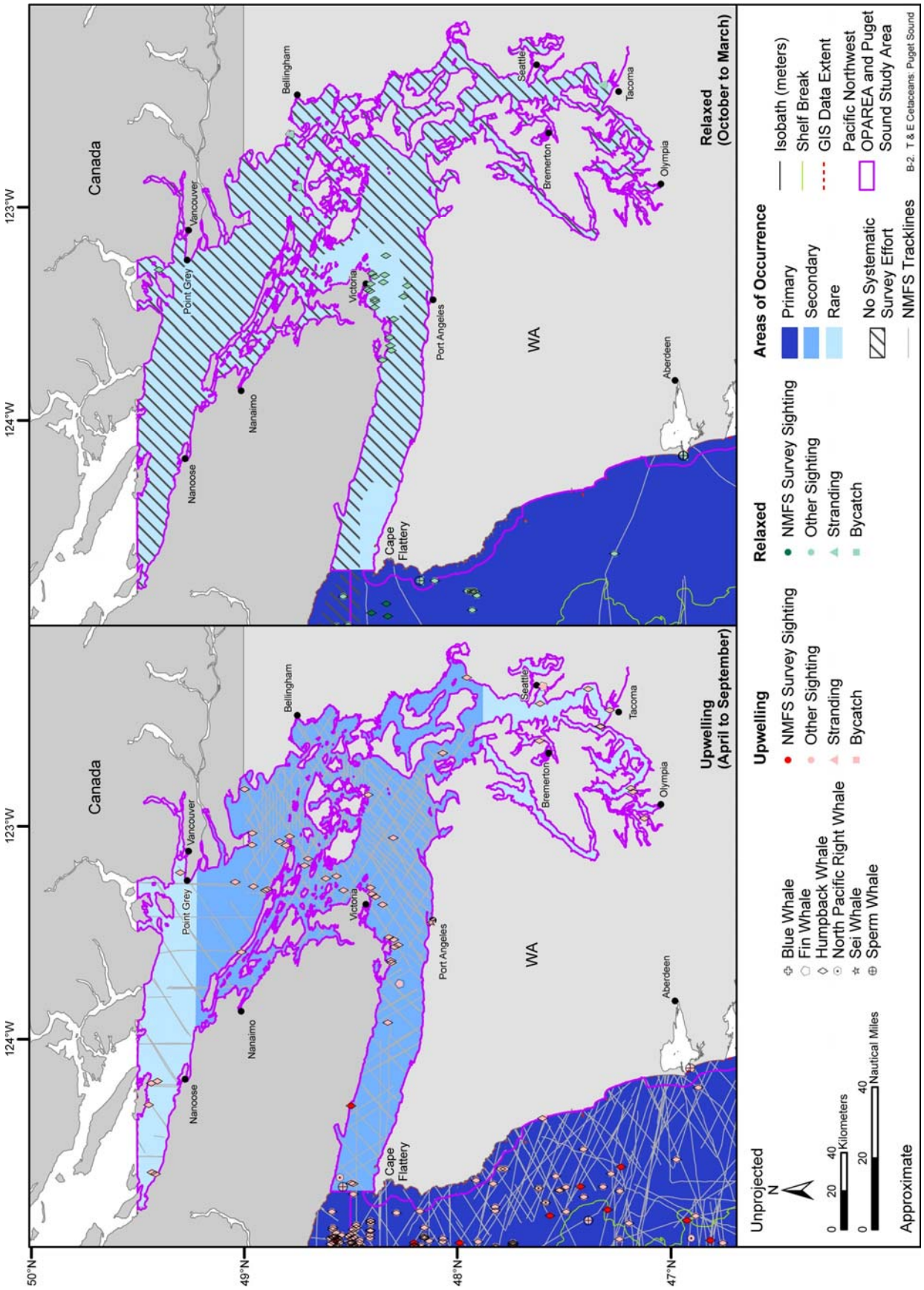

Figure B-2. Areas of occurrence for threatened and endangered cetaceans, excluding the SRKW, in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

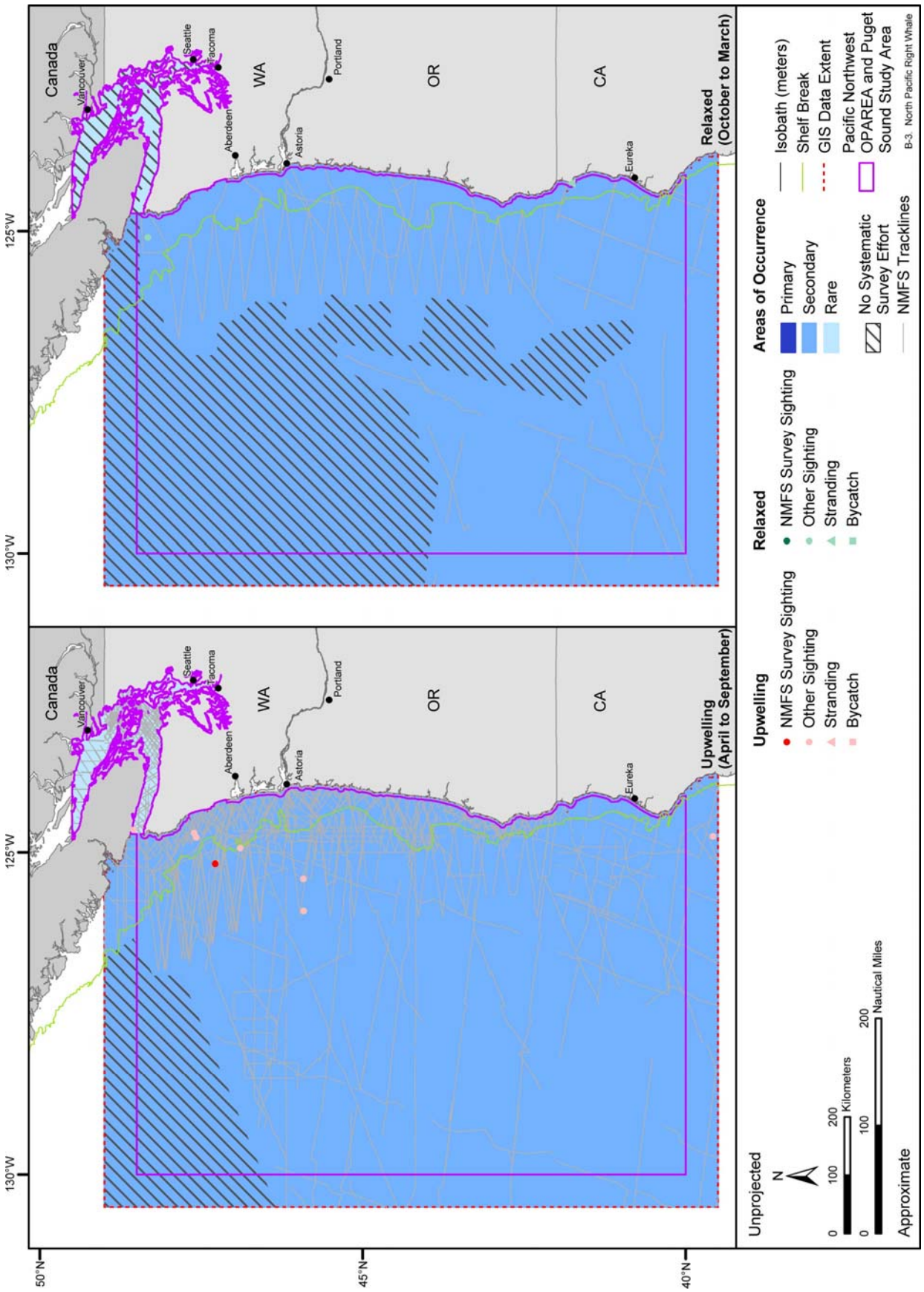

Figure B-3. Areas of occurrence for the North Pacific right whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

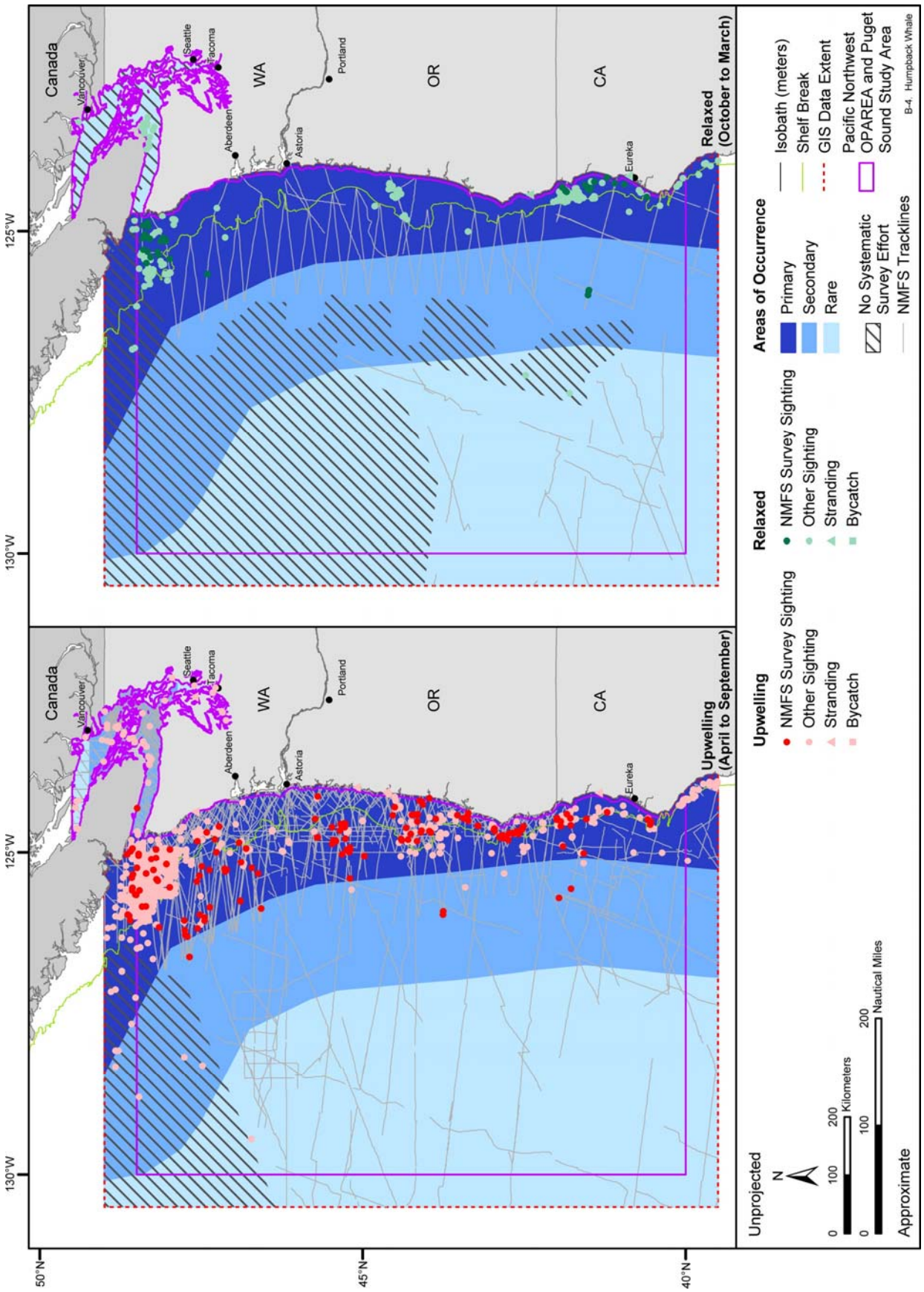

Figure B-4. Areas of occurrence for the humpback whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

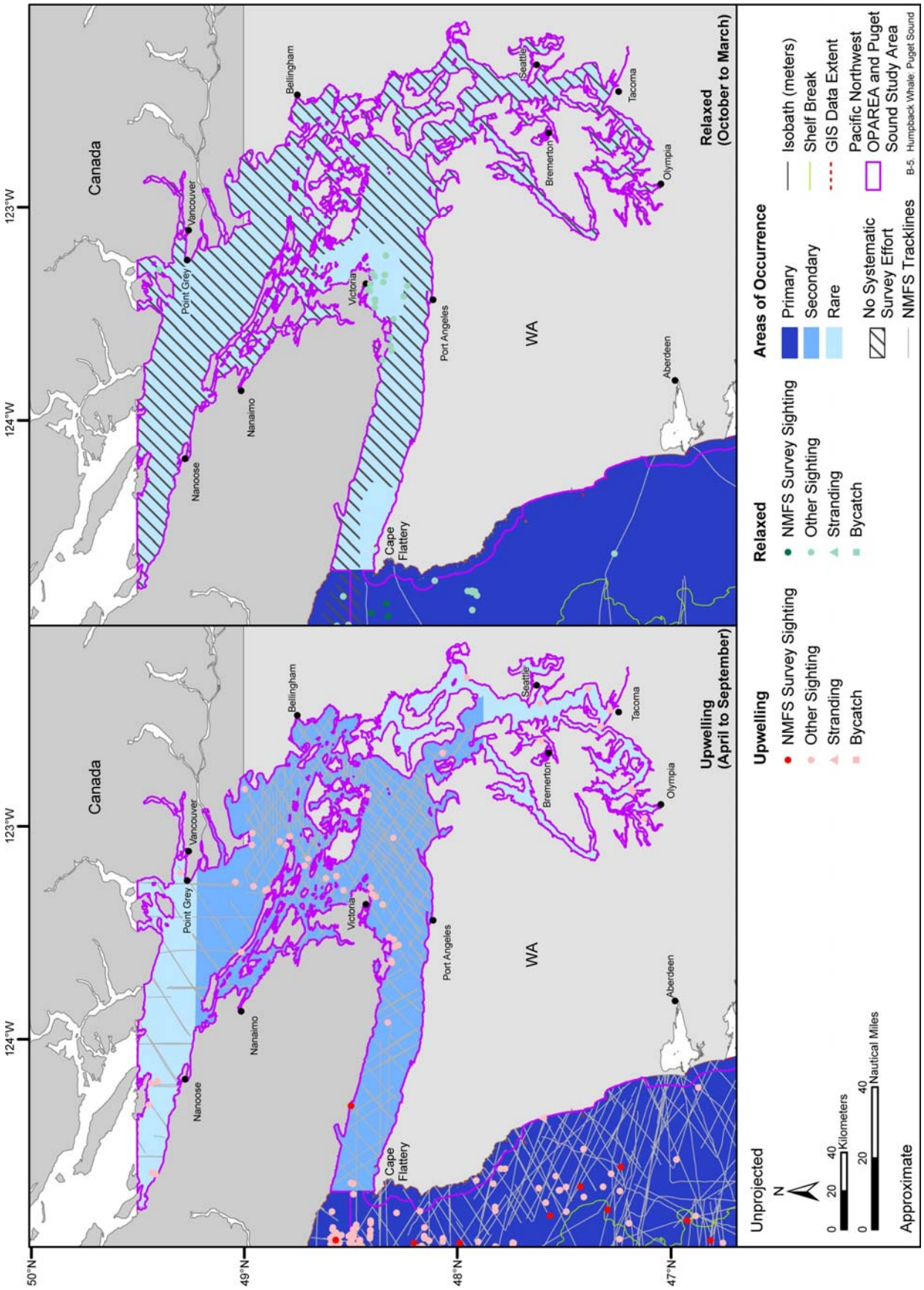

Figure B-5. Areas of occurrence for the humpback whale in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

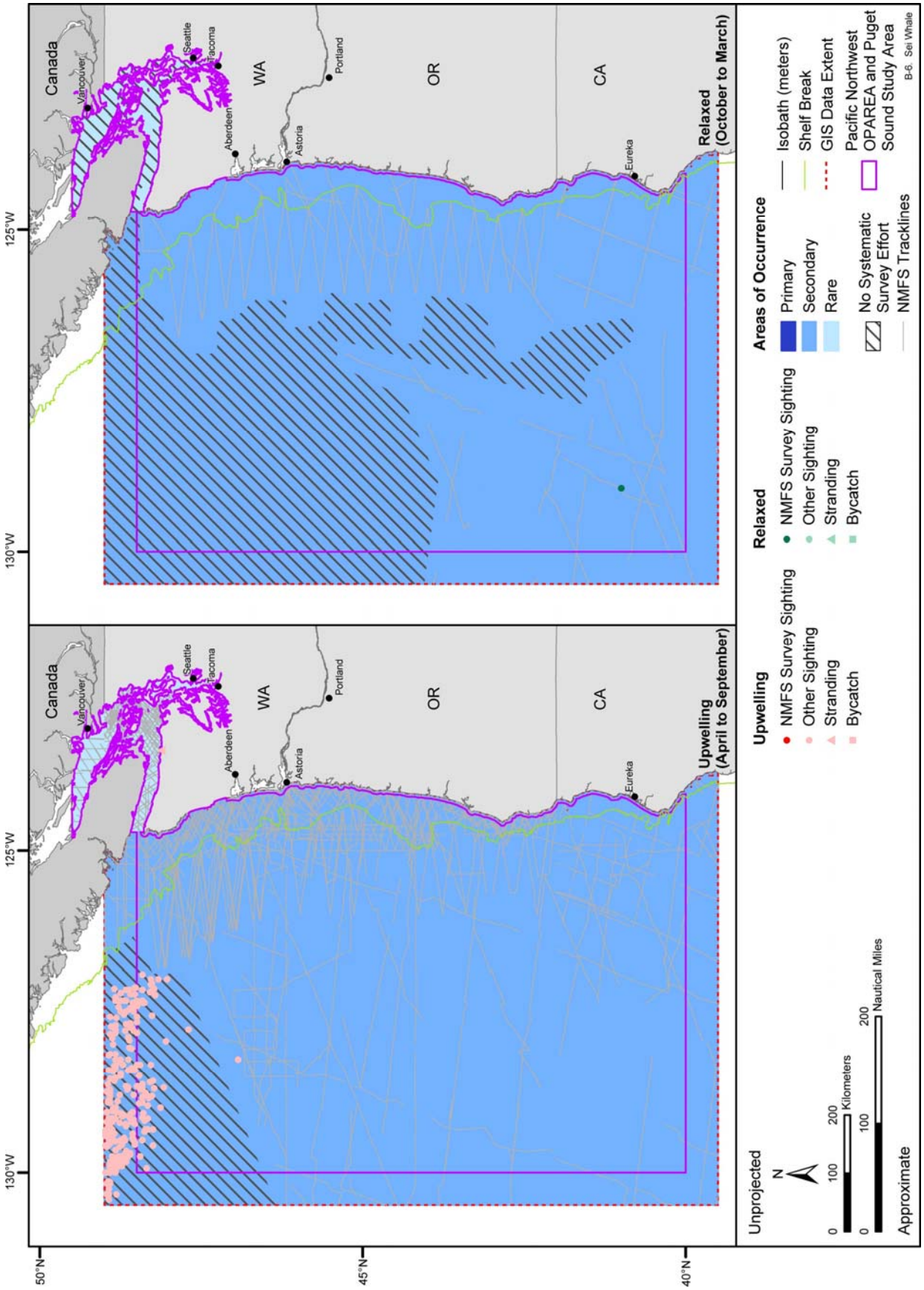

Figure B-6. Areas of occurrence for the sei whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

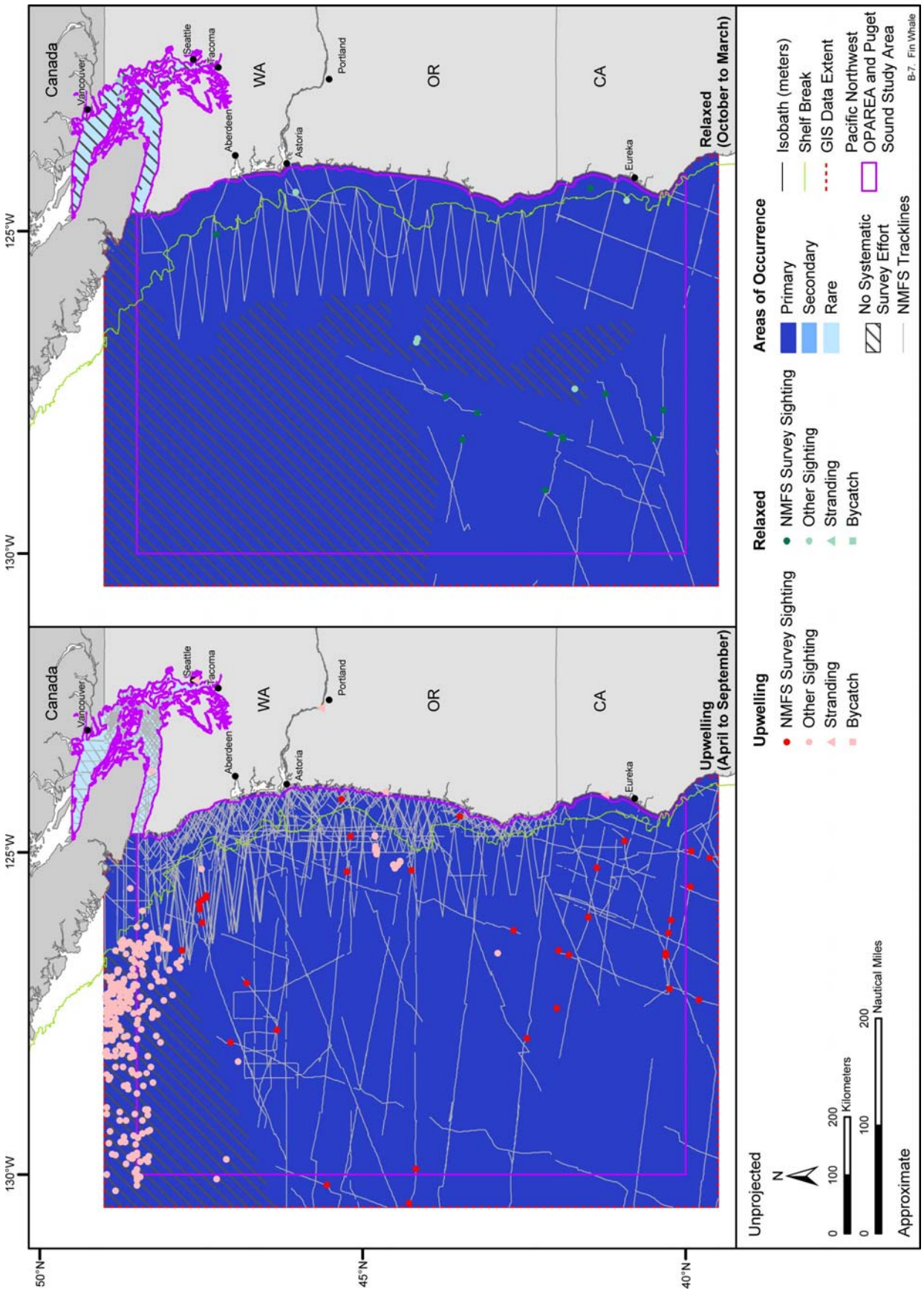

Figure B-7. Areas of occurrence for the fin whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

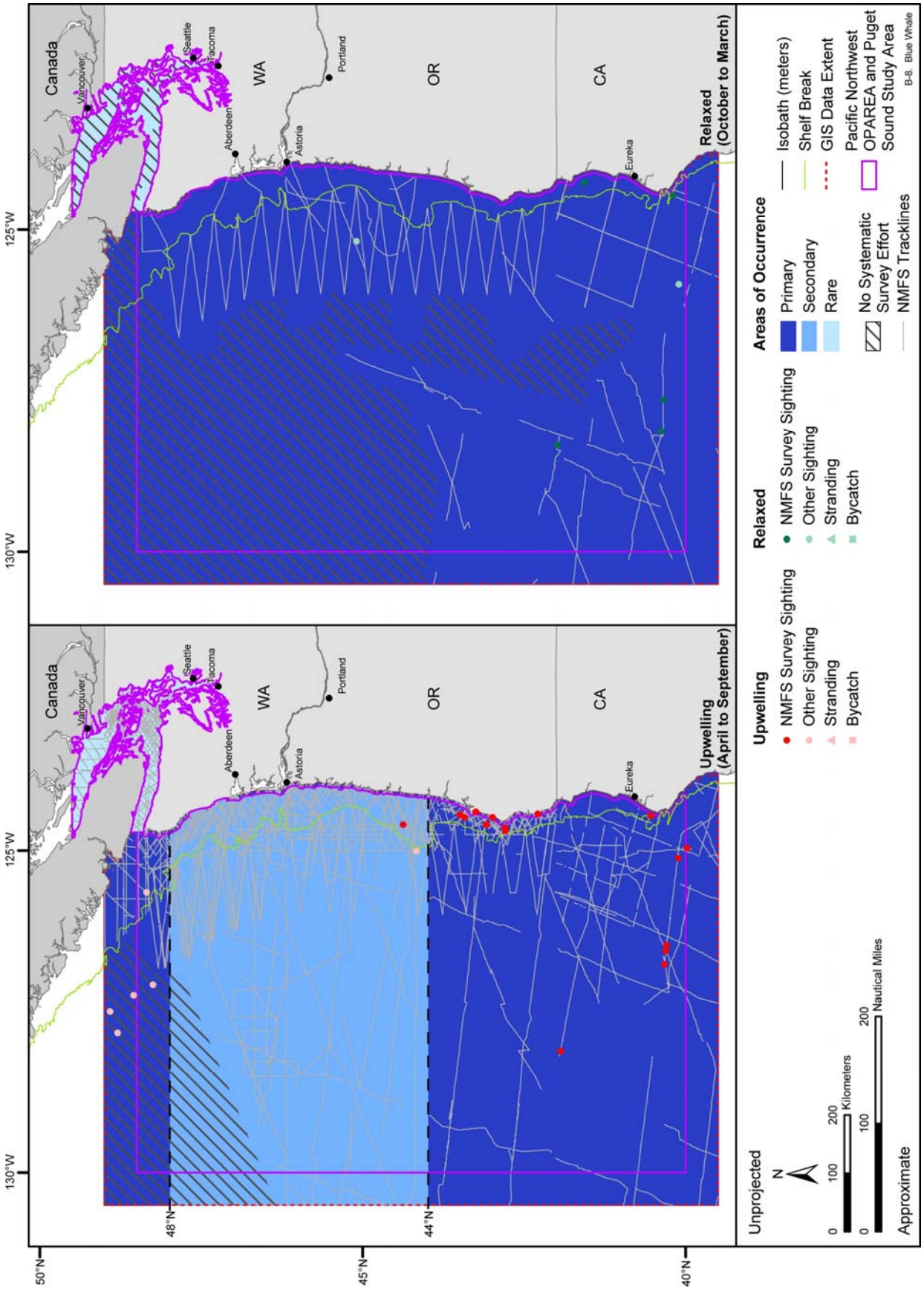

Figure B-8. Areas of occurrence for the blue whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

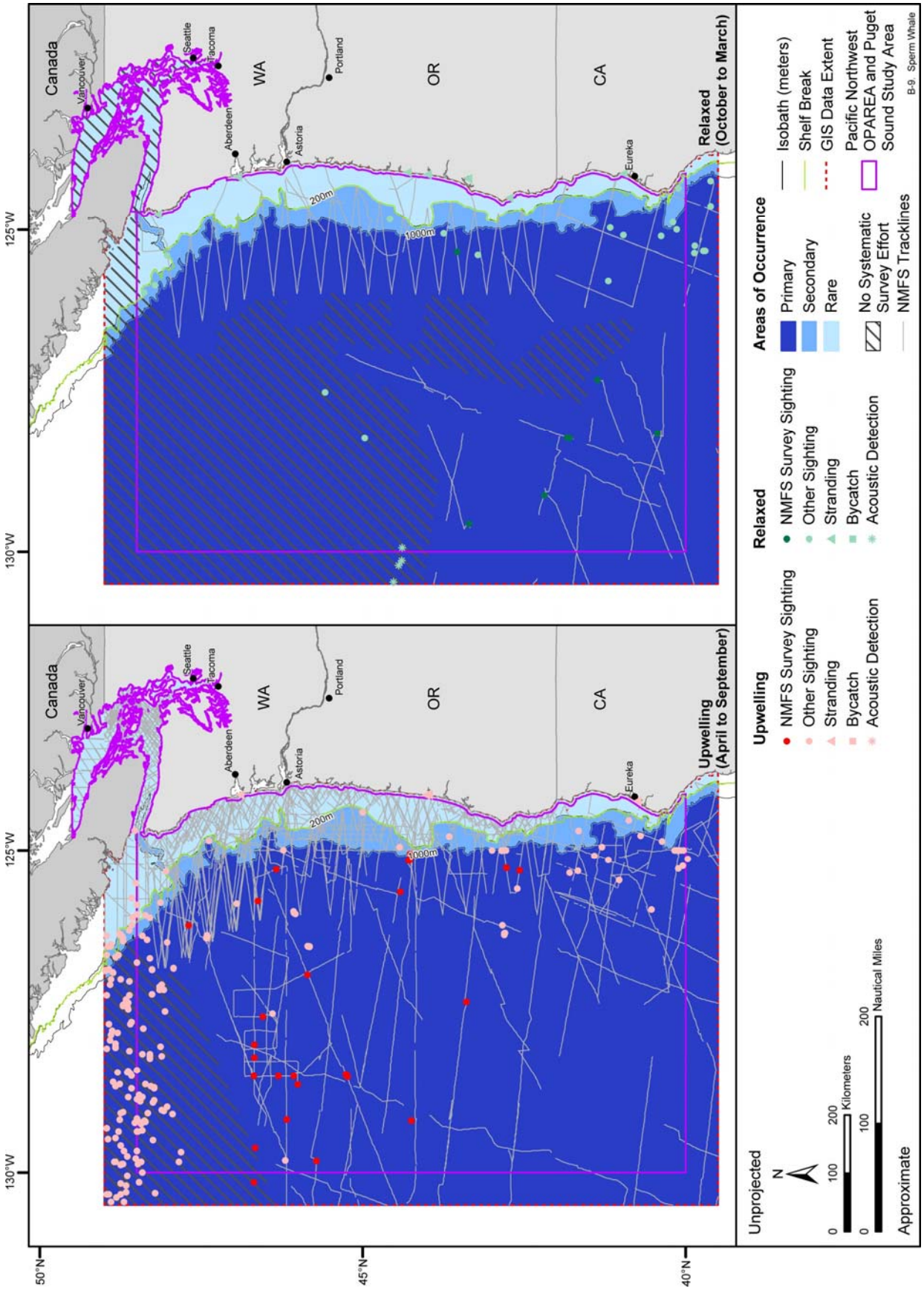

Figure B-9. Areas of occurrence for the sperm whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

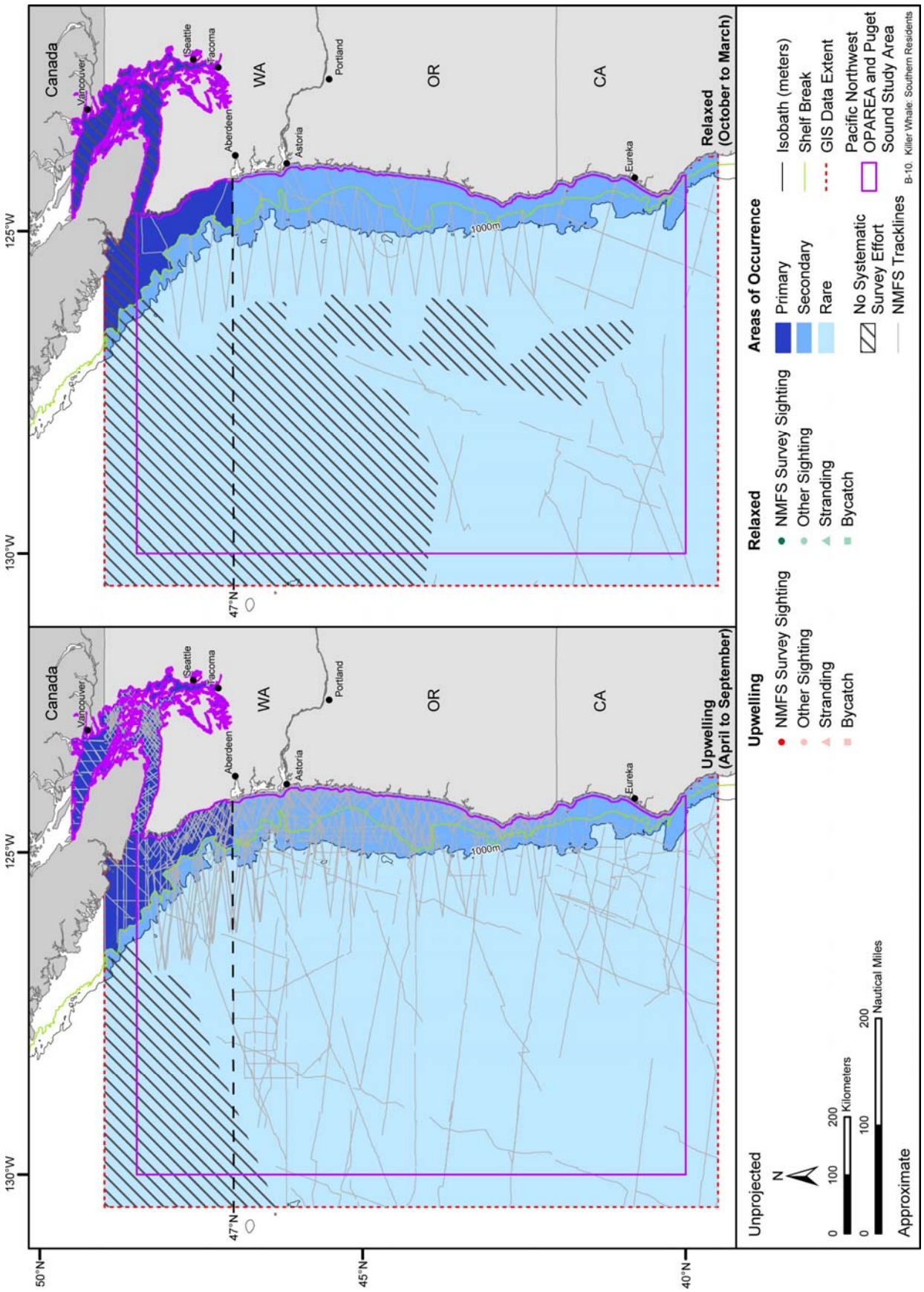

Figure B-10. Areas of occurrence for the southern resident killer whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

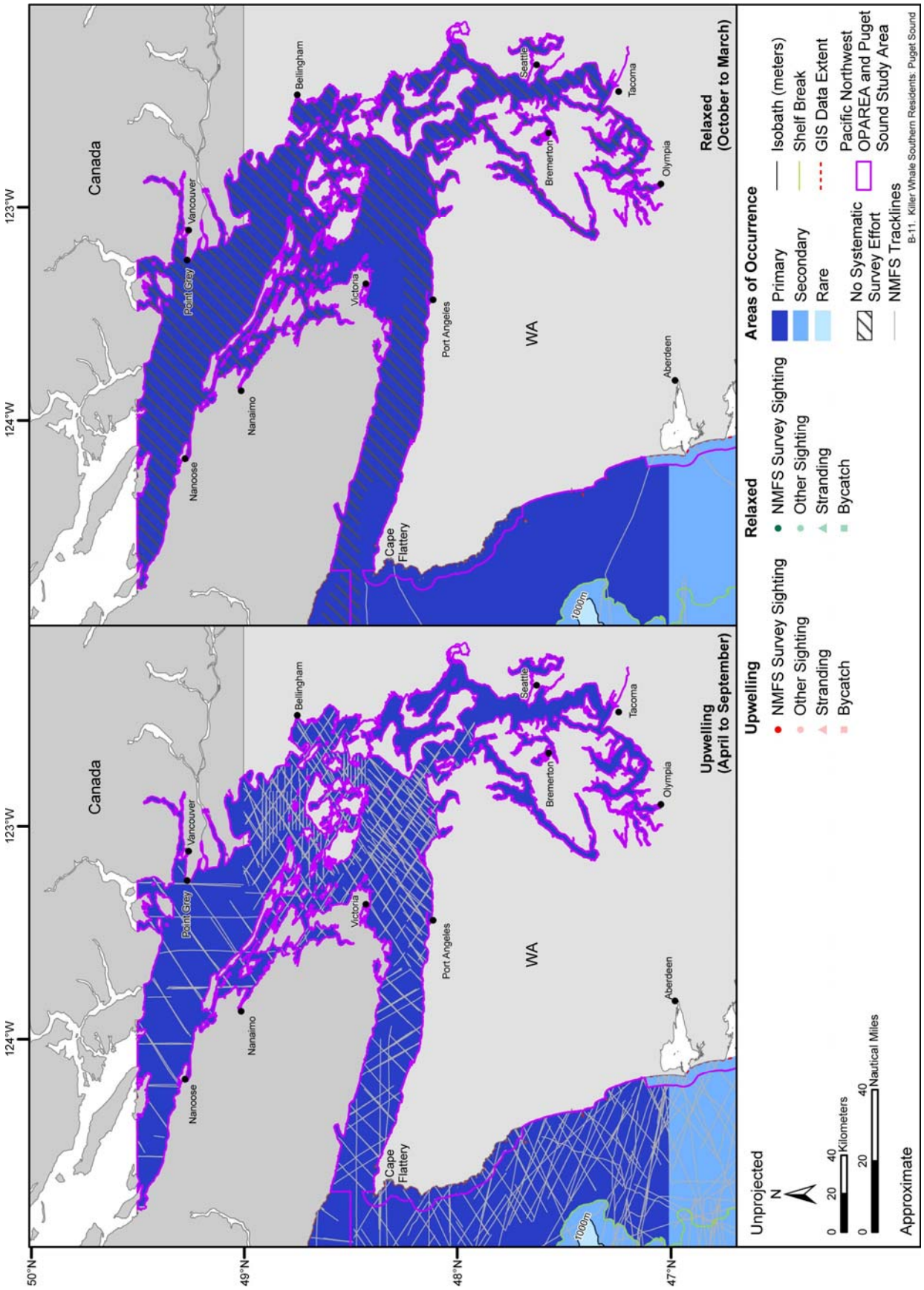

Figure B-11. Areas of occurrence for the southern resident killer whale in the Puget Sound Study Area. Upwelling season patterns are applicable during July through September. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

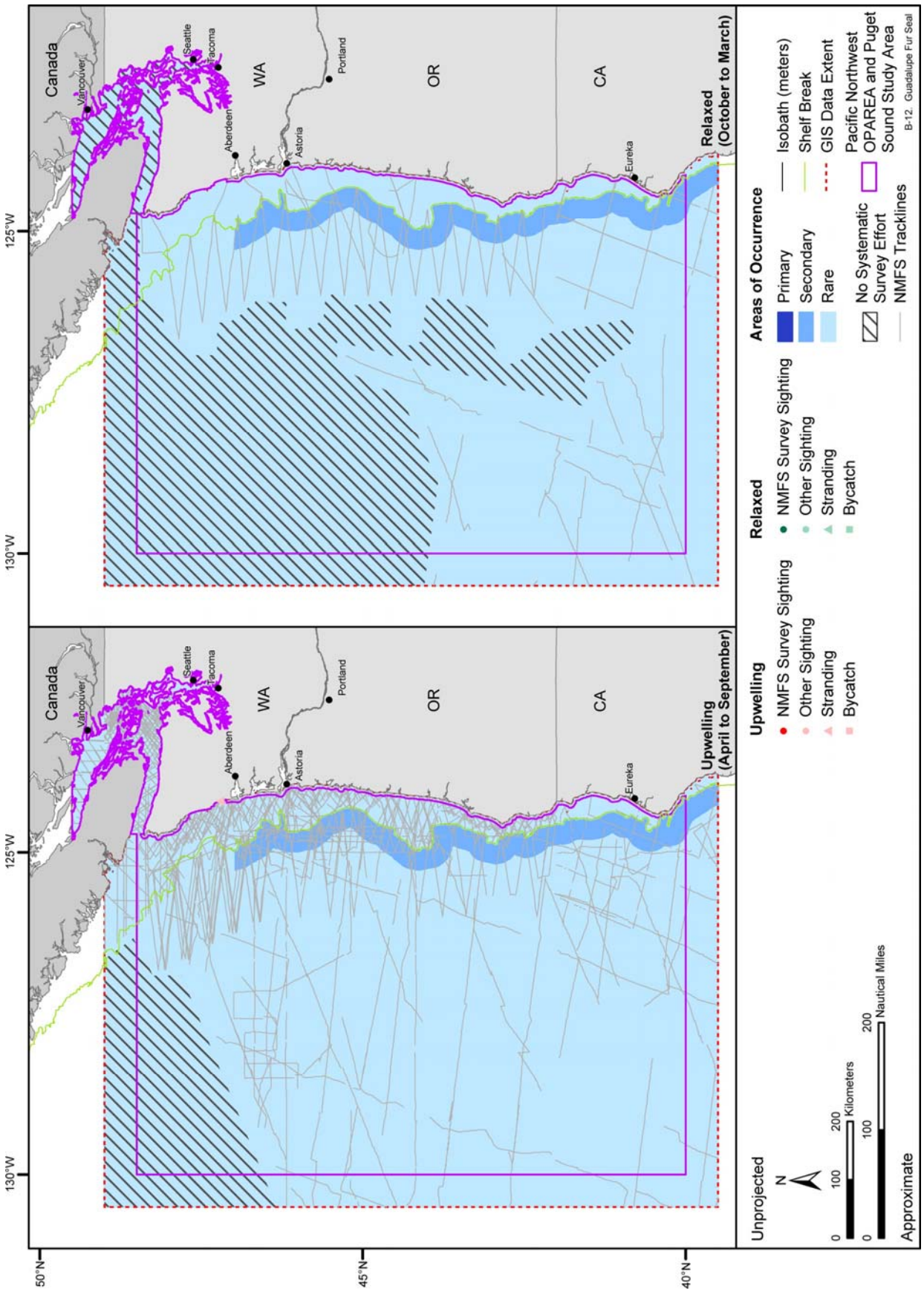

Figure B-12. Areas of occurrence for the Guadalupe fur seal in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

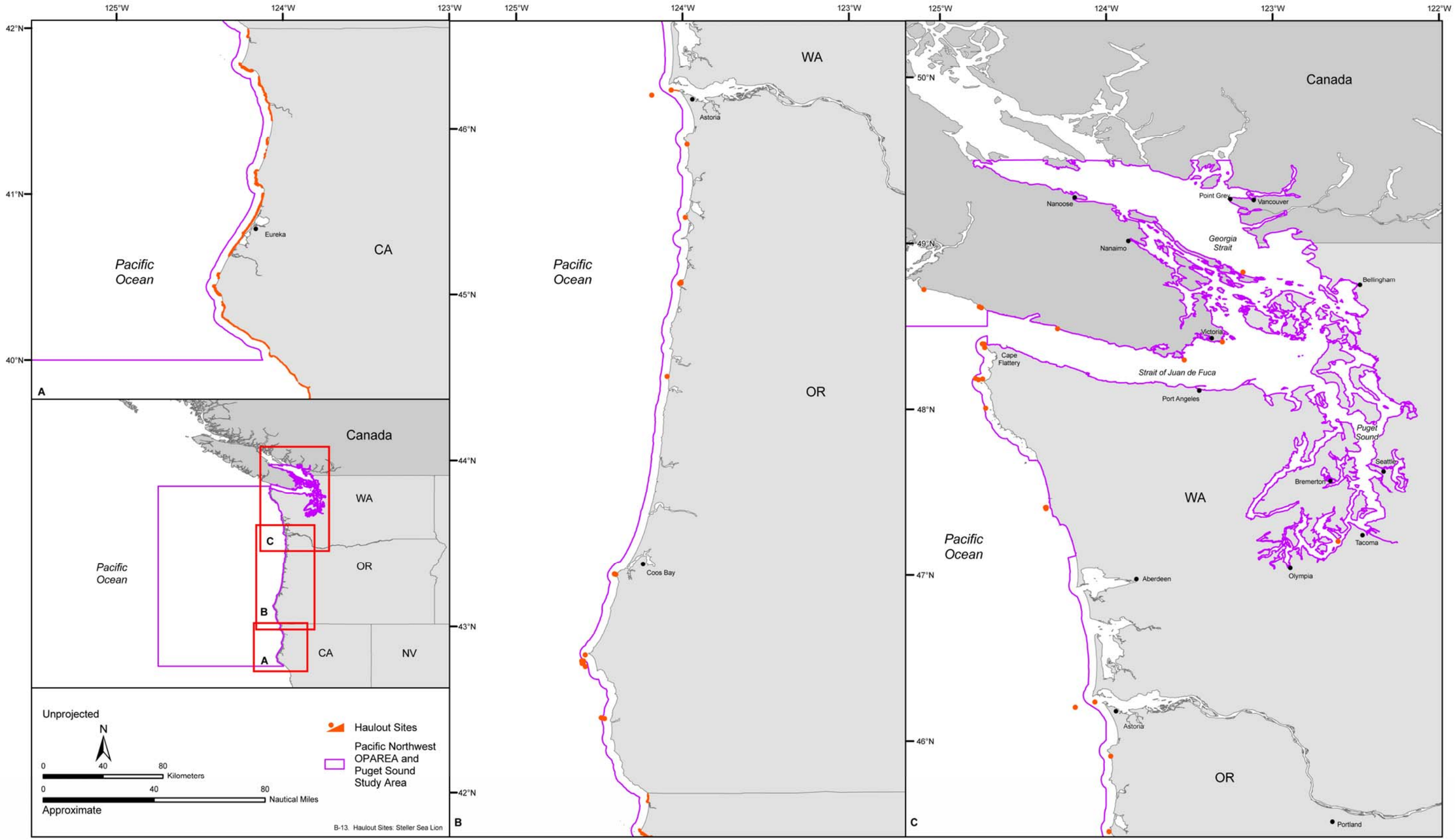

Figure B-13. Steller sea lion haulout sites in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOS (2001), Oregon Ocean Coastal Management Program (2002), WDFW (2005), and Province of British Columbia.[7]

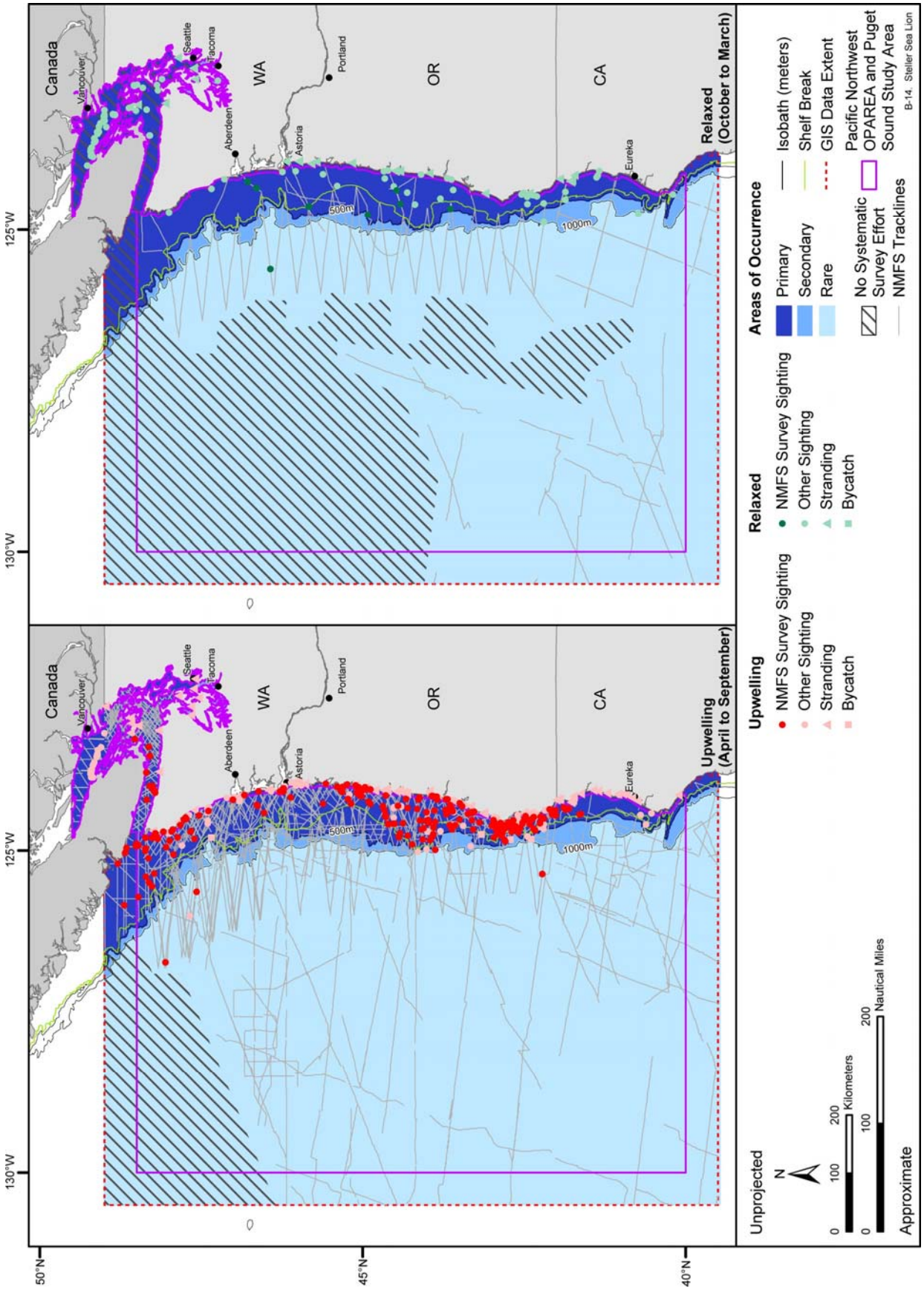

Figure B-14. Areas of occurrence for the Steller sea lion in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

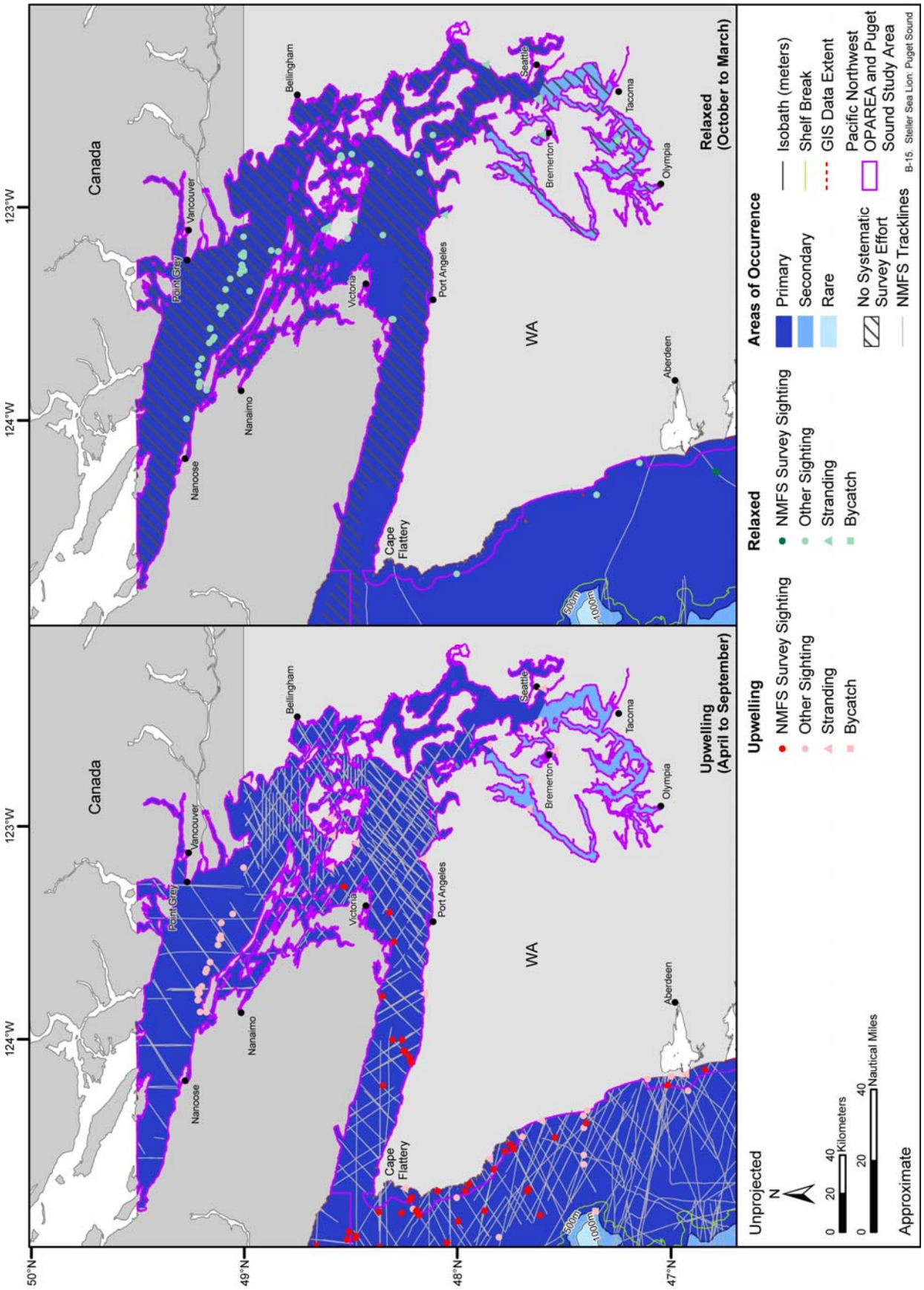

Figure B-15. Areas of occurrence for the Steller sea lion in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

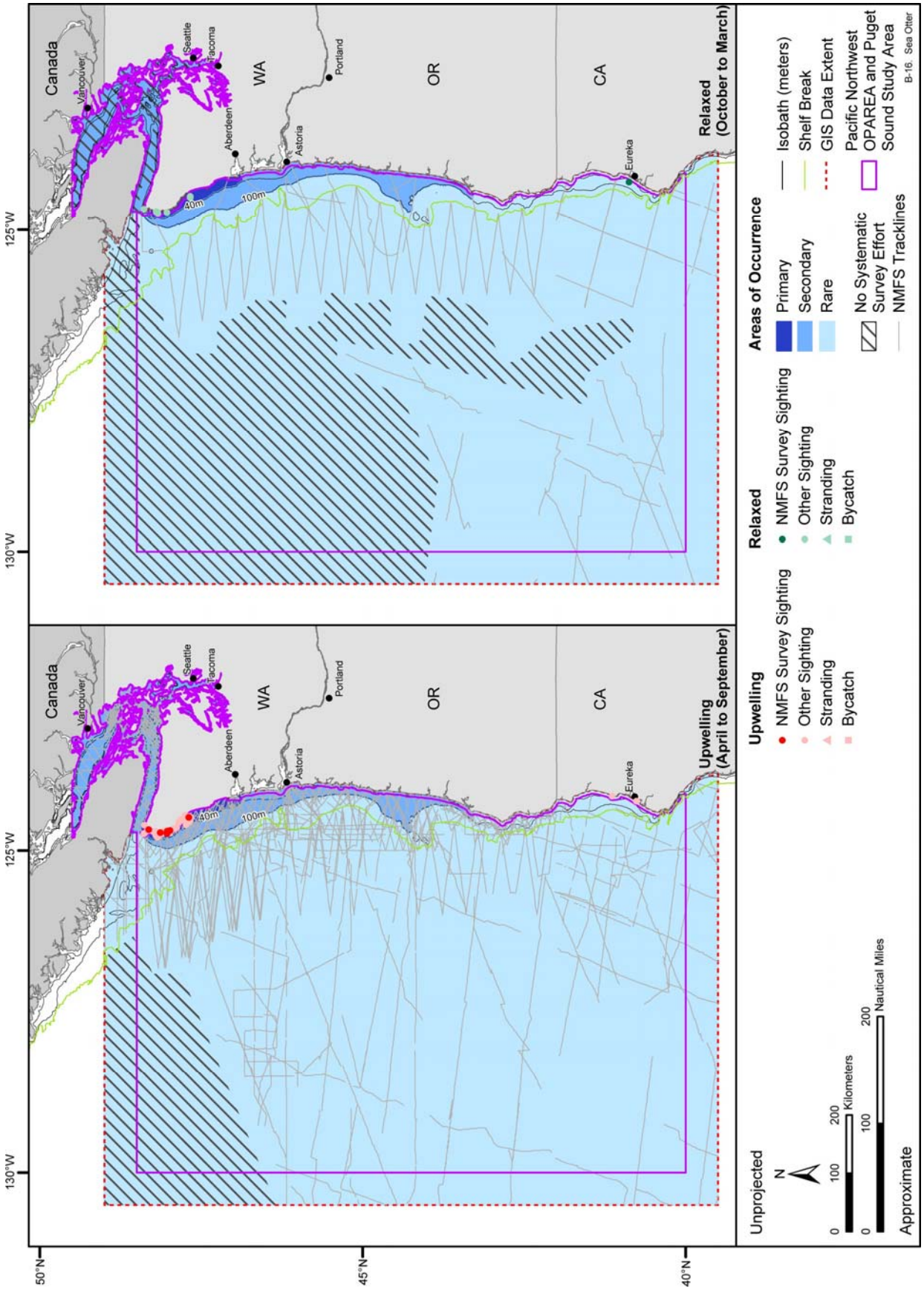

Figure B-16. Areas of occurrence for the sea otter in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

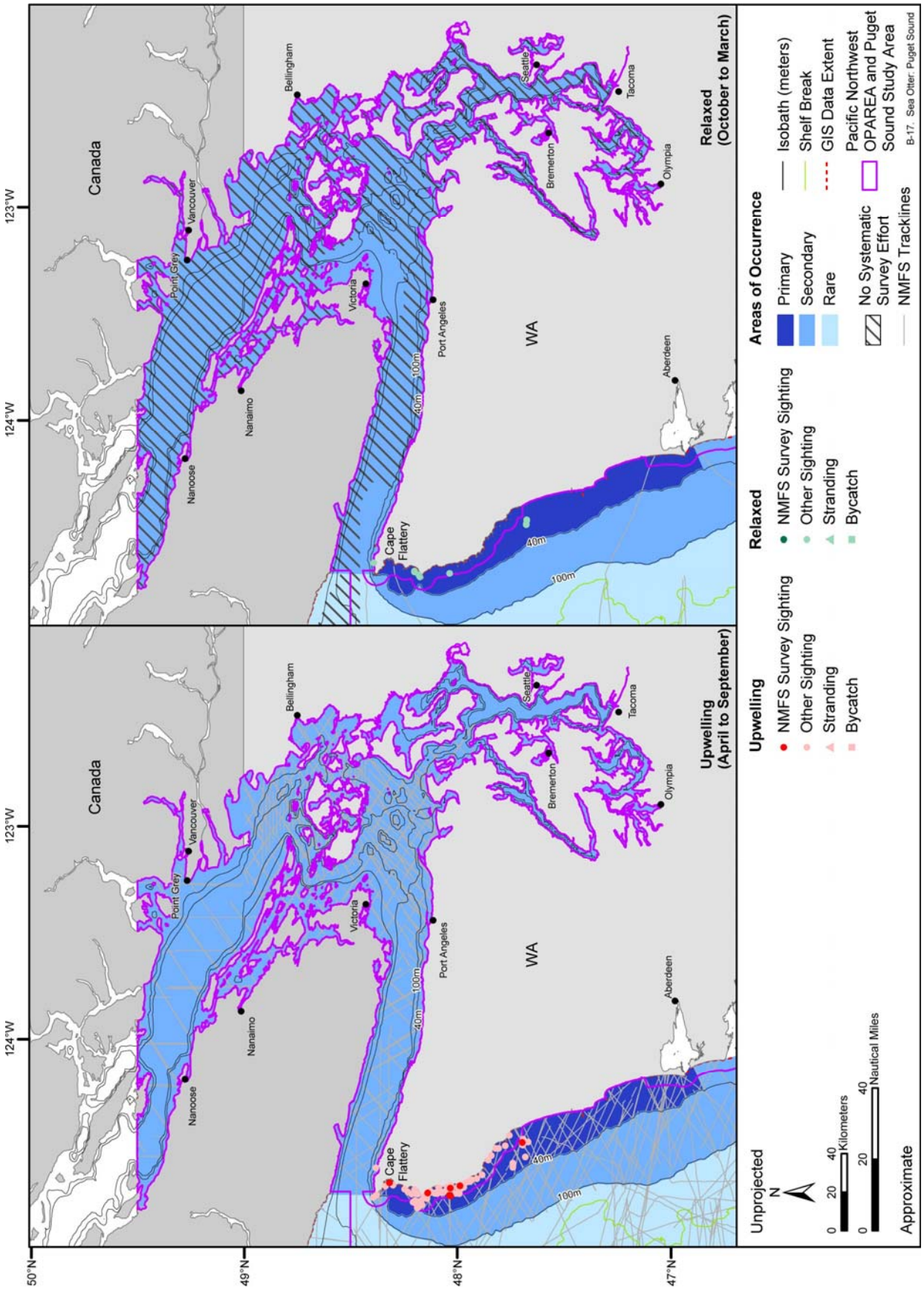

Figure B-17. Areas of occurrence for the sea otter in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

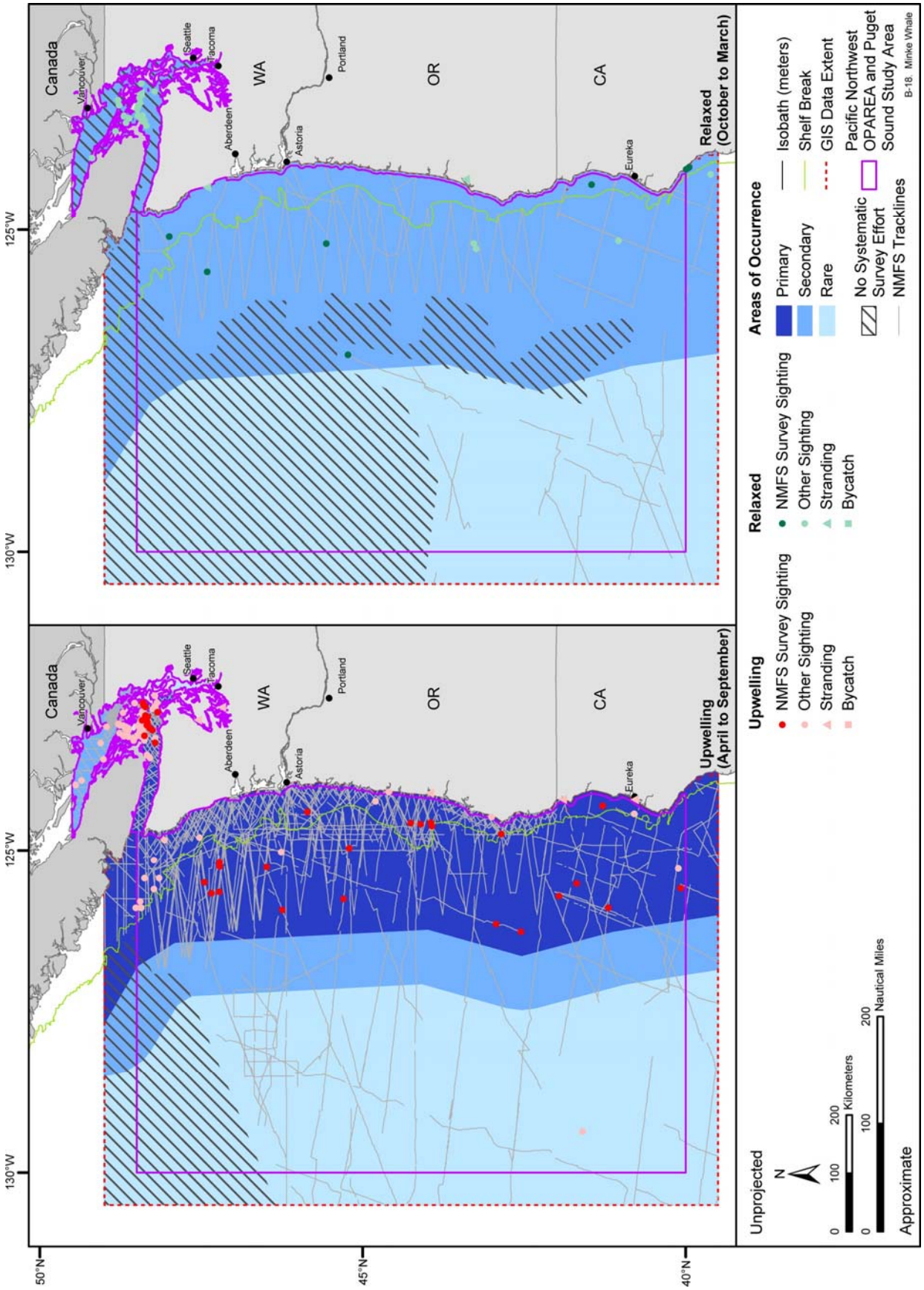

Figure B-18. Areas of occurrence for the minke whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

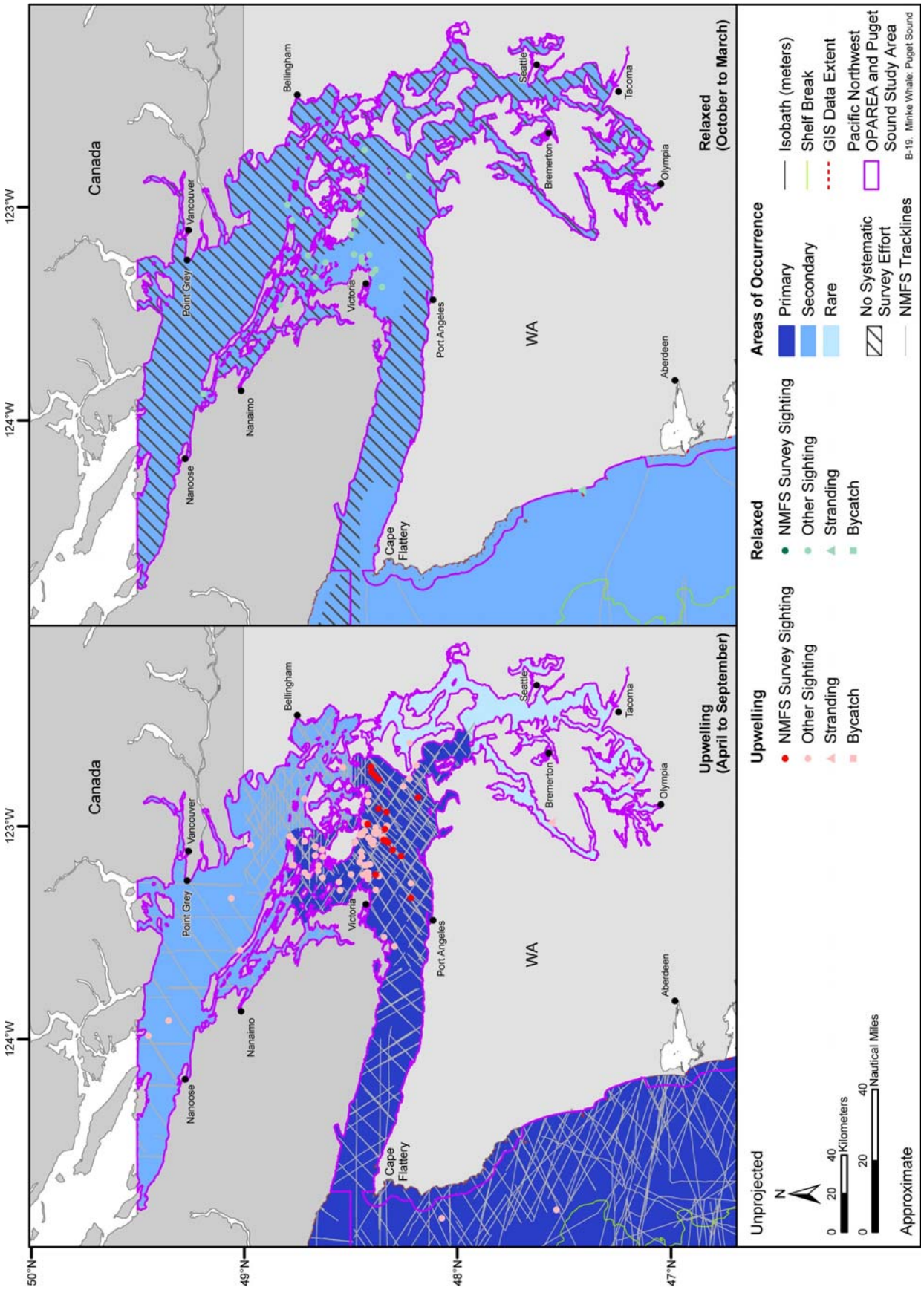

Figure B-19. Areas of occurrence for the minke whale in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

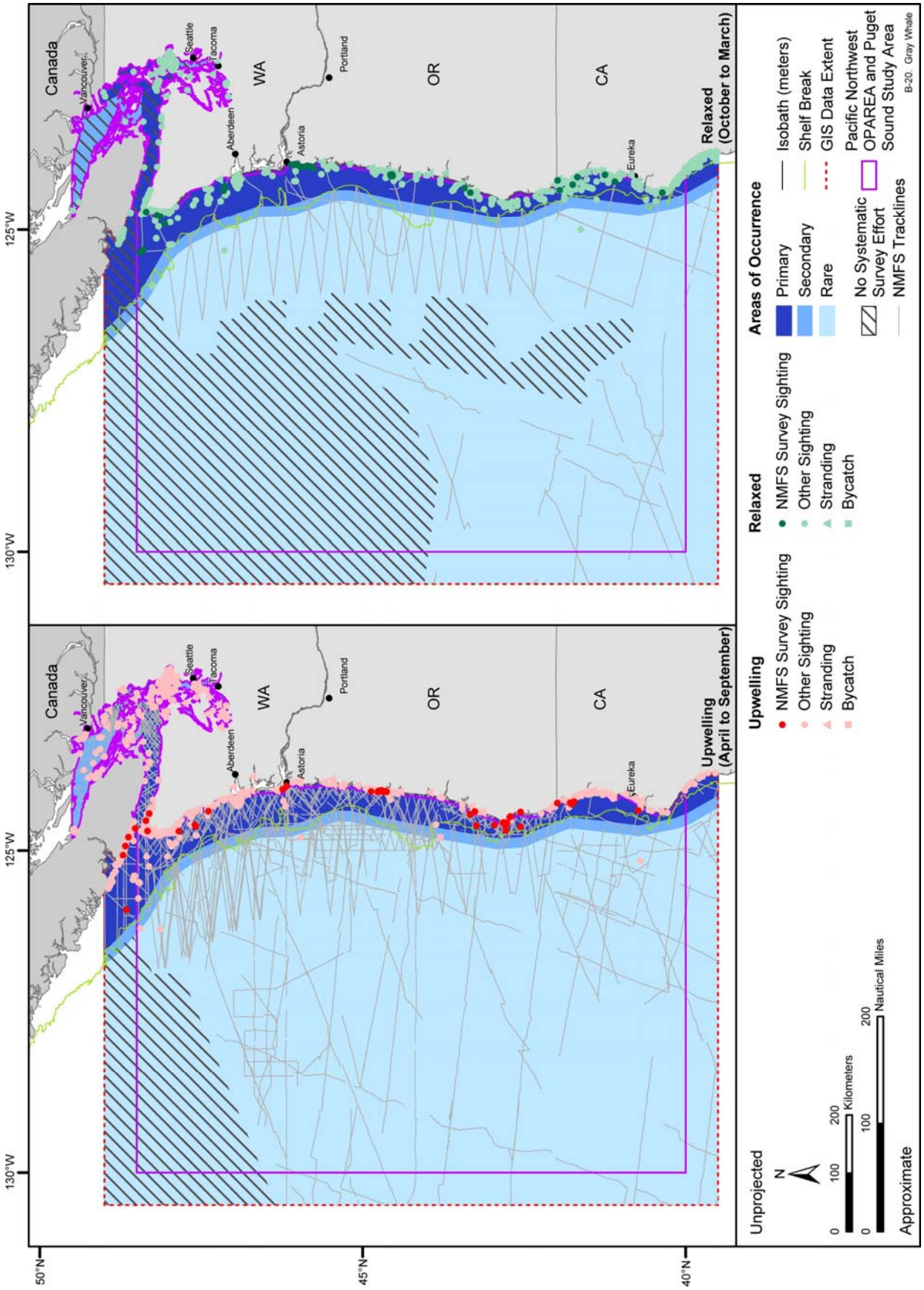

Figure B-20. Areas of occurrence for the gray whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

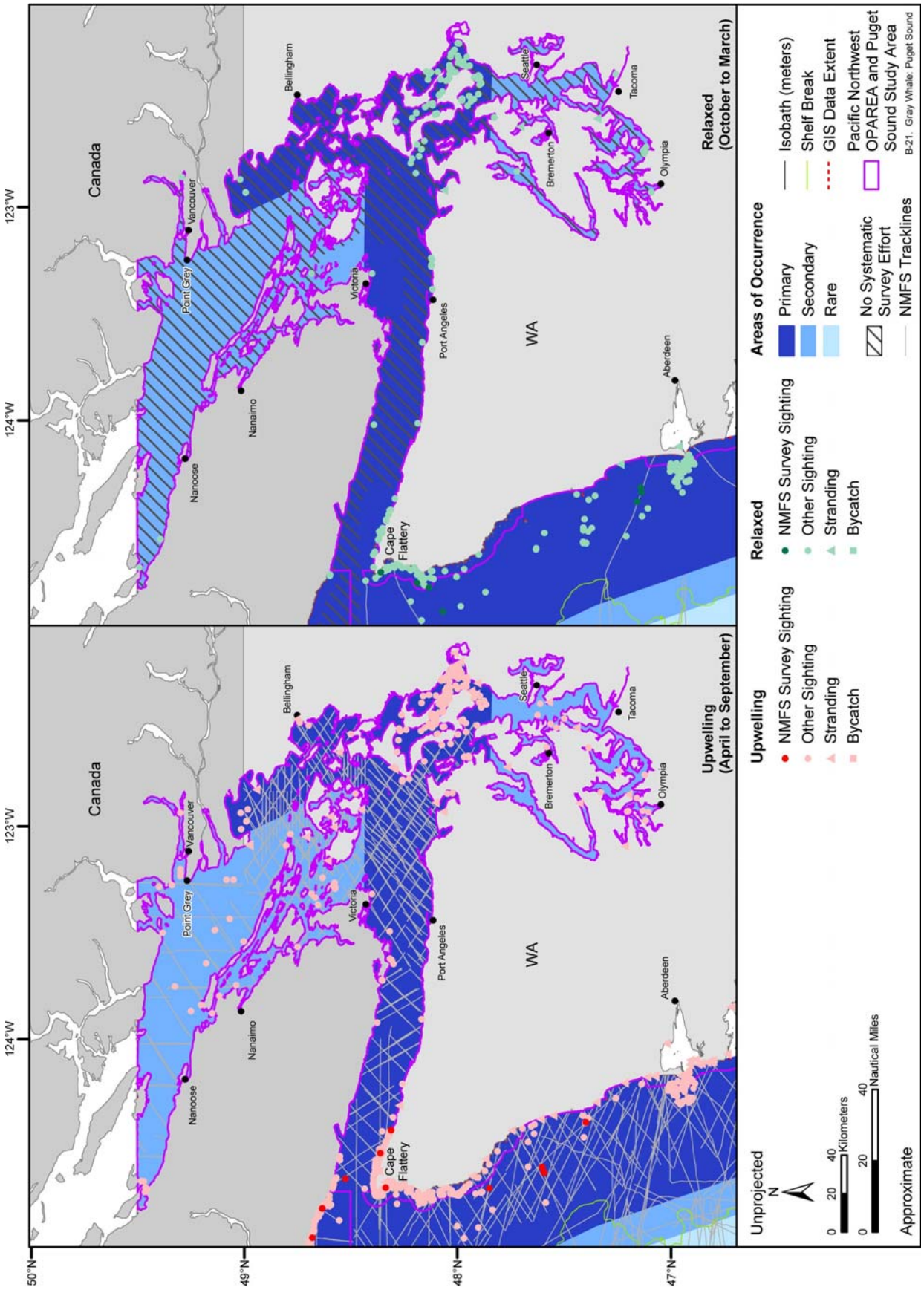

Figure B-21. Areas of occurrence for the gray whale in the Puget Sound Study Area. During the relaxed season, gray whales are observed feeding in February and March. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

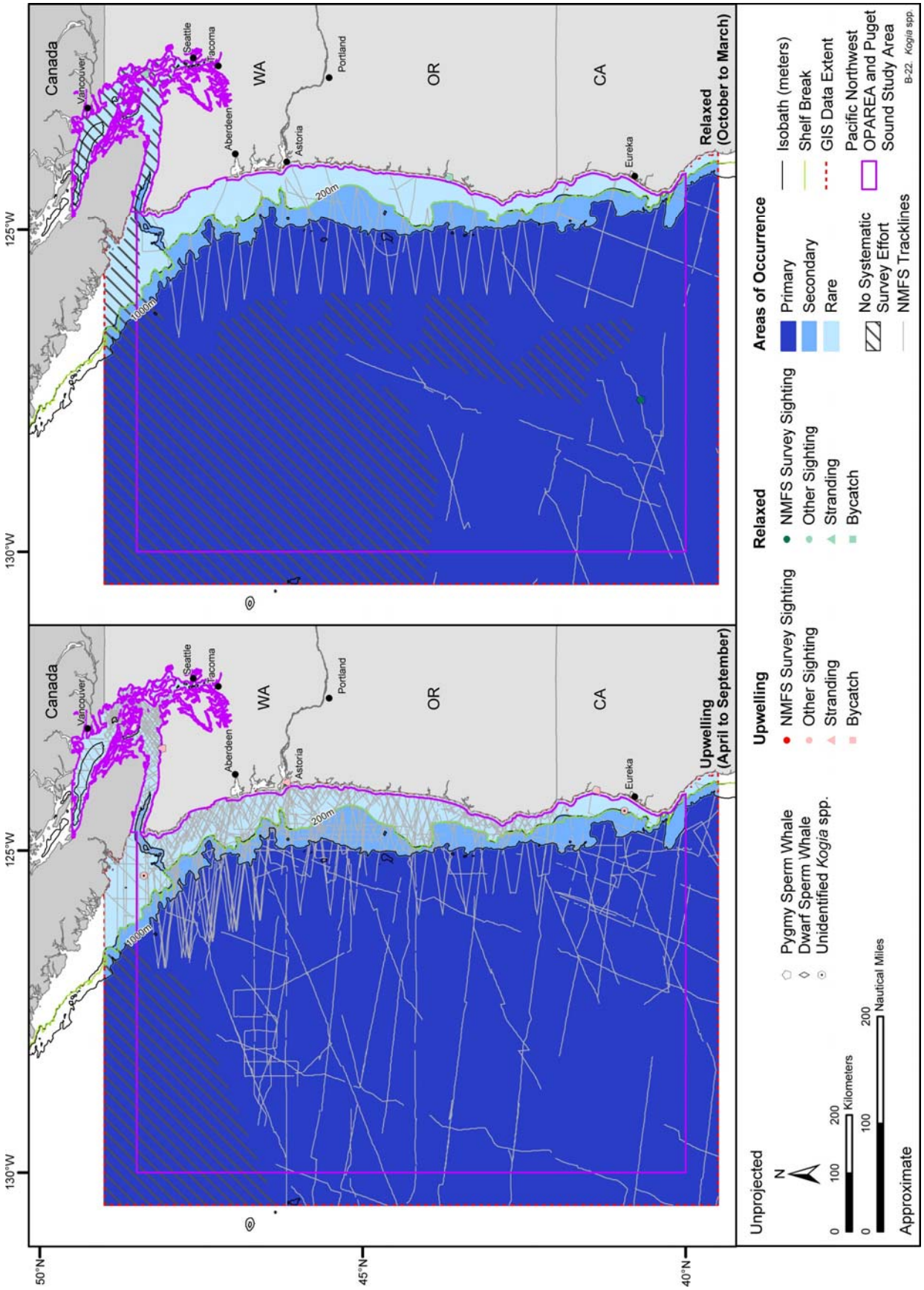

Figure B-22. Areas of occurrence for *Kogia* spp. in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

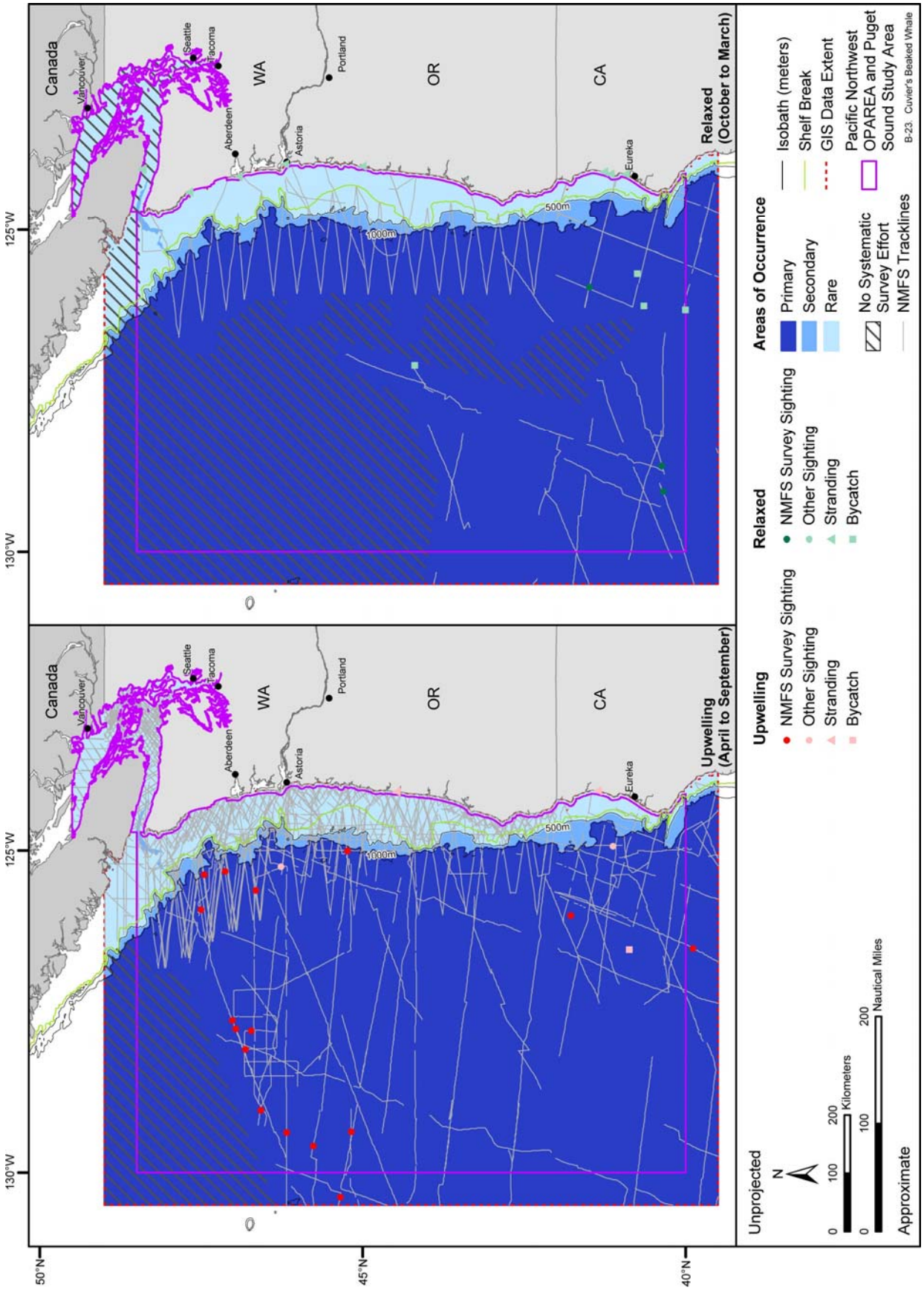

Figure B-23. Areas of occurrence for the Cuvier's beaked whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

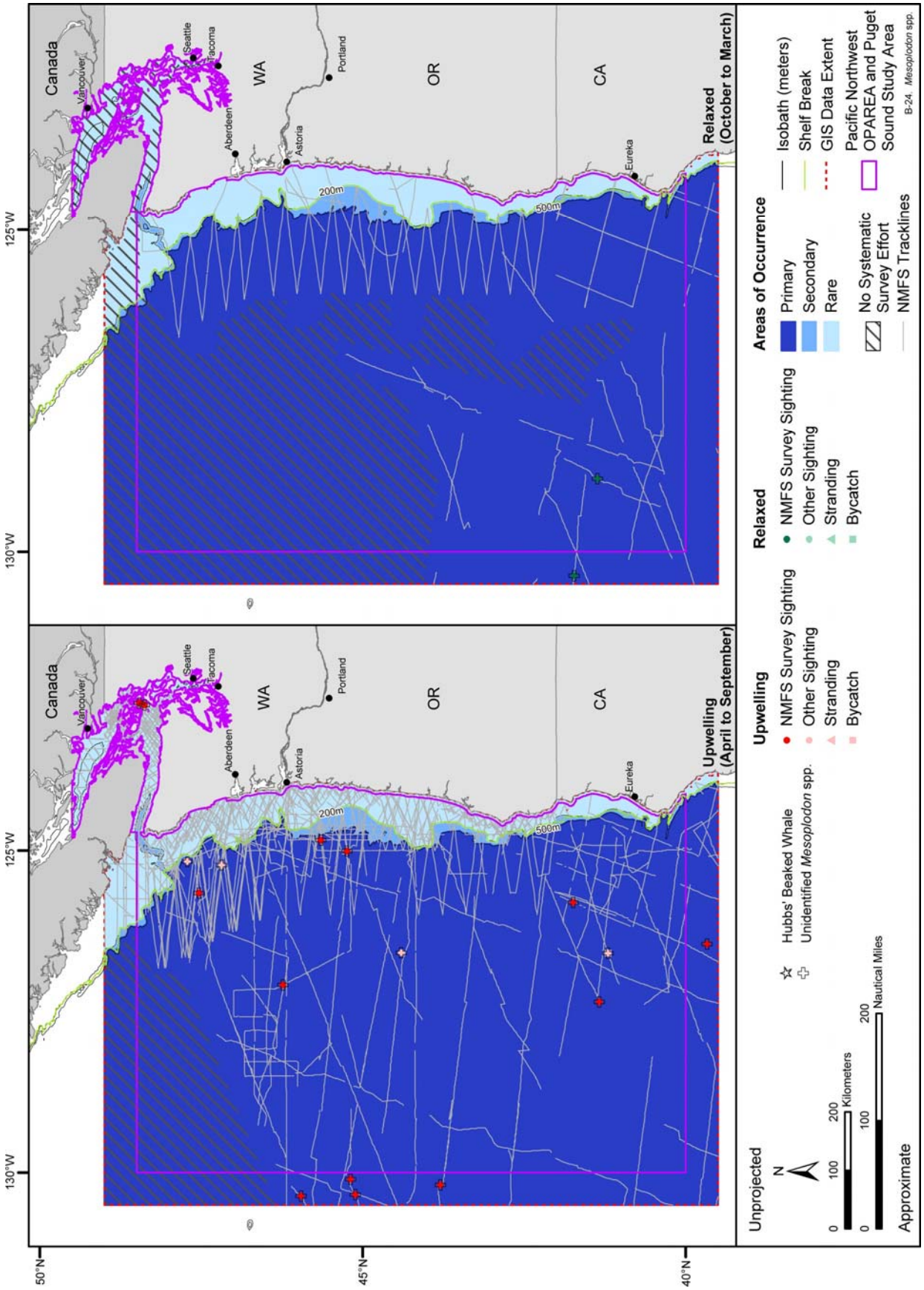

Figure B-24. Areas of occurrence for *Mesoplodon* spp. in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

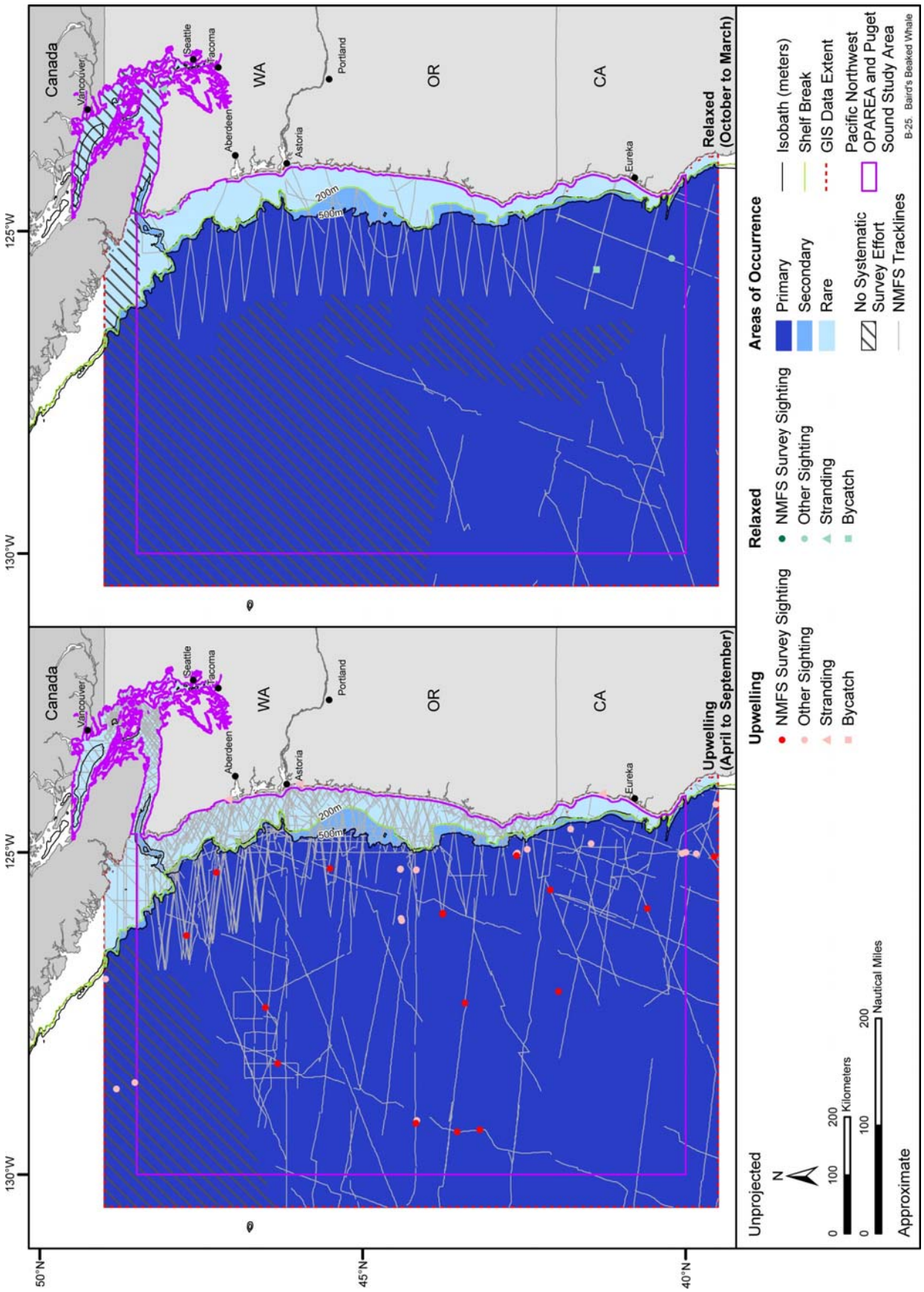

Figure B-25. Areas of occurrence for the Baird's beaked whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

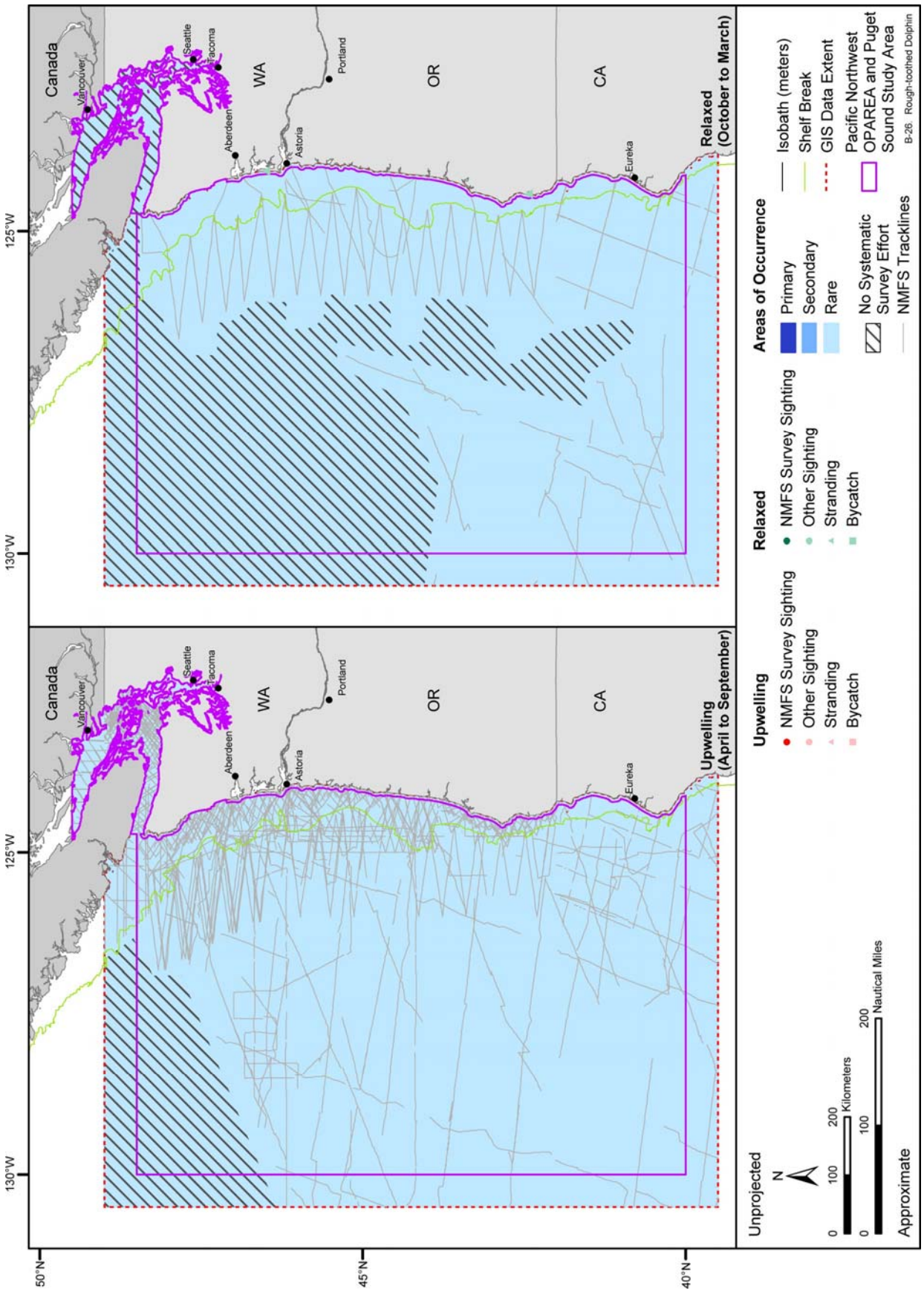

Figure B-26. Areas of occurrence for the rough-toothed dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

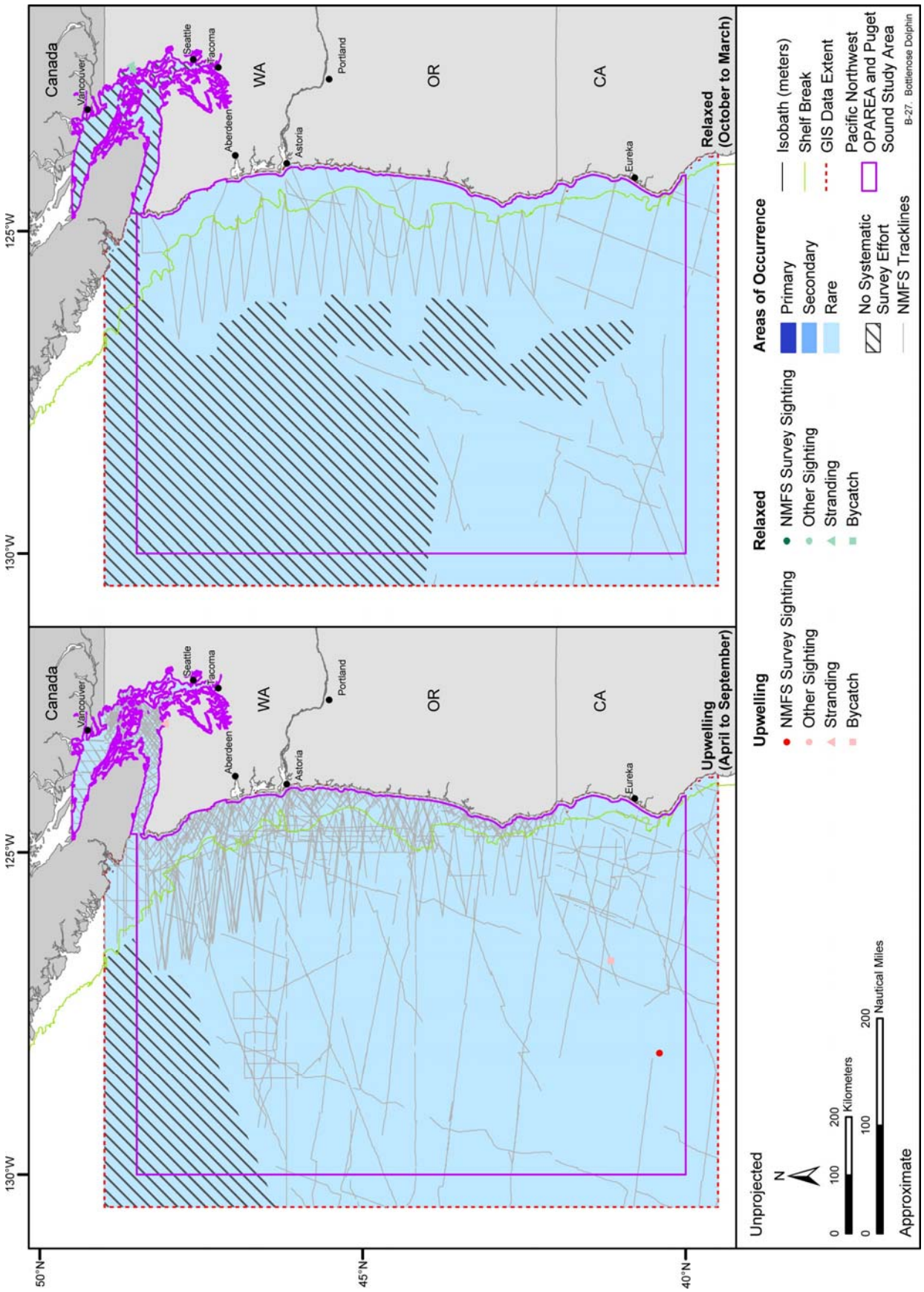

Figure B-27. Areas of occurrence for the bottlenose dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

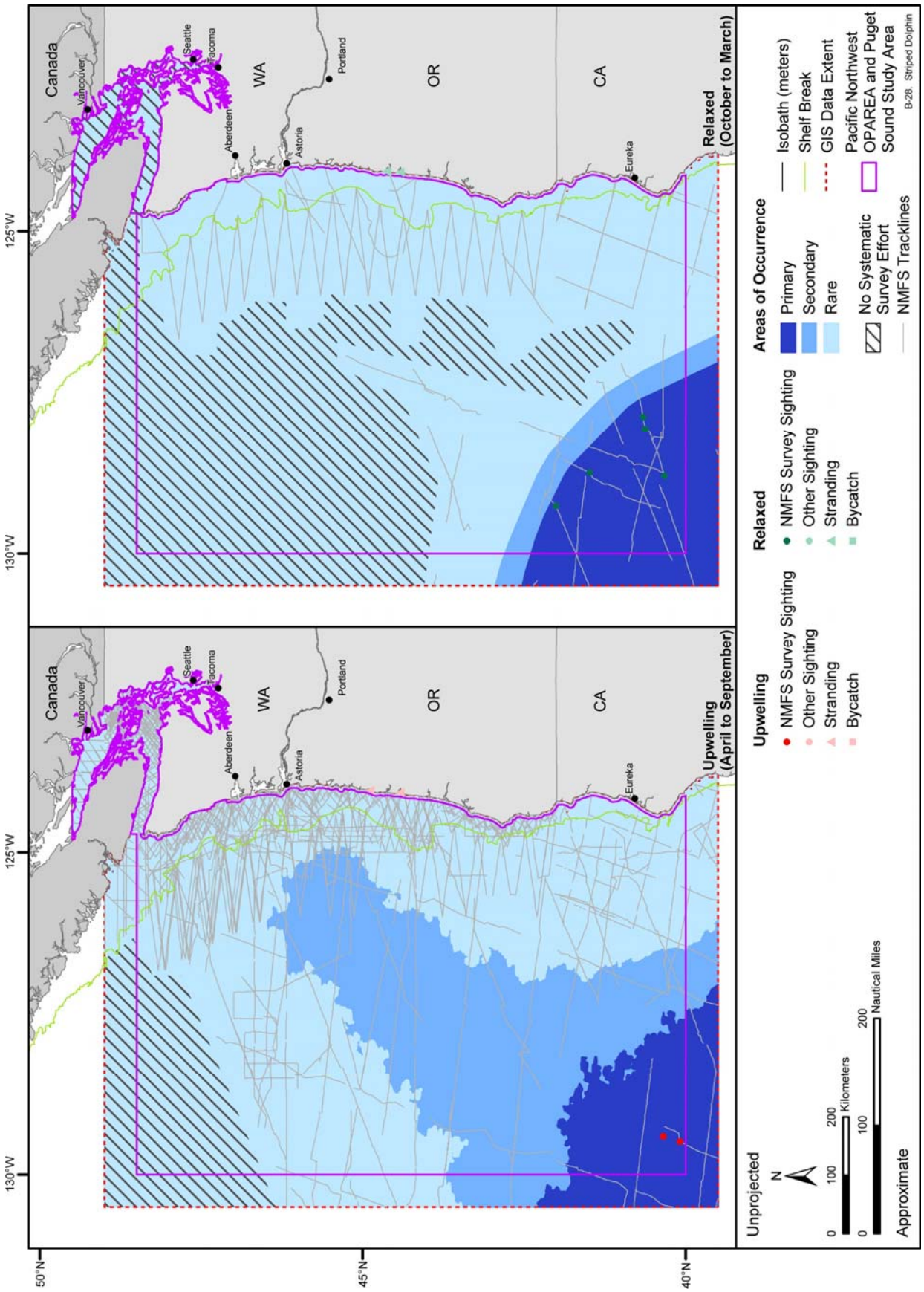

Figure B-28. Areas of occurrence for the striped dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

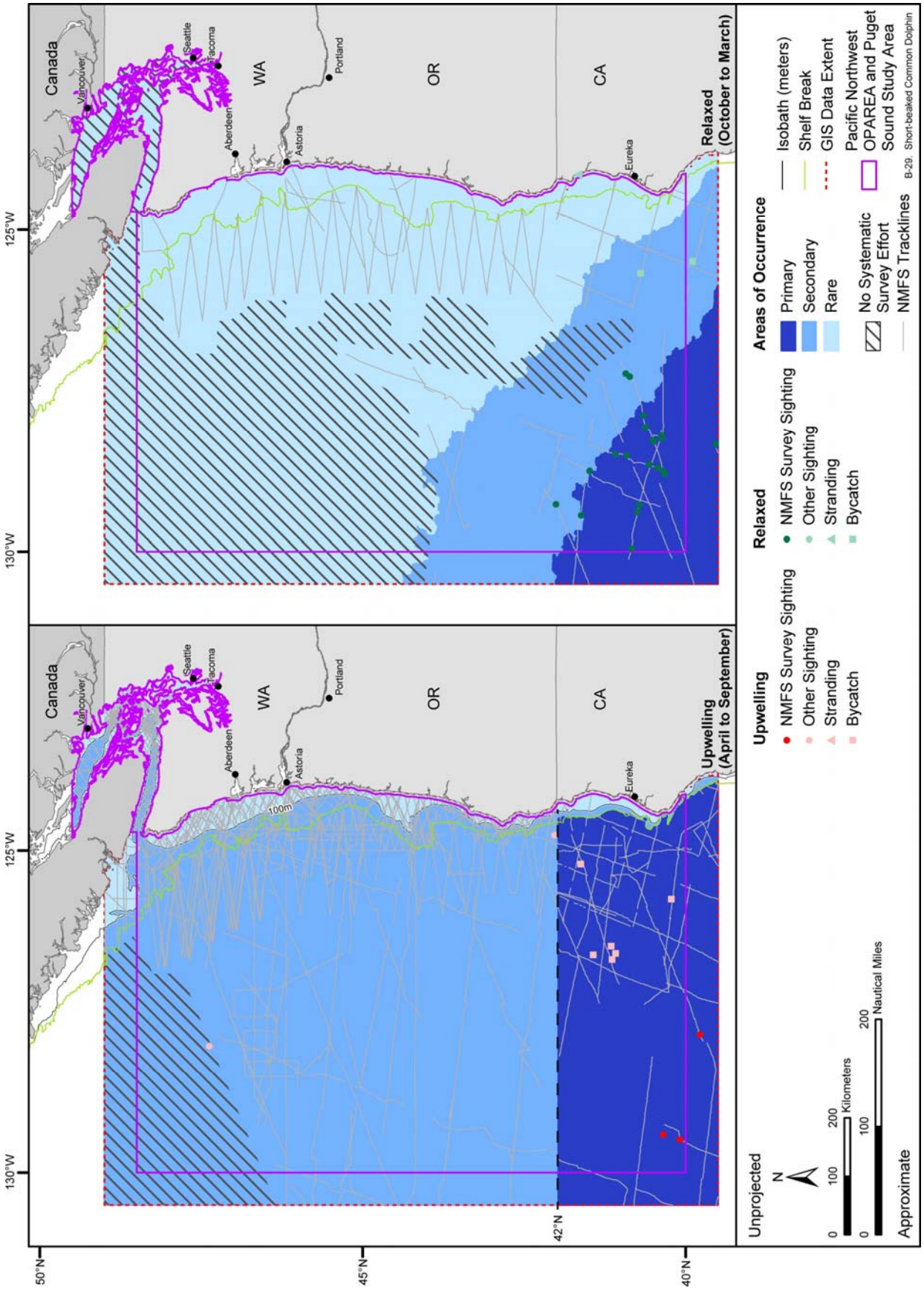

Figure B-29. Areas of occurrence for the short-beaked common dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

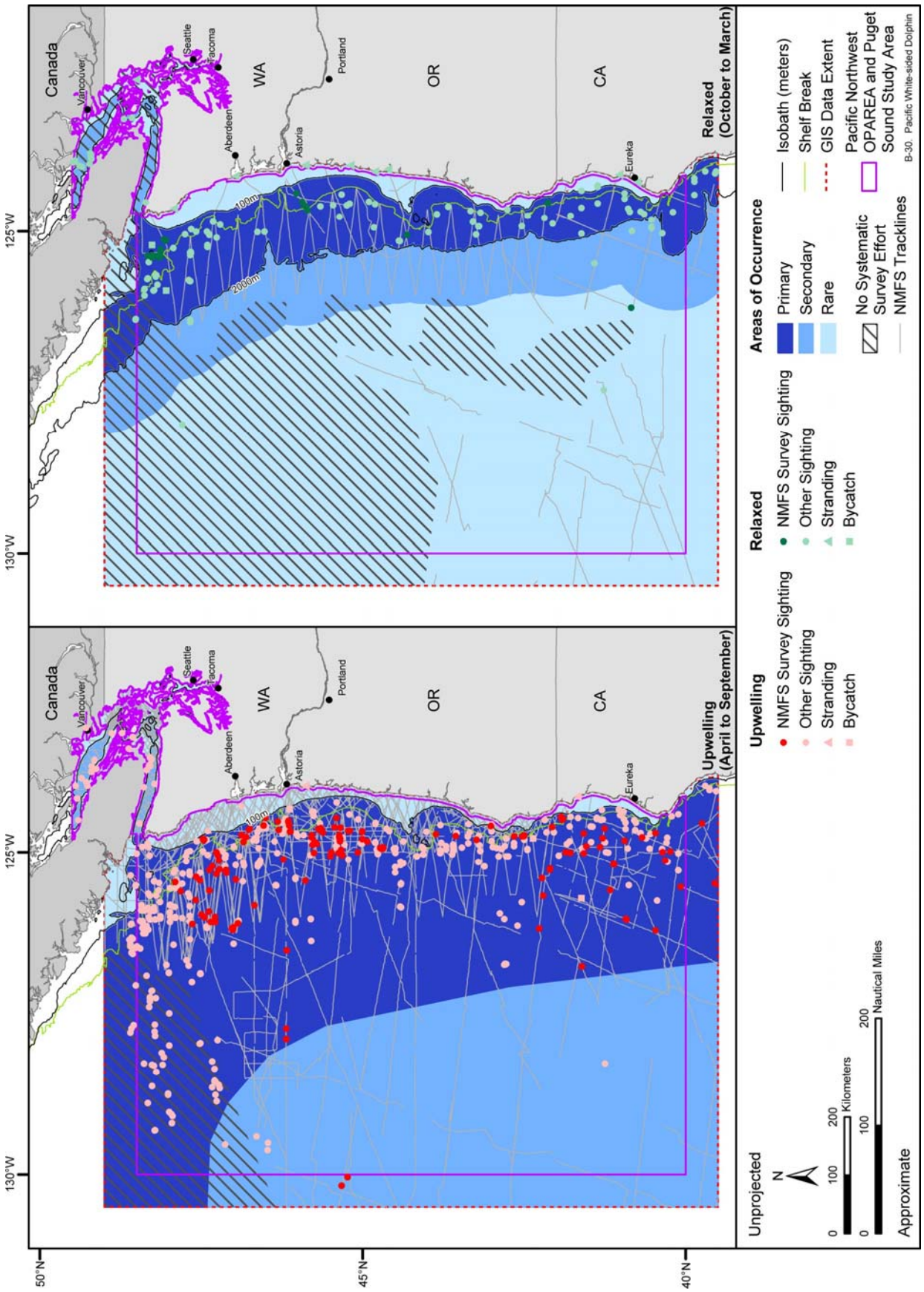

Figure B-30. Areas of occurrence for the Pacific white-sided dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

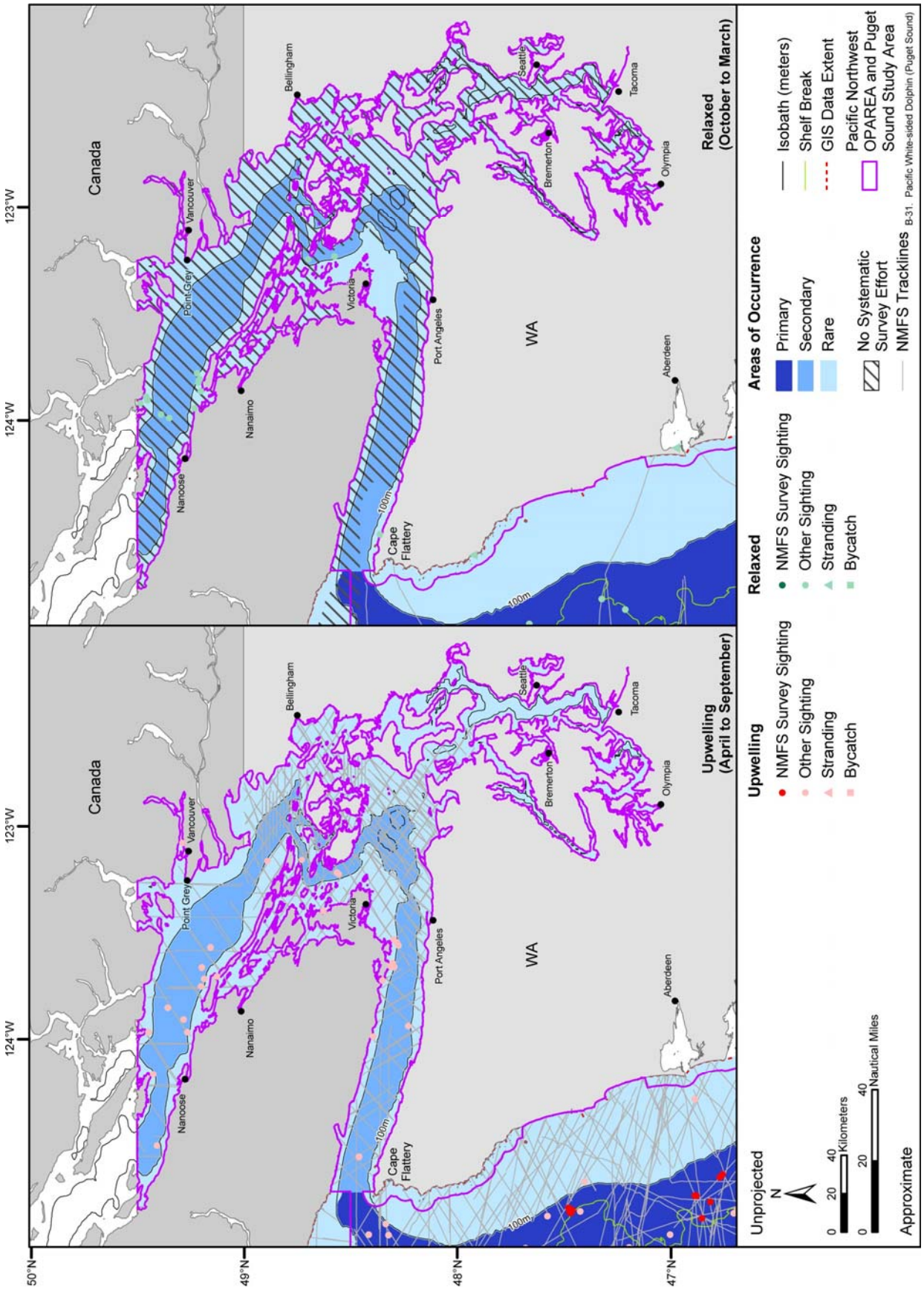

Figure B-31. Areas of occurrence for the Pacific white-sided dolphin in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

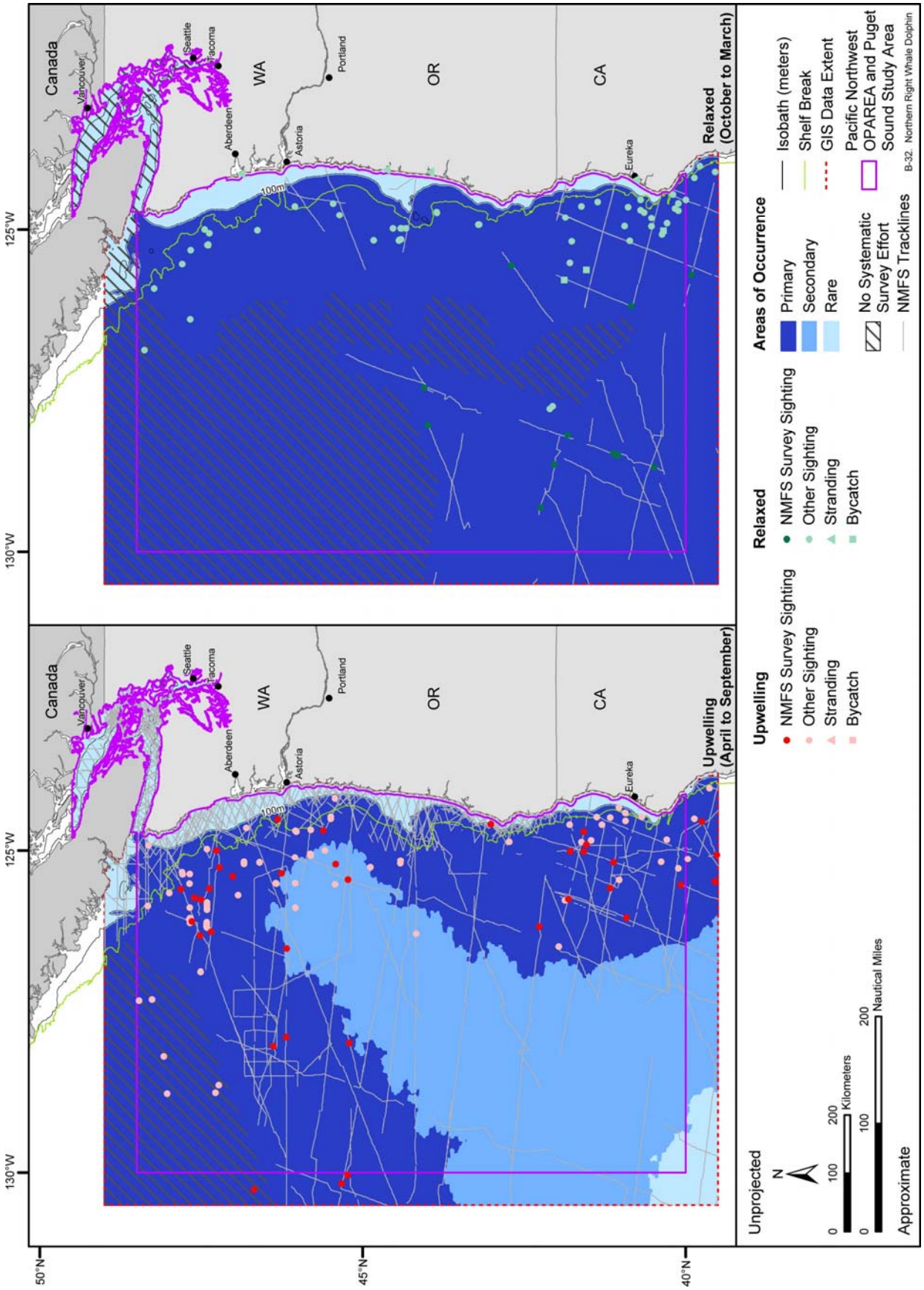

Figure B-32. Areas of occurrence for the northern right whale dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

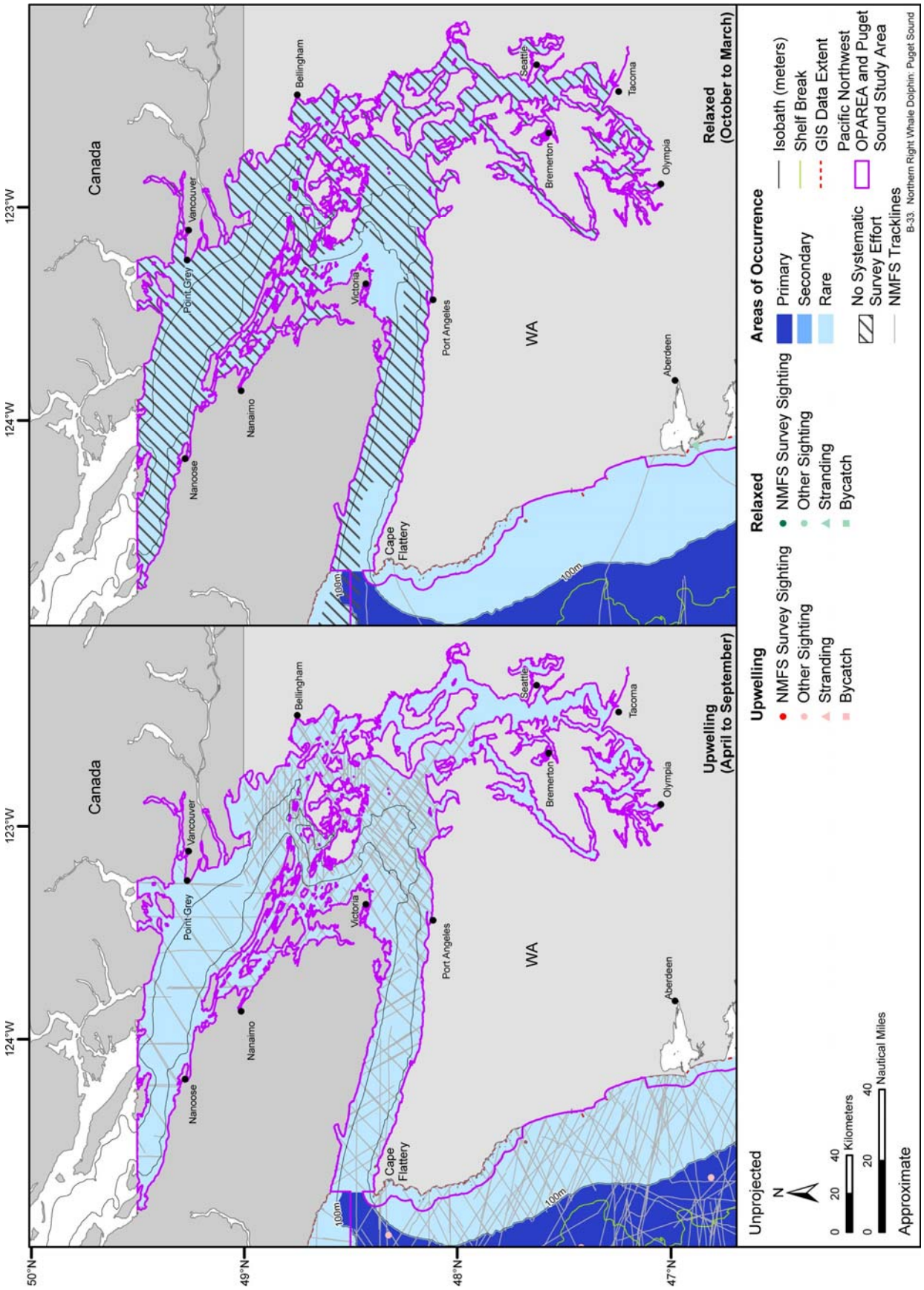

Figure B-33. Areas of occurrence for the northern right whale dolphin in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

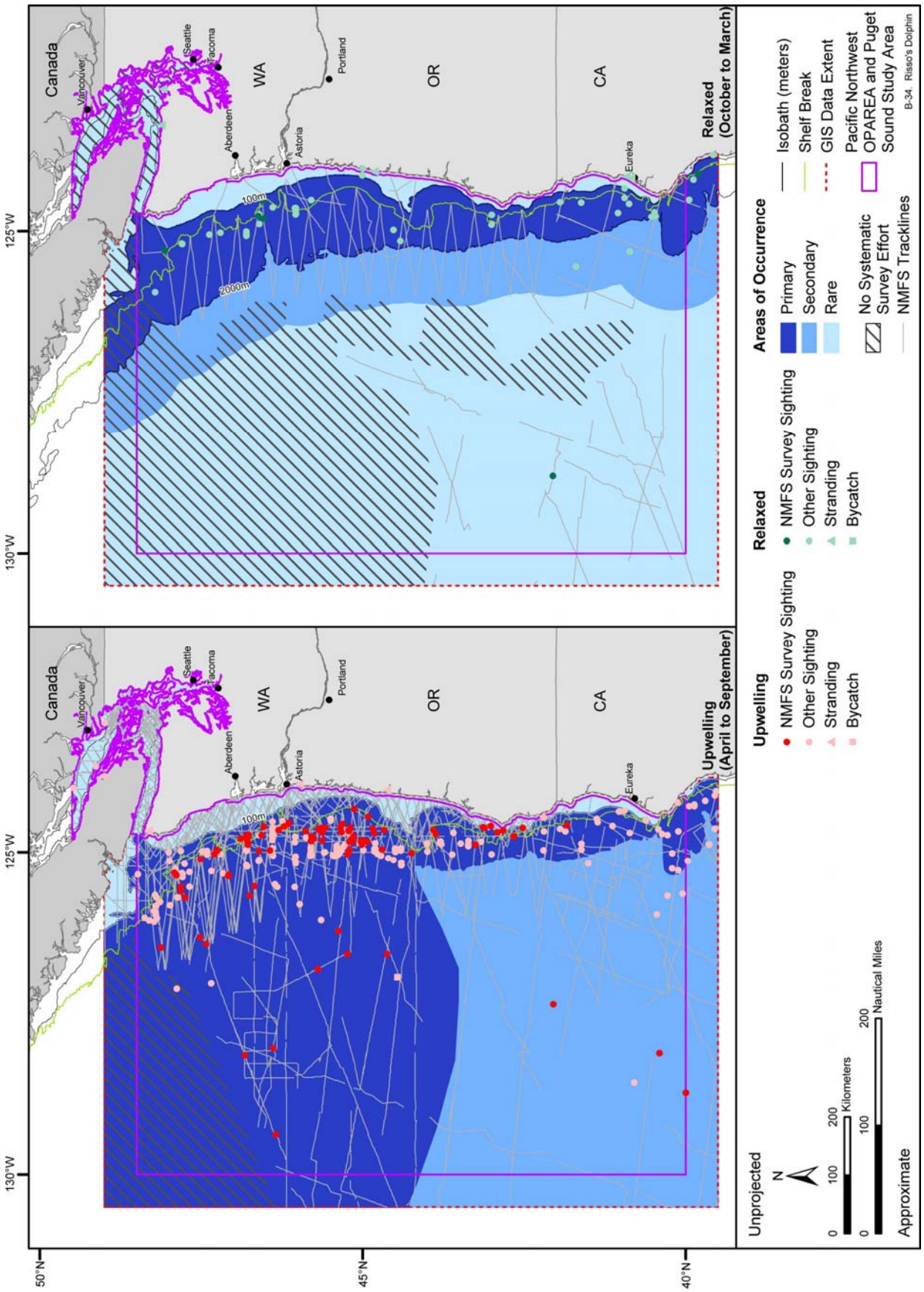

Figure B-34. Areas of occurrence for the Risso's dolphin in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

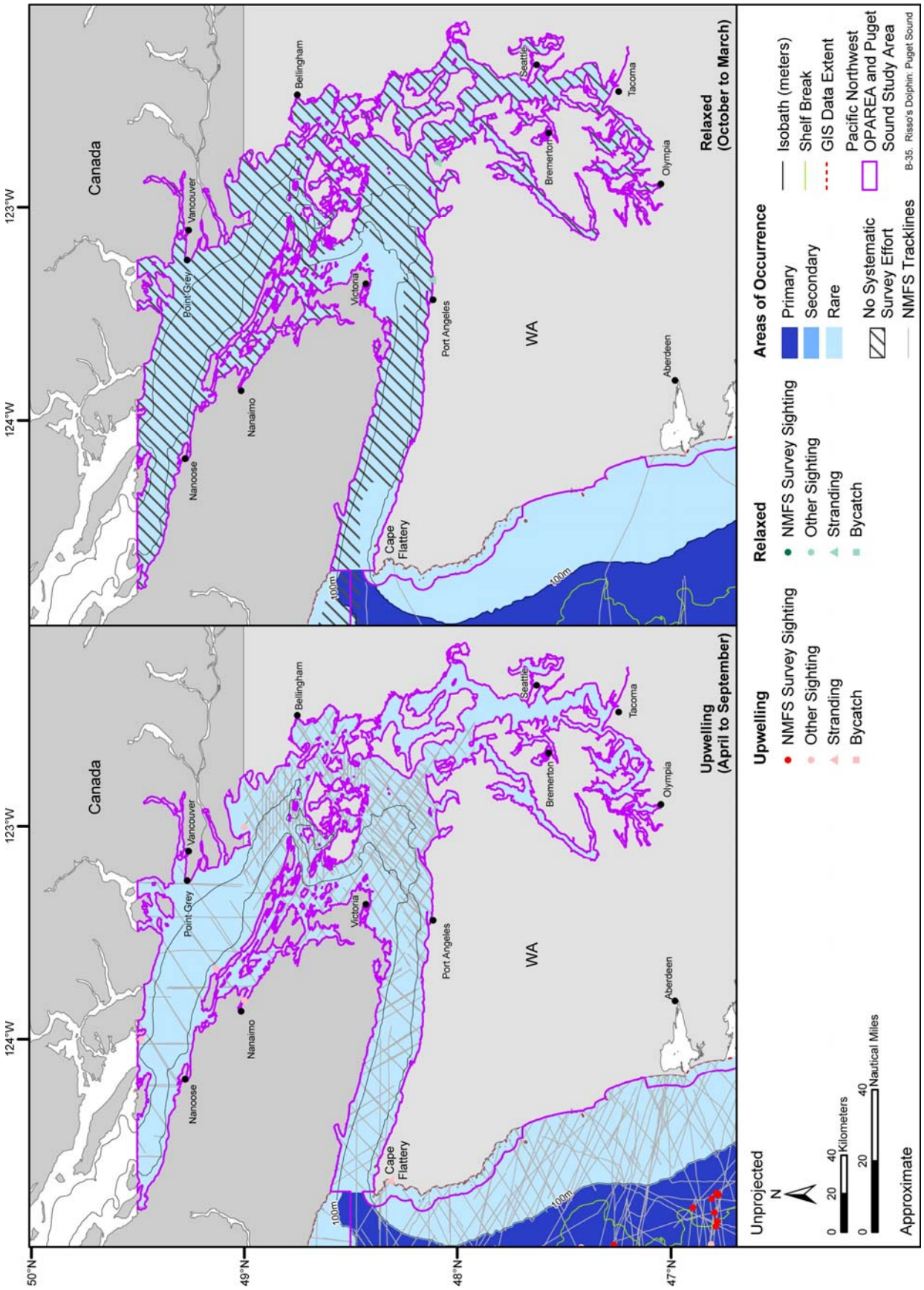

Figure B-35. Areas of occurrence for the Risso's dolphin in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

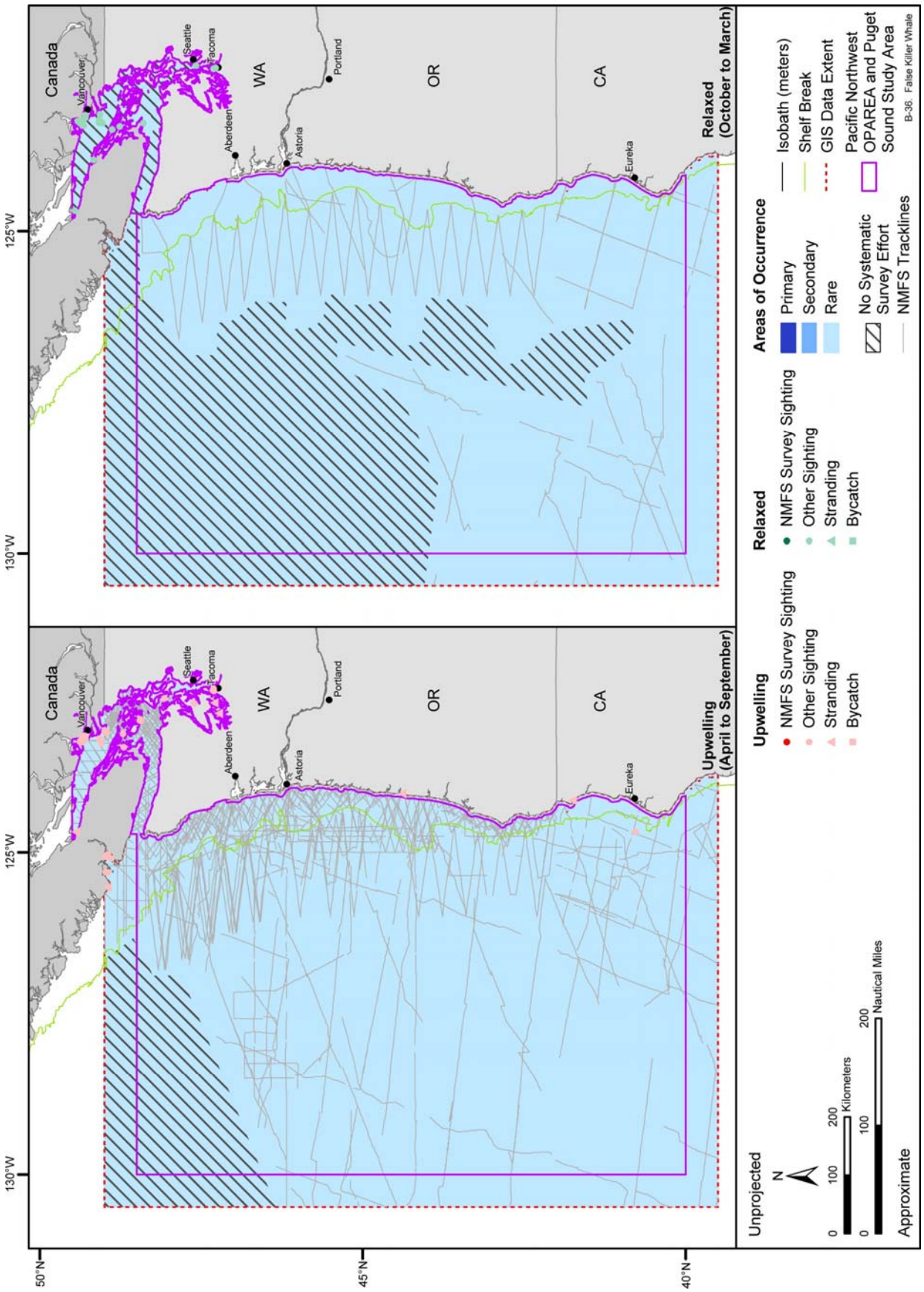

Figure B-36. Areas of occurrence for the false killer whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

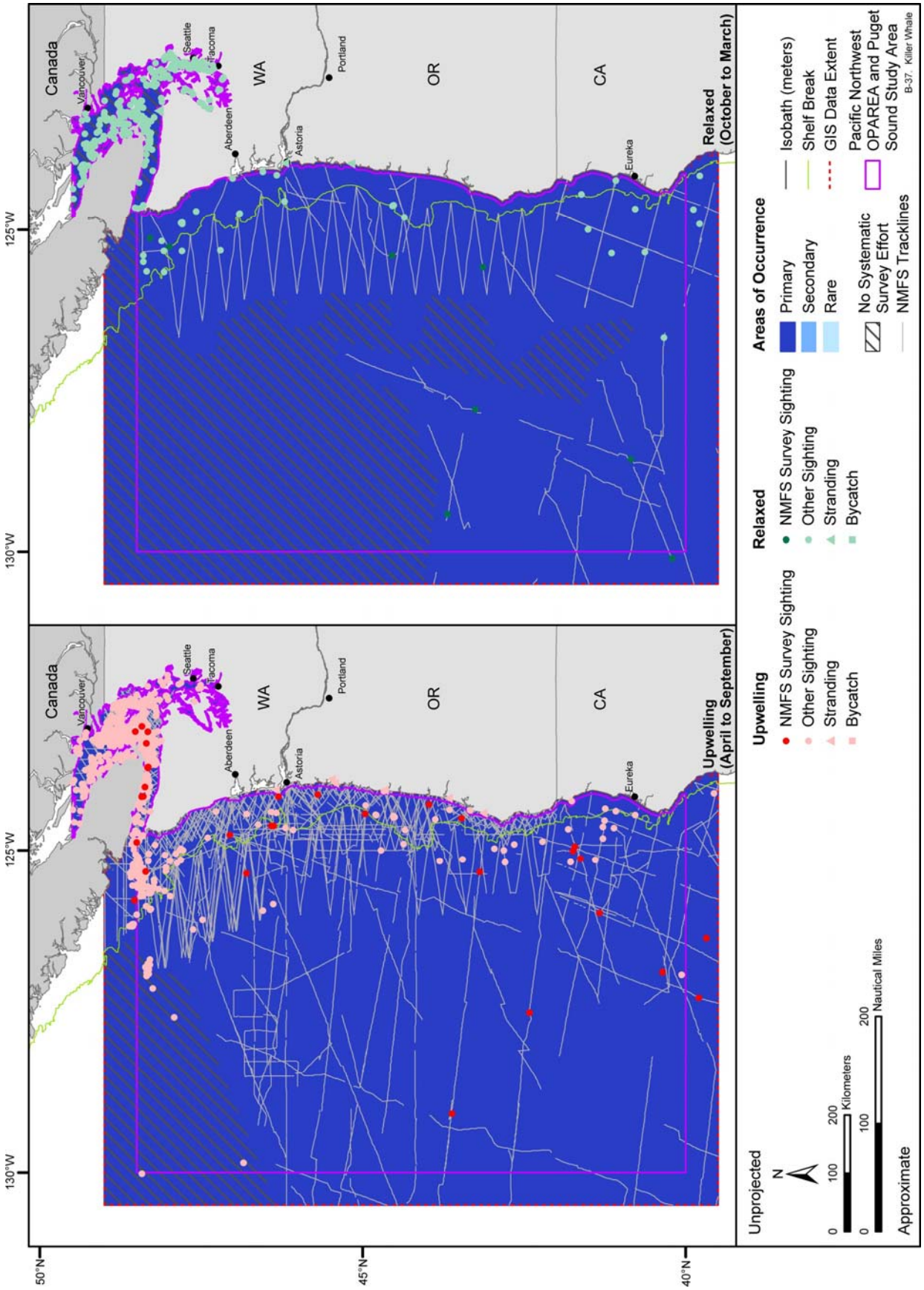

Figure B-37. Areas of occurrence for the killer whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

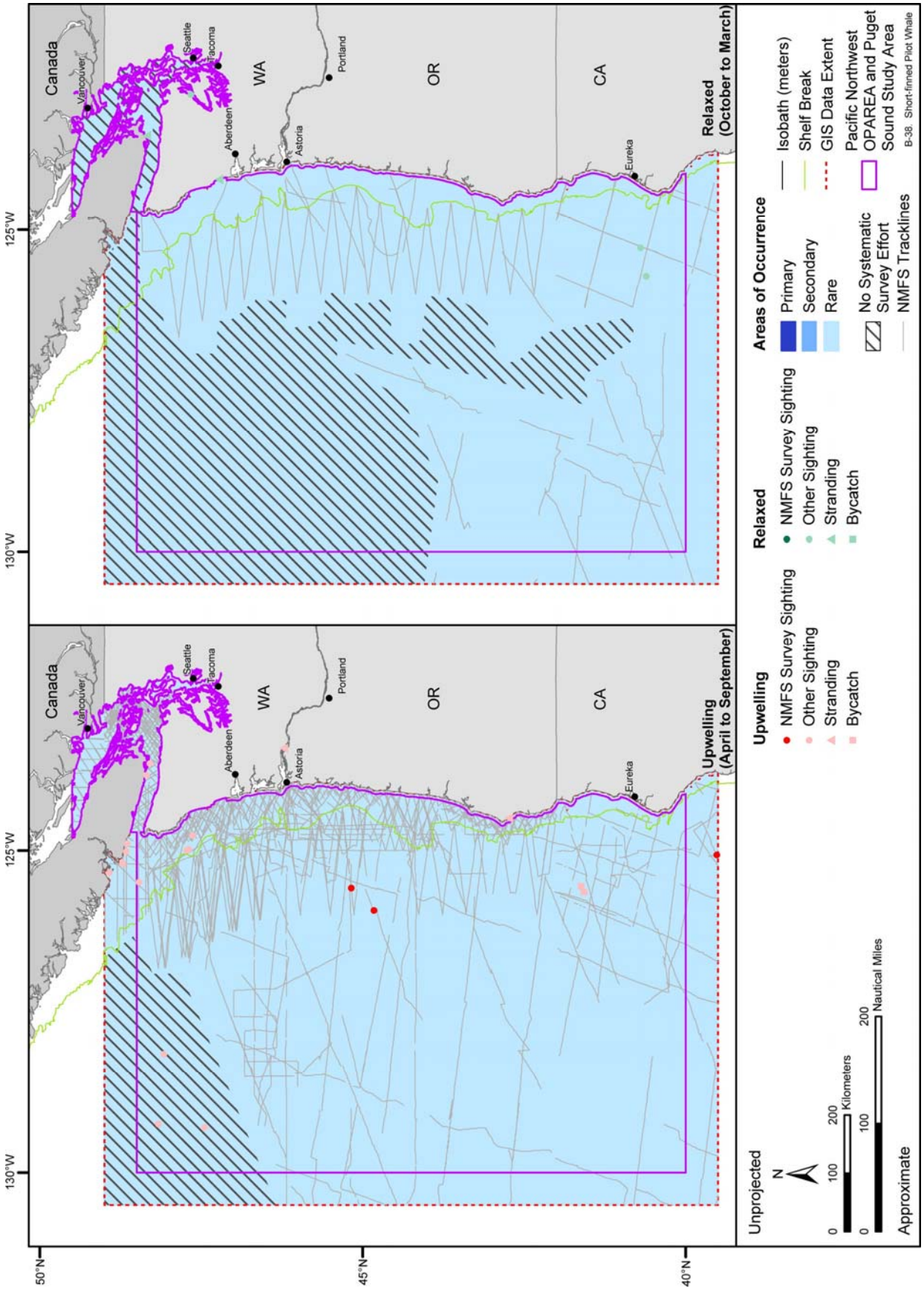

Figure B-38. Areas of occurrence for the short-finned pilot whale in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

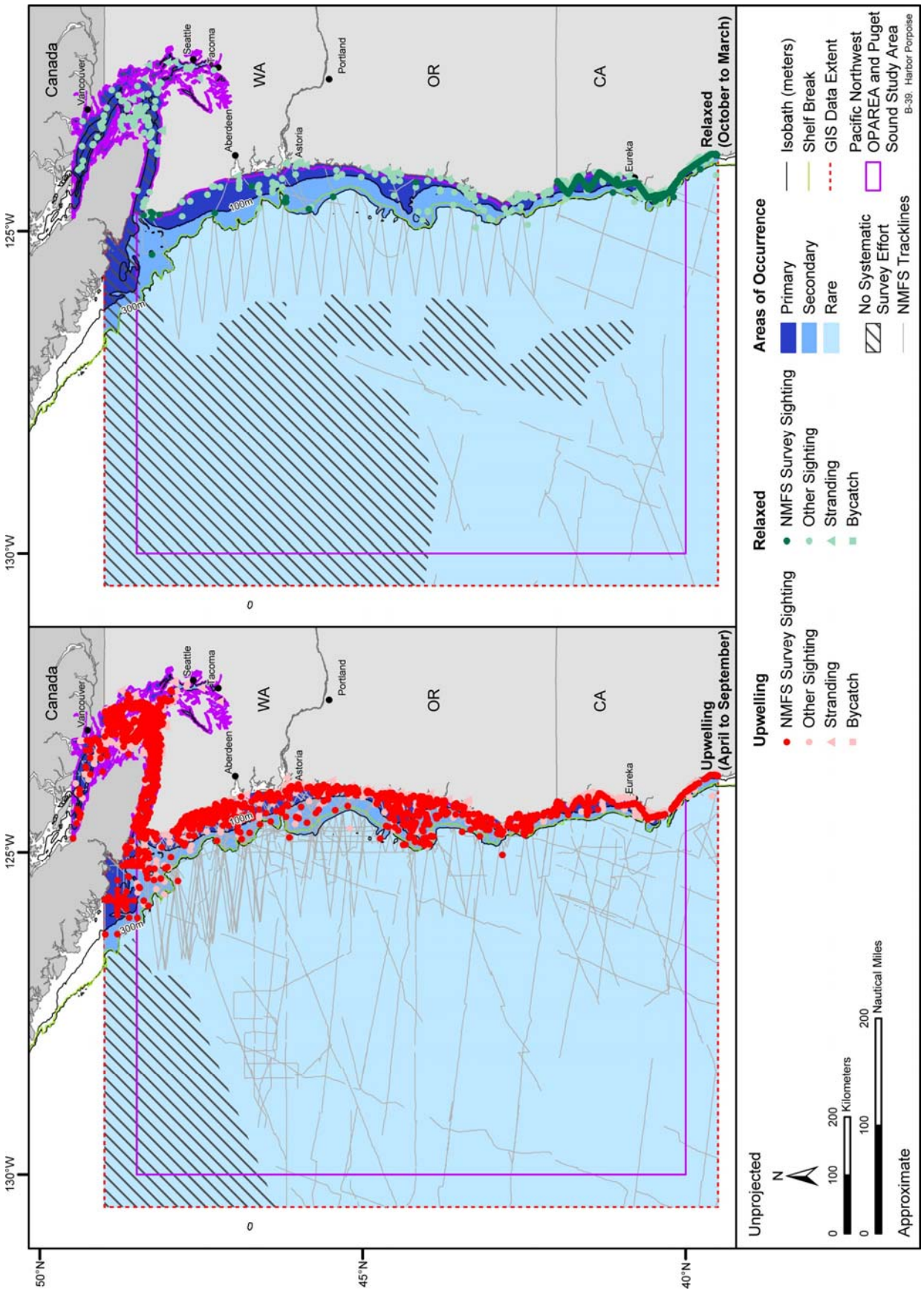

Figure B-39. Areas of occurrence for the harbor porpoise in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

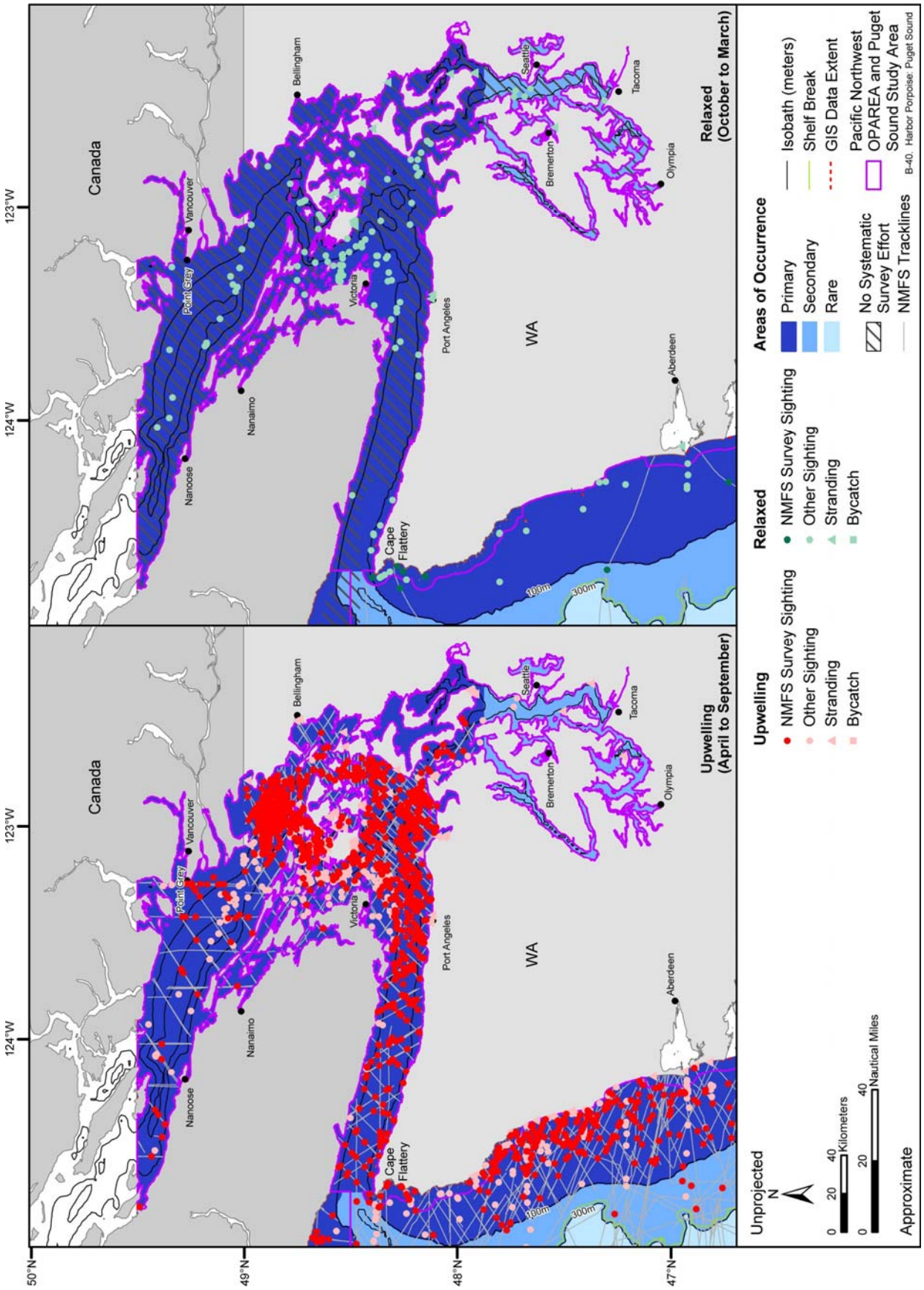

Figure B-40. Areas of occurrence for the harbor porpoise in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

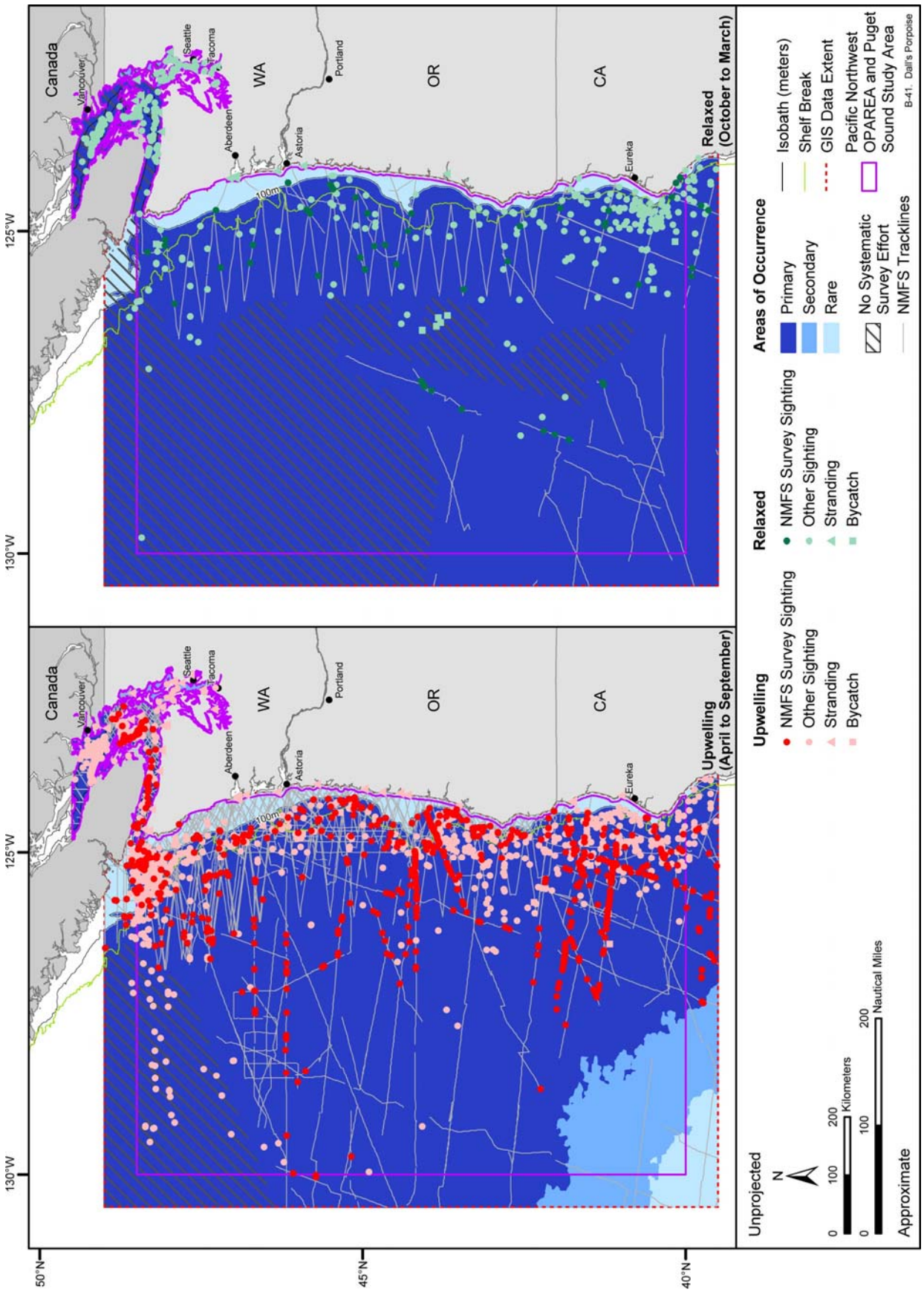

Figure B-41. Areas of occurrence for the Dall's porpoise in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

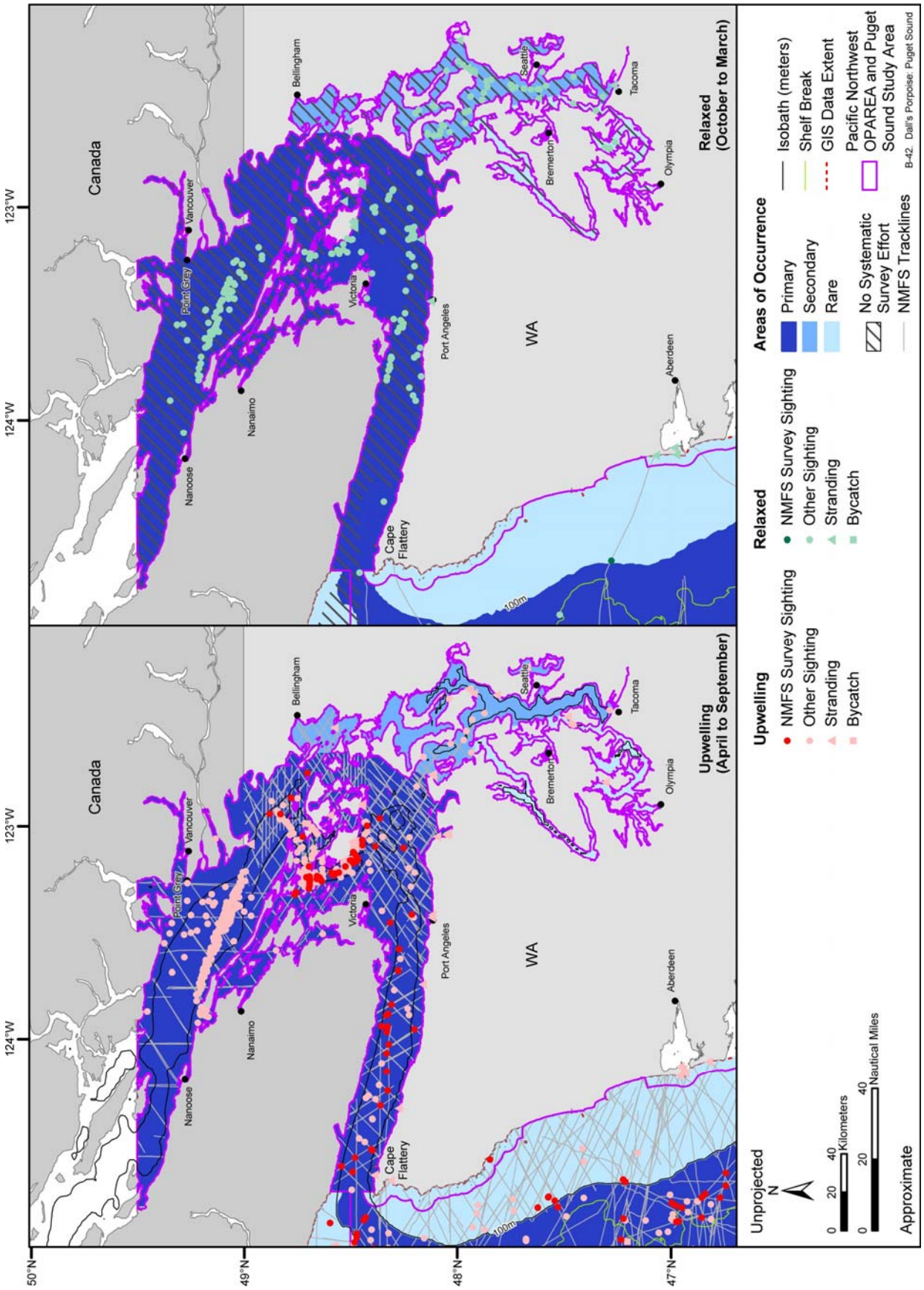

Figure B-42. Areas of occurrence for the Dall's porpoise in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

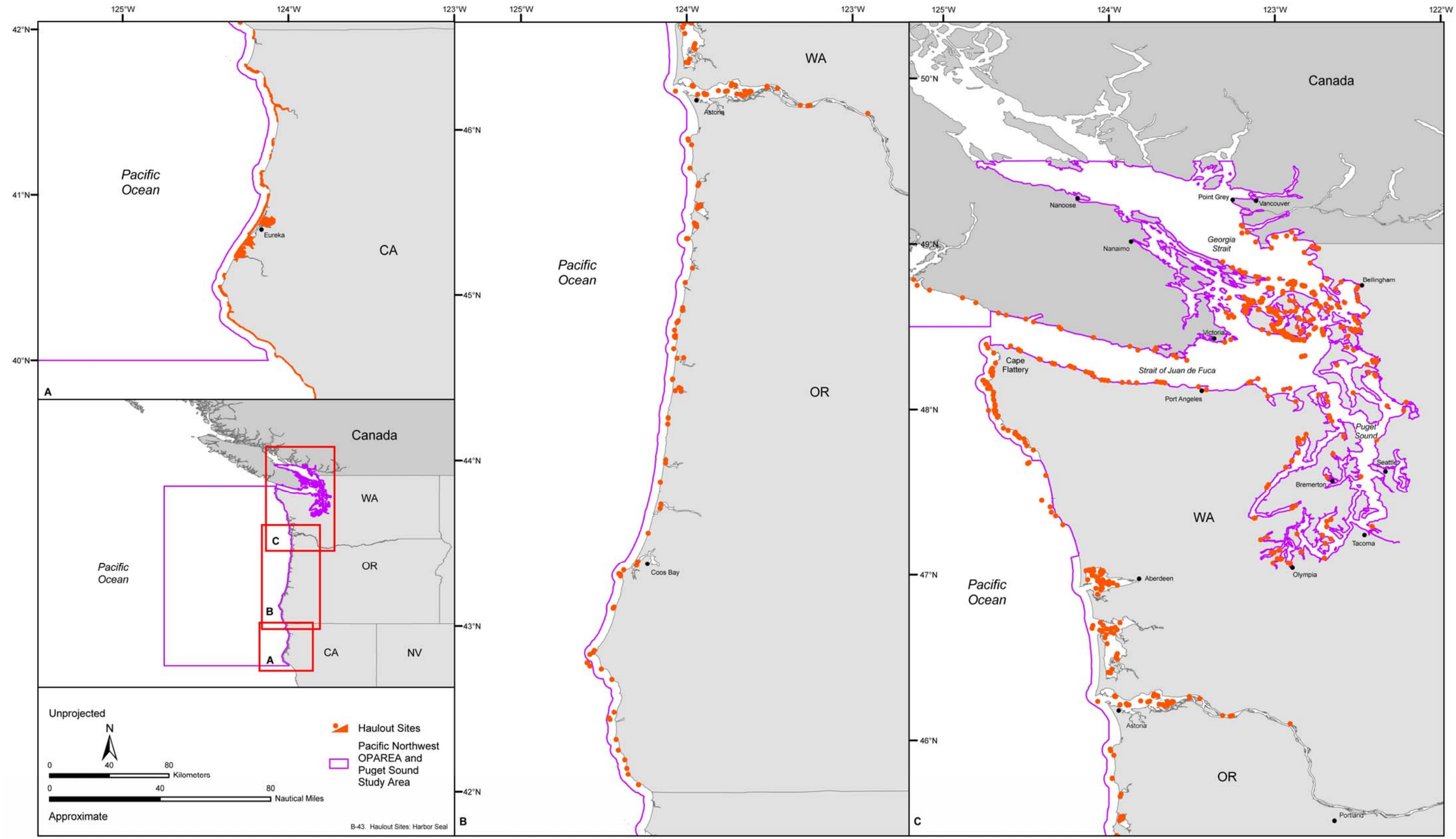

Figure B-43. Harbor seal haulout sites in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOS (2001), Oregon Ocean Coastal Management Program (2002), WDFW (2005), and Province of British Columbia.[7]

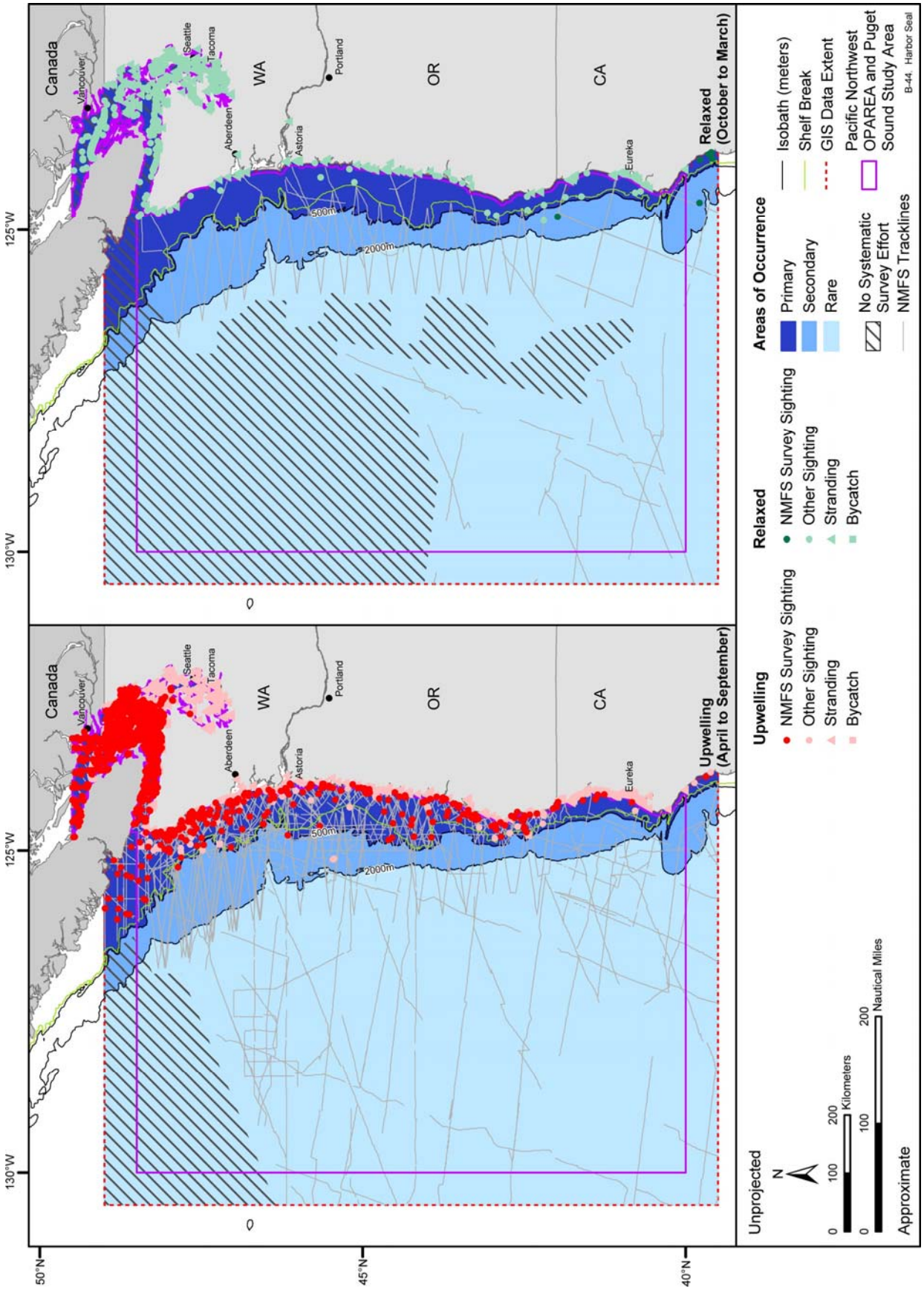

Figure B-44. Areas of occurrence for the harbor seal in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

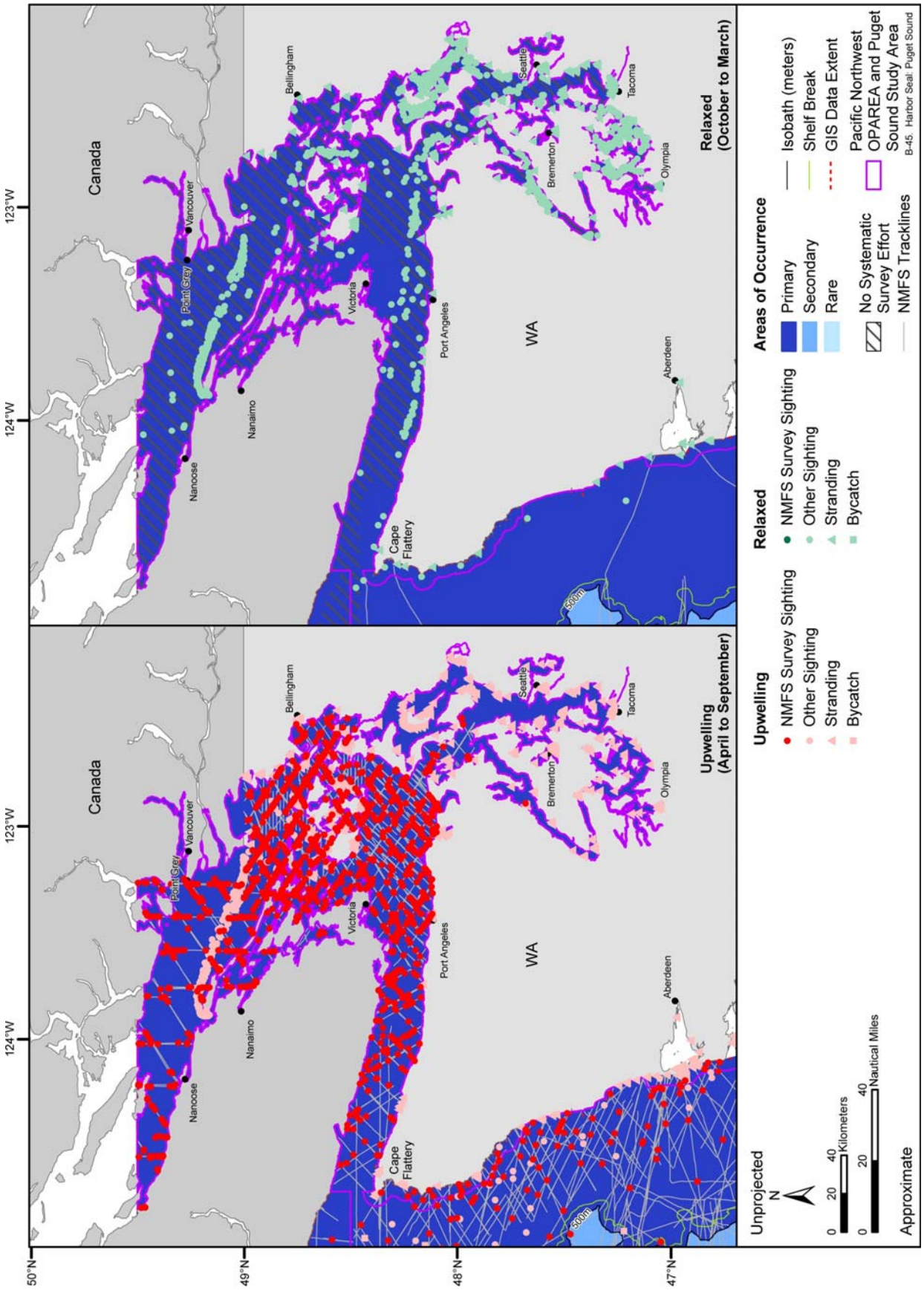

Figure B-45. Areas of occurrence for the harbor seal in the Puget Sound Study Area. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

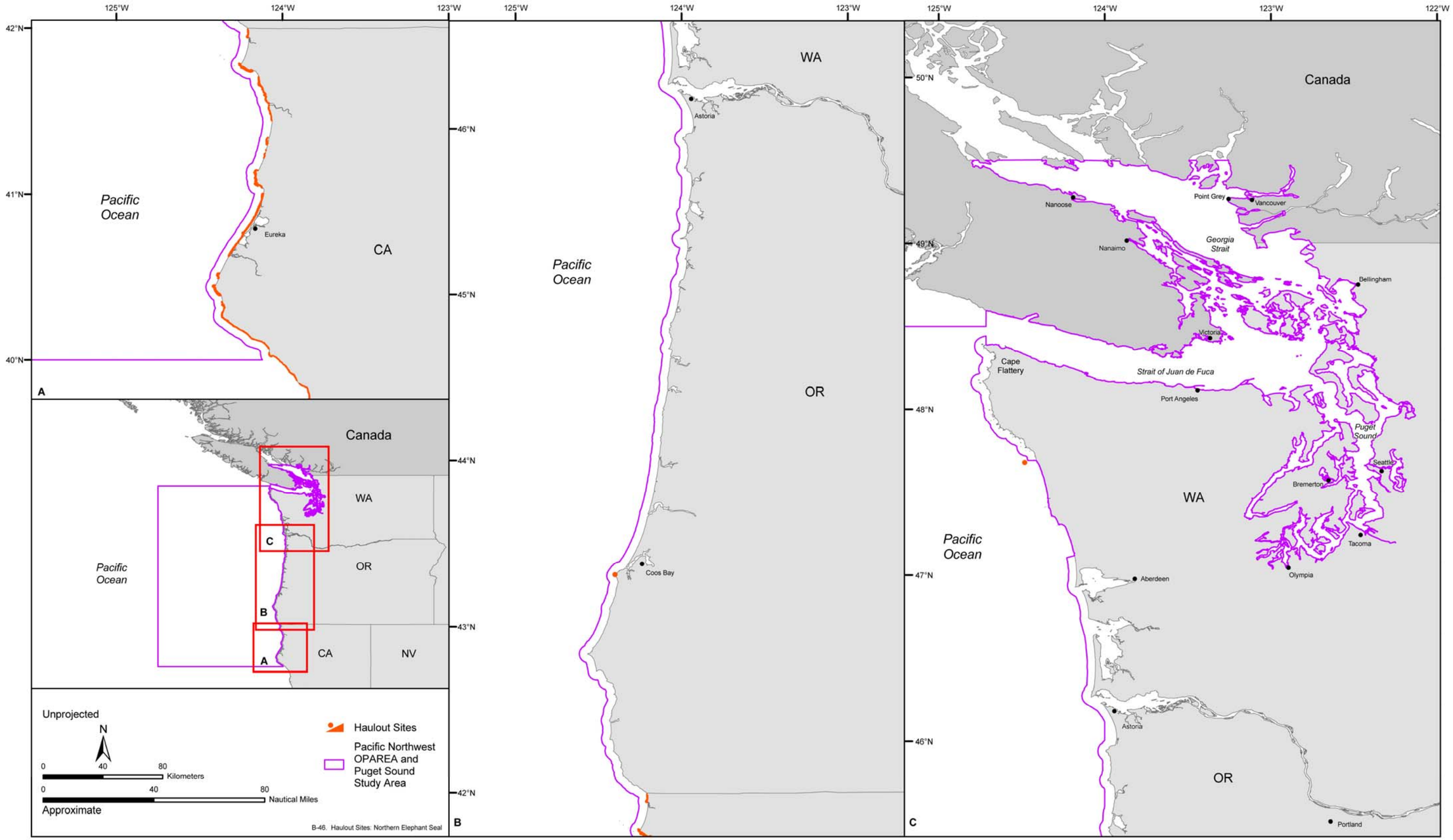

Figure B-46. Northern elephant seal haulout sites in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOS (2001), Oregon Ocean Coastal Management Program (2002), WDFW (2005), and Province of British Columbia.[7]

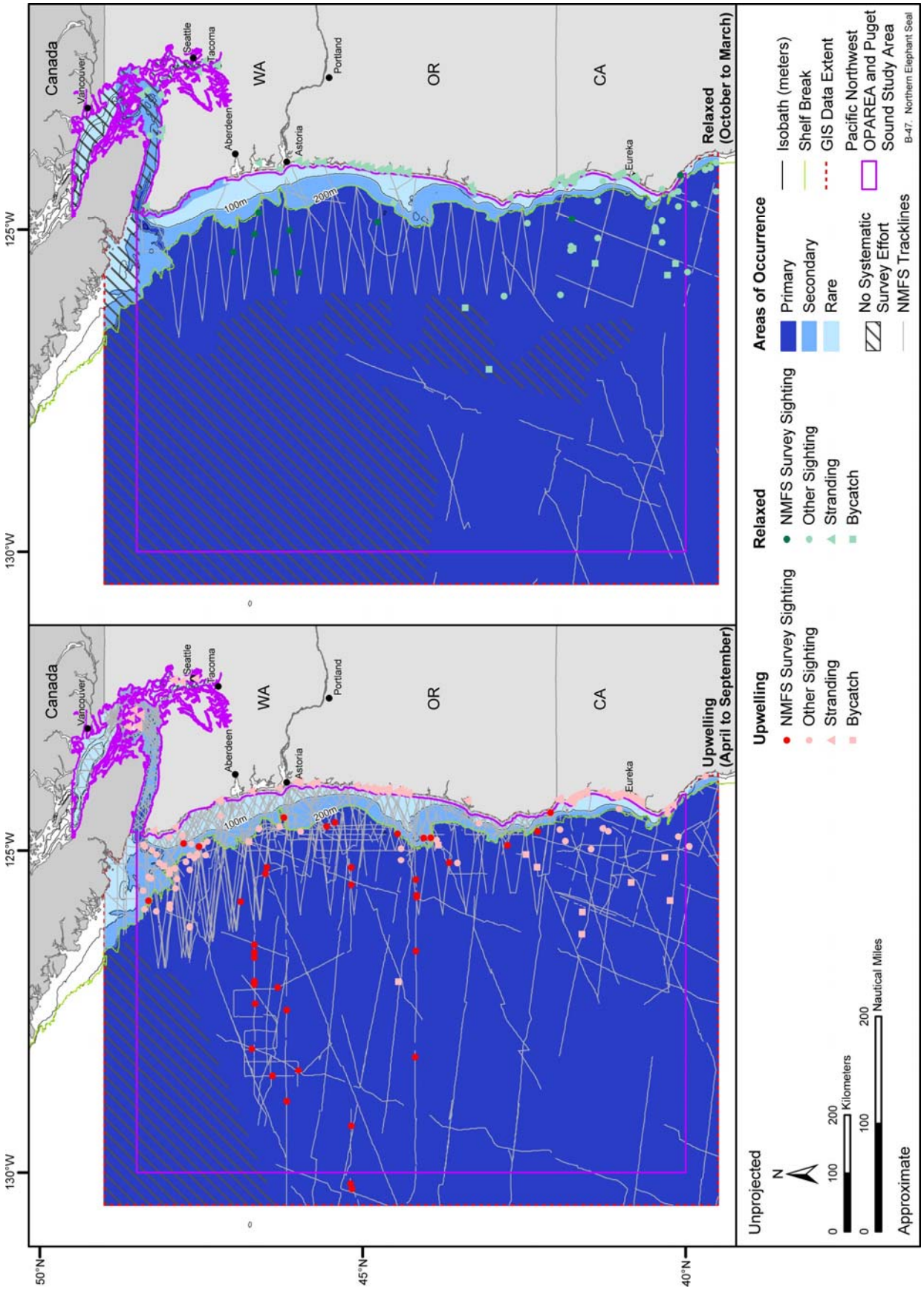

Figure B-47. Areas of occurrence for the northern elephant seal in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity, except during December through April when this species should occur further south in breeding areas. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

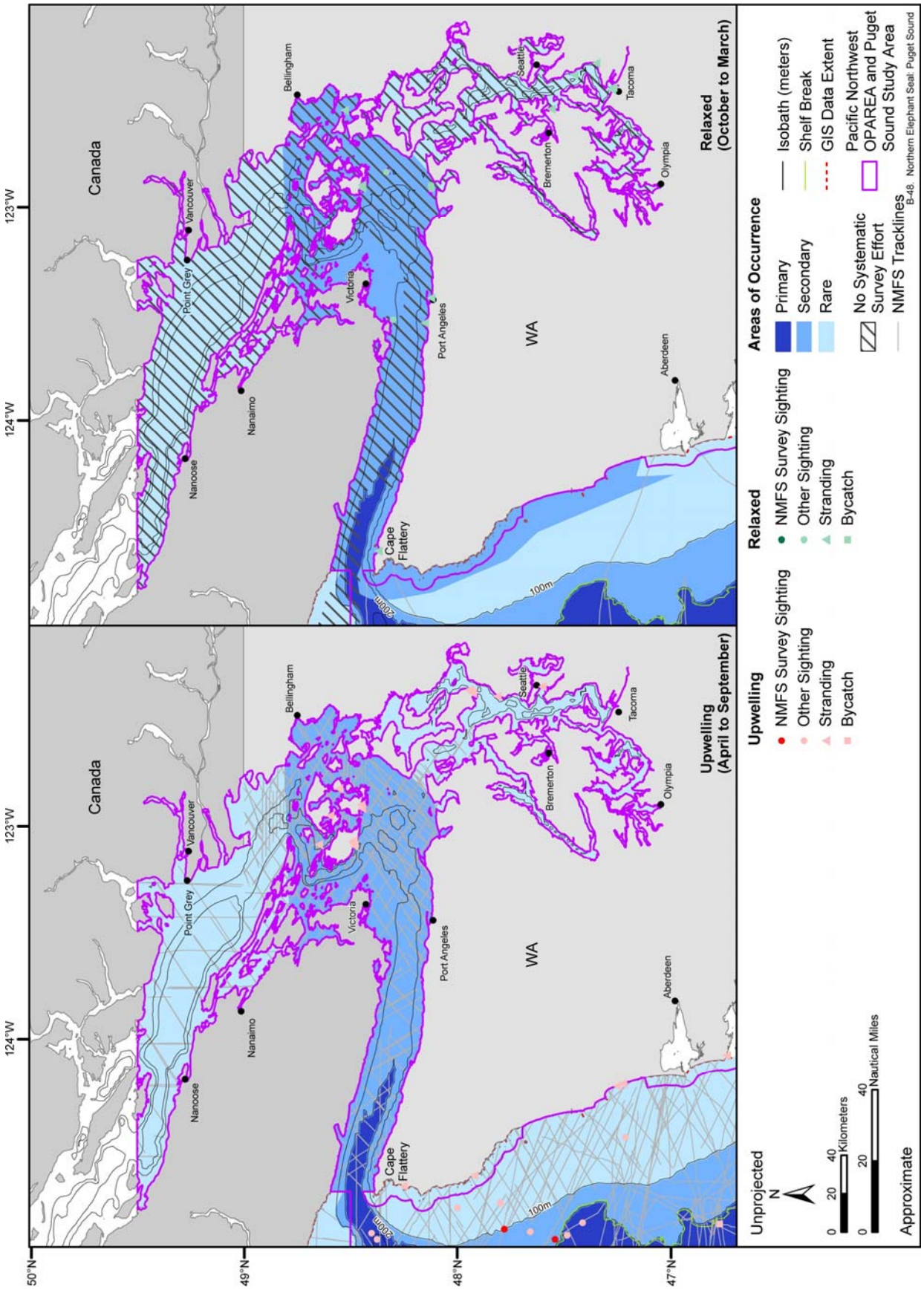

Figure B-48. Areas of occurrence for the northern elephant seal in the Puget Sound Study Area, except during December through April when this species should occur further south in breeding areas. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

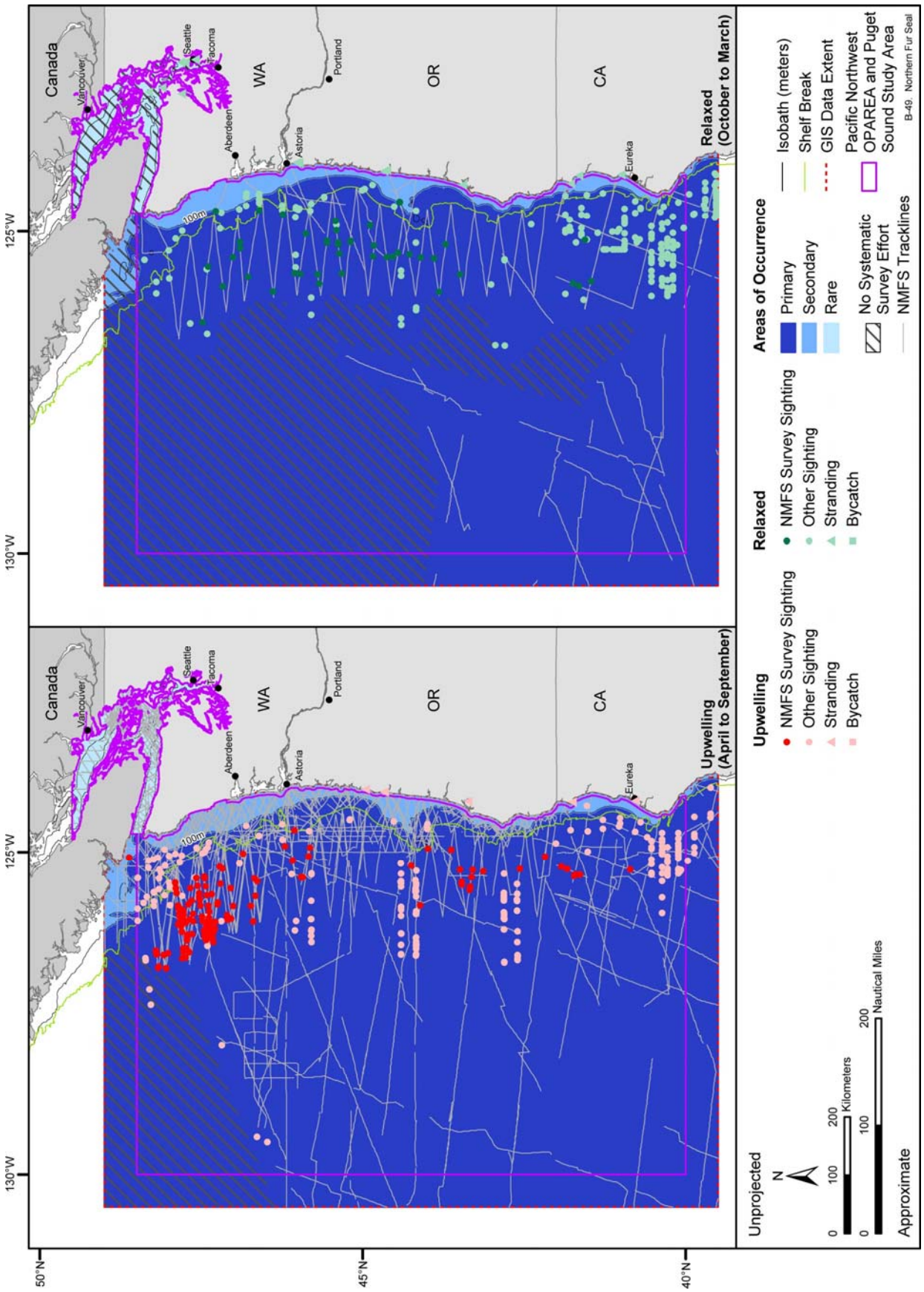

Figure B-49. Areas of occurrence for the northern fur seal in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

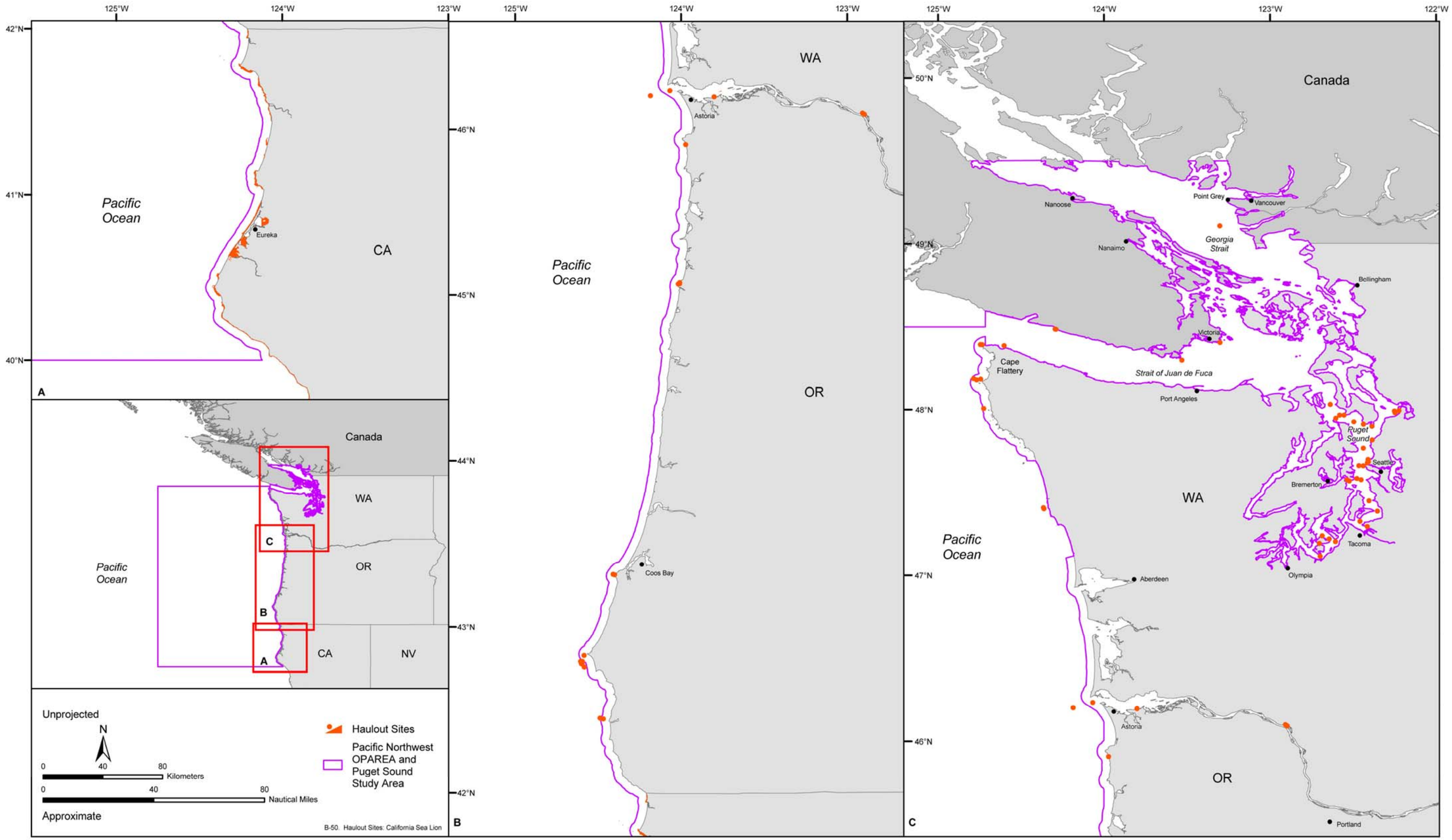

Figure B-50. California sea lion haulout sites in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NOS (2001), Oregon Ocean Coastal Management Program (2002), WDFW (2005), and Province of British Columbia.[7]

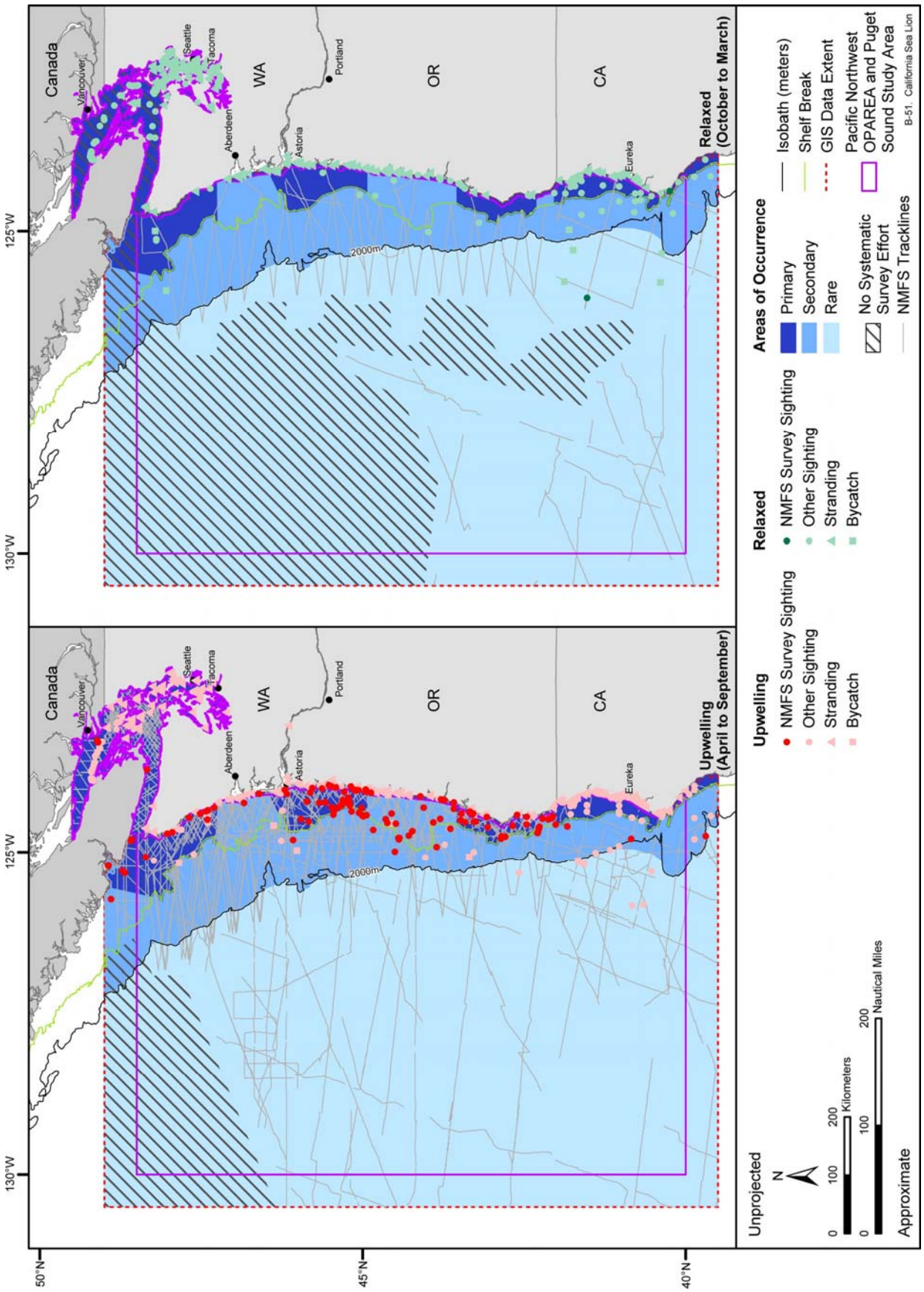

Figure B-51. Areas of occurrence for the California sea lion in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity, except during June and July when this species occurs further south in breeding areas. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

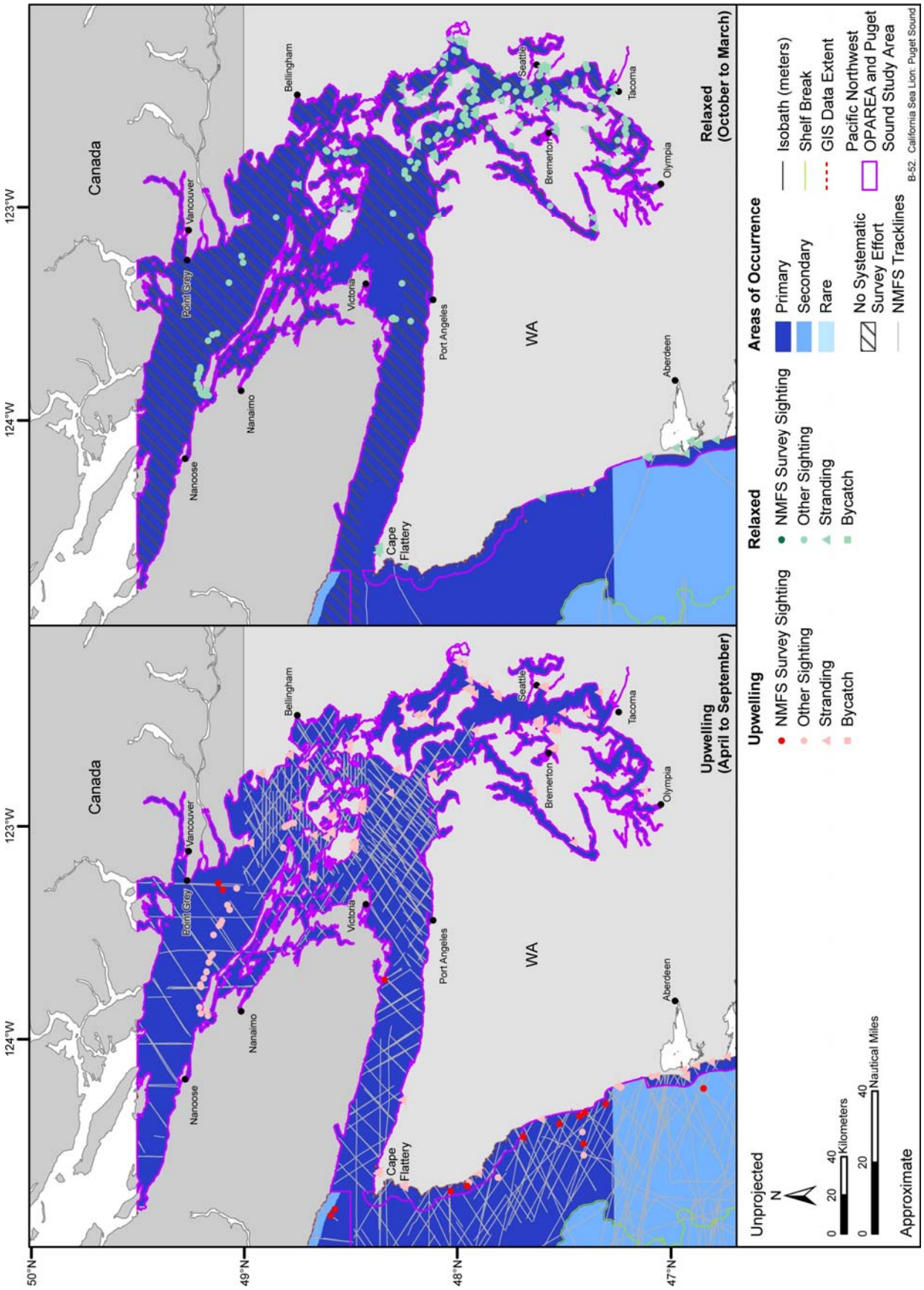

Figure B-52. Areas of occurrence for the California sea lion in the Puget Sound Study Area, except during June and July when this species should occur further south in breeding areas. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

APPENDIX C: SEA TURTLES

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C-1	Areas of occurrence for all sea turtles in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
C-2	Areas of occurrence for the leatherback turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
C-3	Areas of occurrence for the green turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
C-4	Areas of occurrence for the loggerhead turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
C-5	Areas of occurrence for the olive ridley turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.

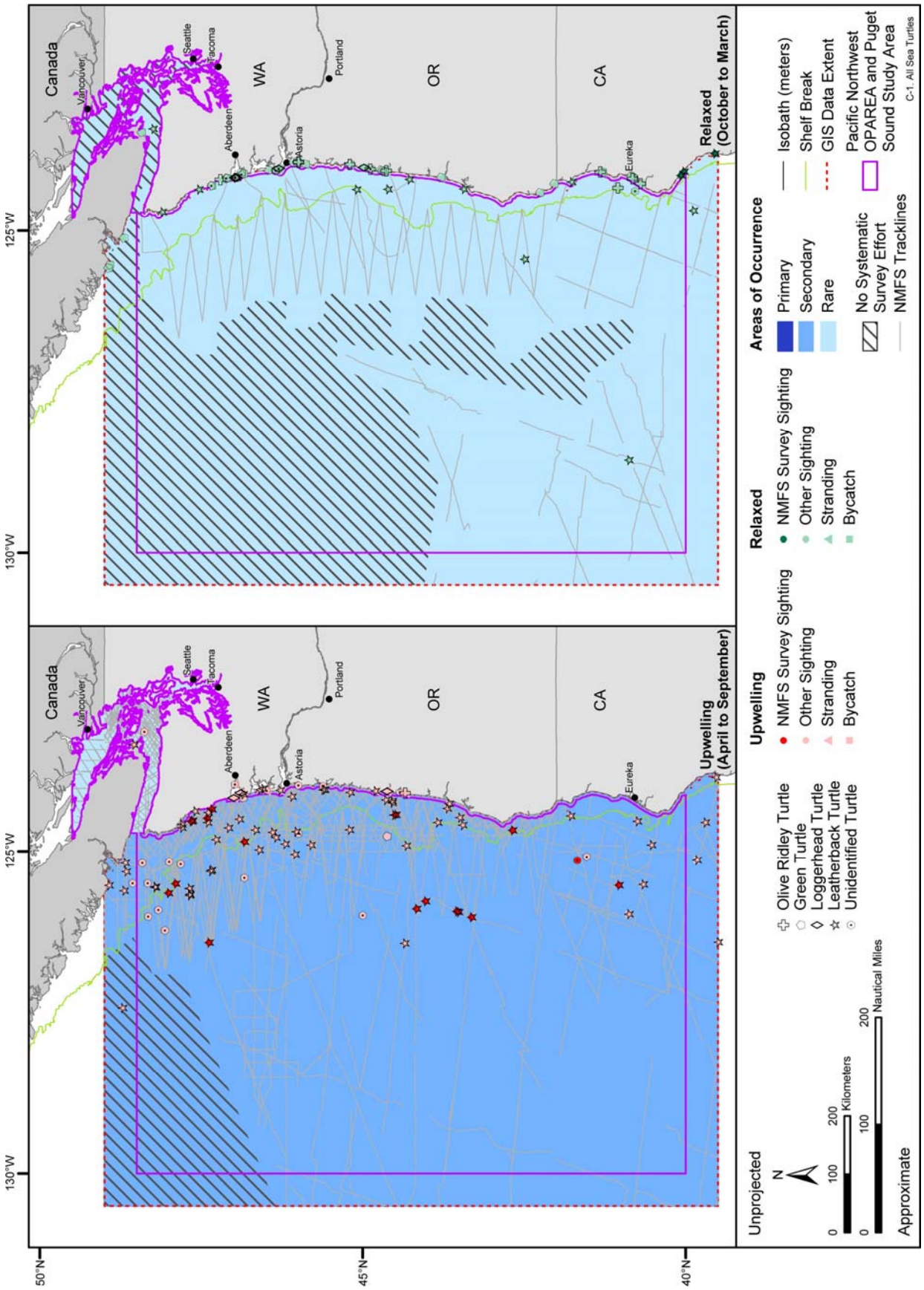

Figure C-1. Areas of occurrence for all sea turtles in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

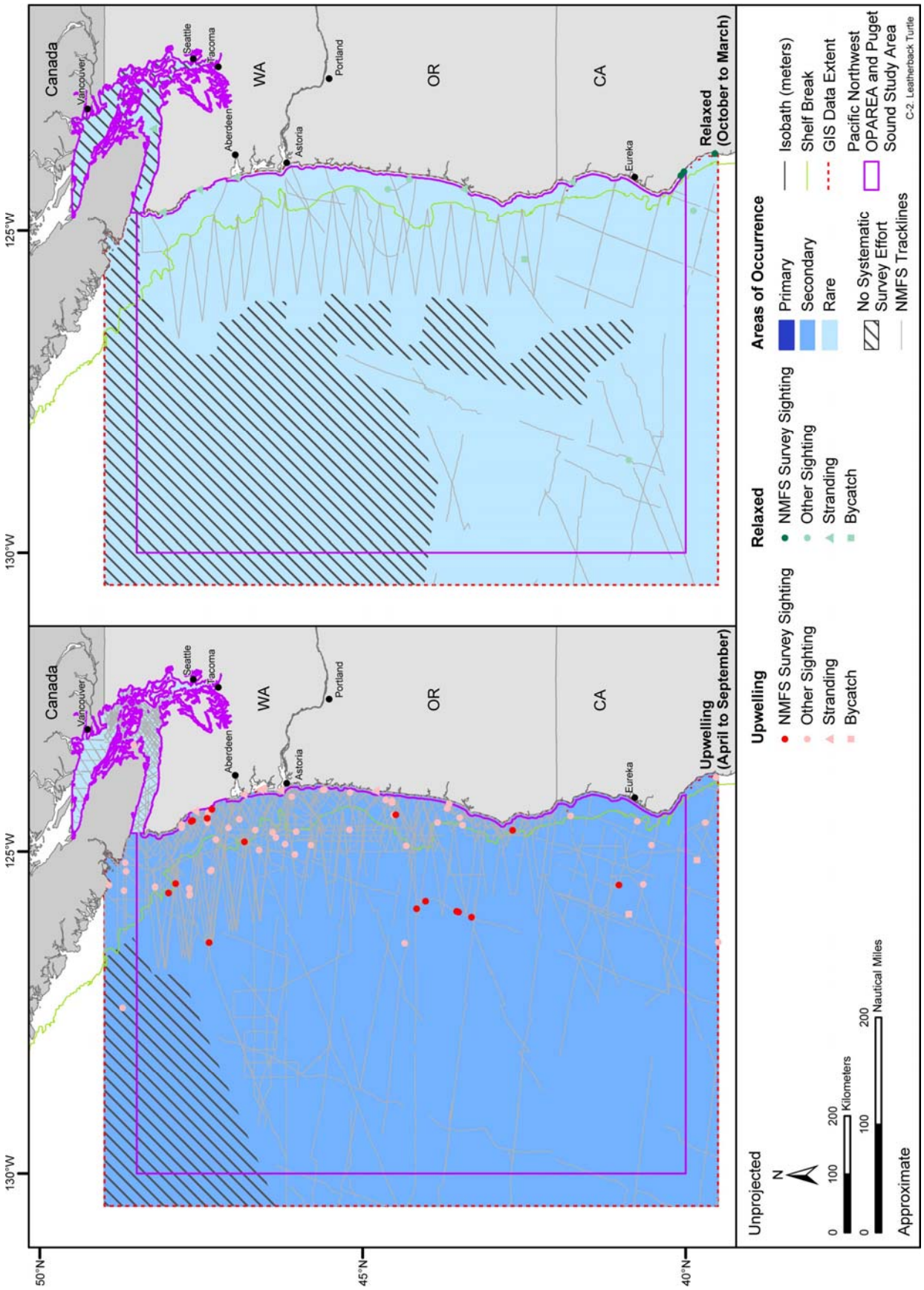

Figure C-2. Areas of occurrence for the leatherback turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

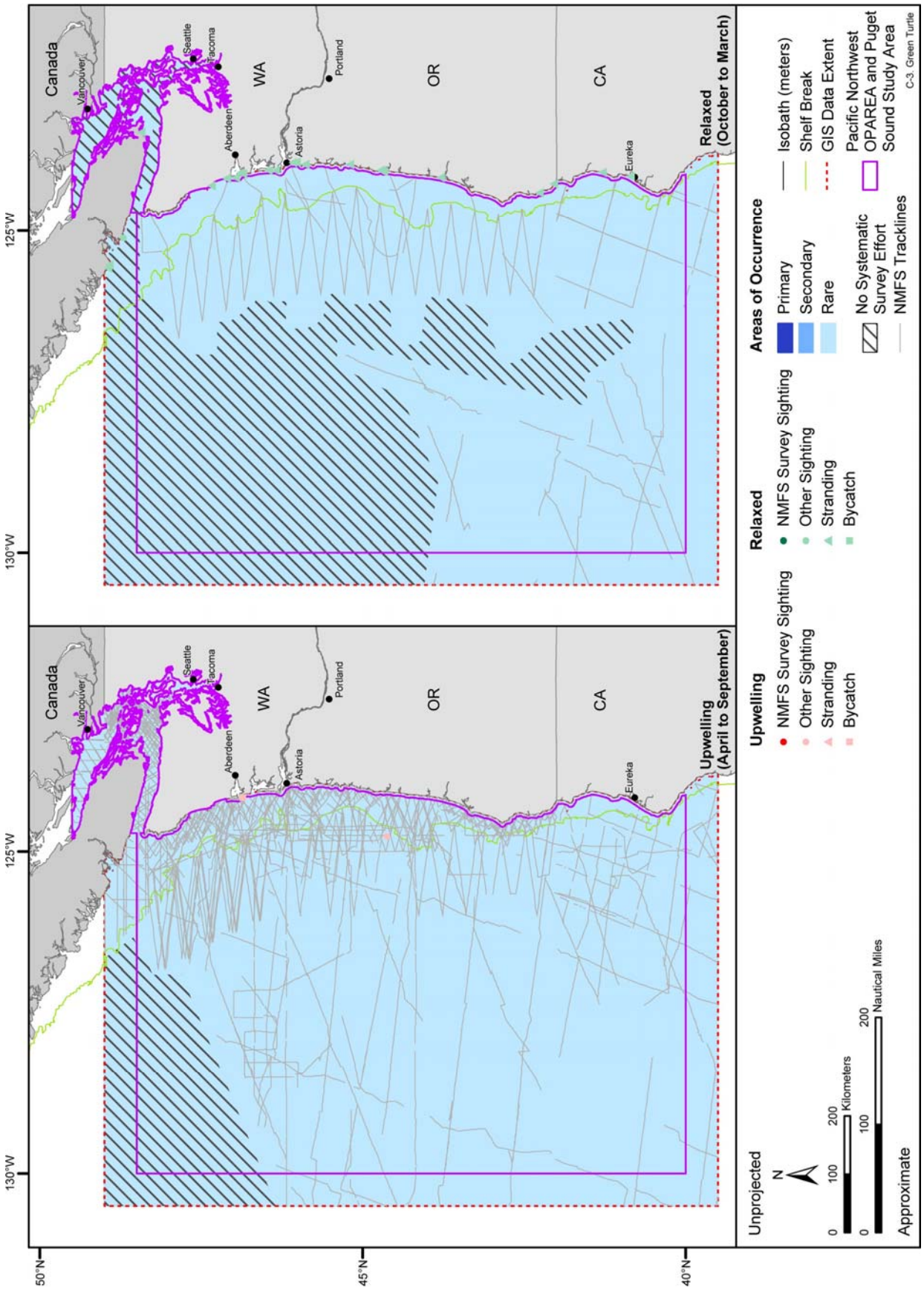

Figure C-3. Areas of occurrence for the green turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

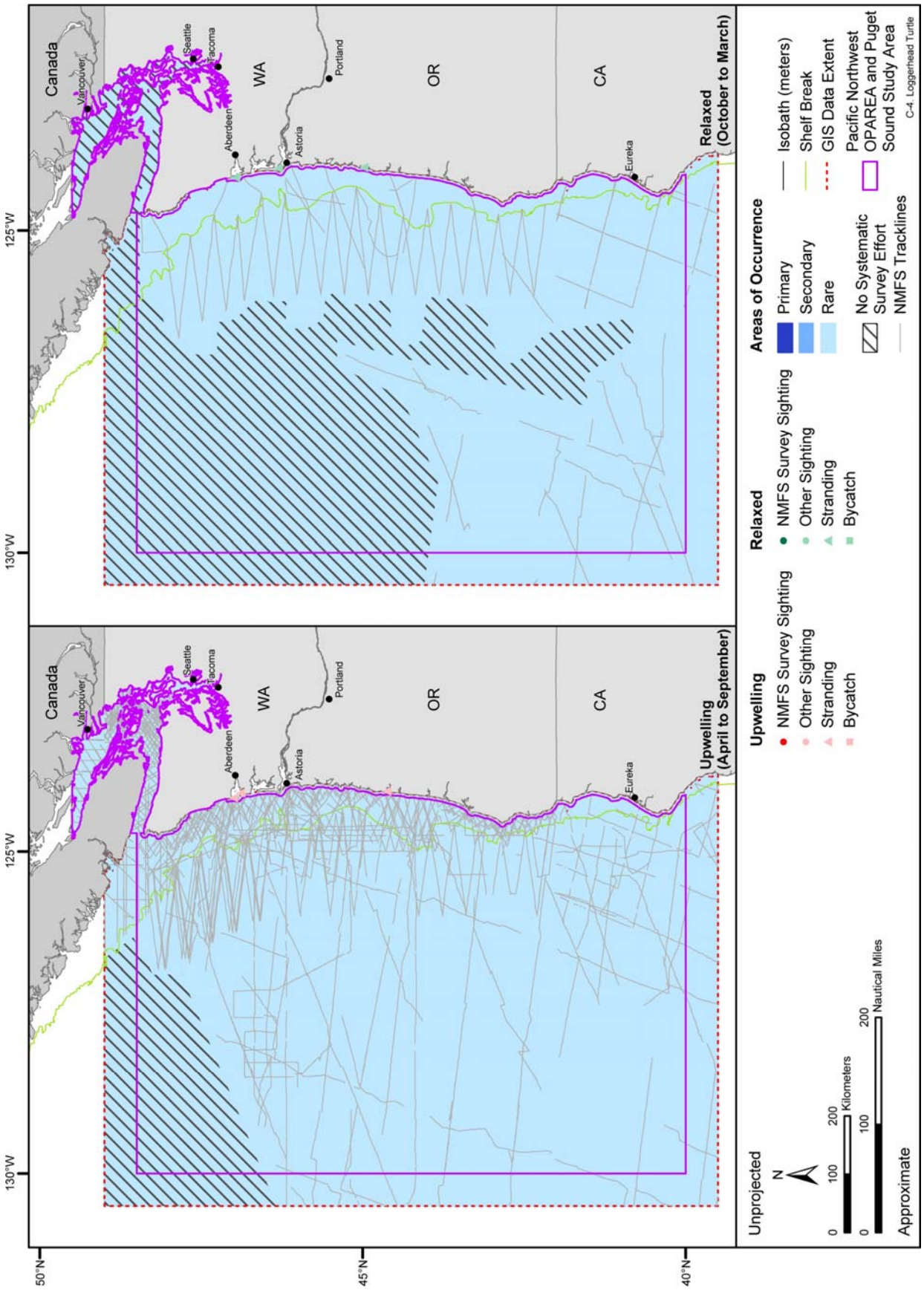

Figure C-4. Areas of occurrence for the loggerhead turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

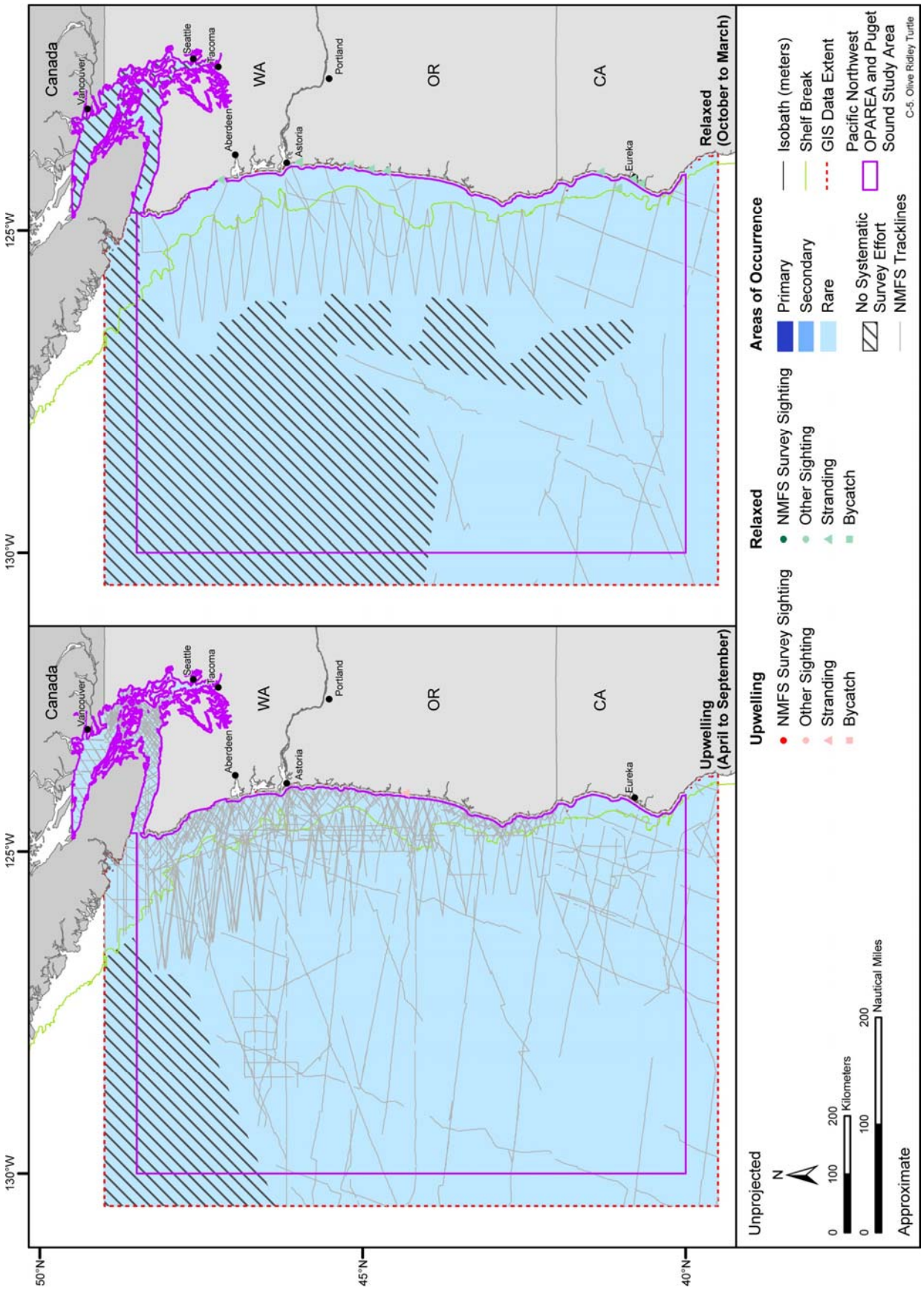

Figure C-5. Areas of occurrence for the olive ridley turtle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which are also depicted on the map. Source data: refer to Table A-1.

APPENDIX D: BIRDS

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D-2	Foraging habitat and recorded sightings of the brown pelican in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
D-3	Foraging habitat and recorded sightings of the marbled murrelet in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
D-4	Foraging habitat and recorded sightings of the short-tailed albatross in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
D-5	Foraging habitat of the western snowy plover in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.

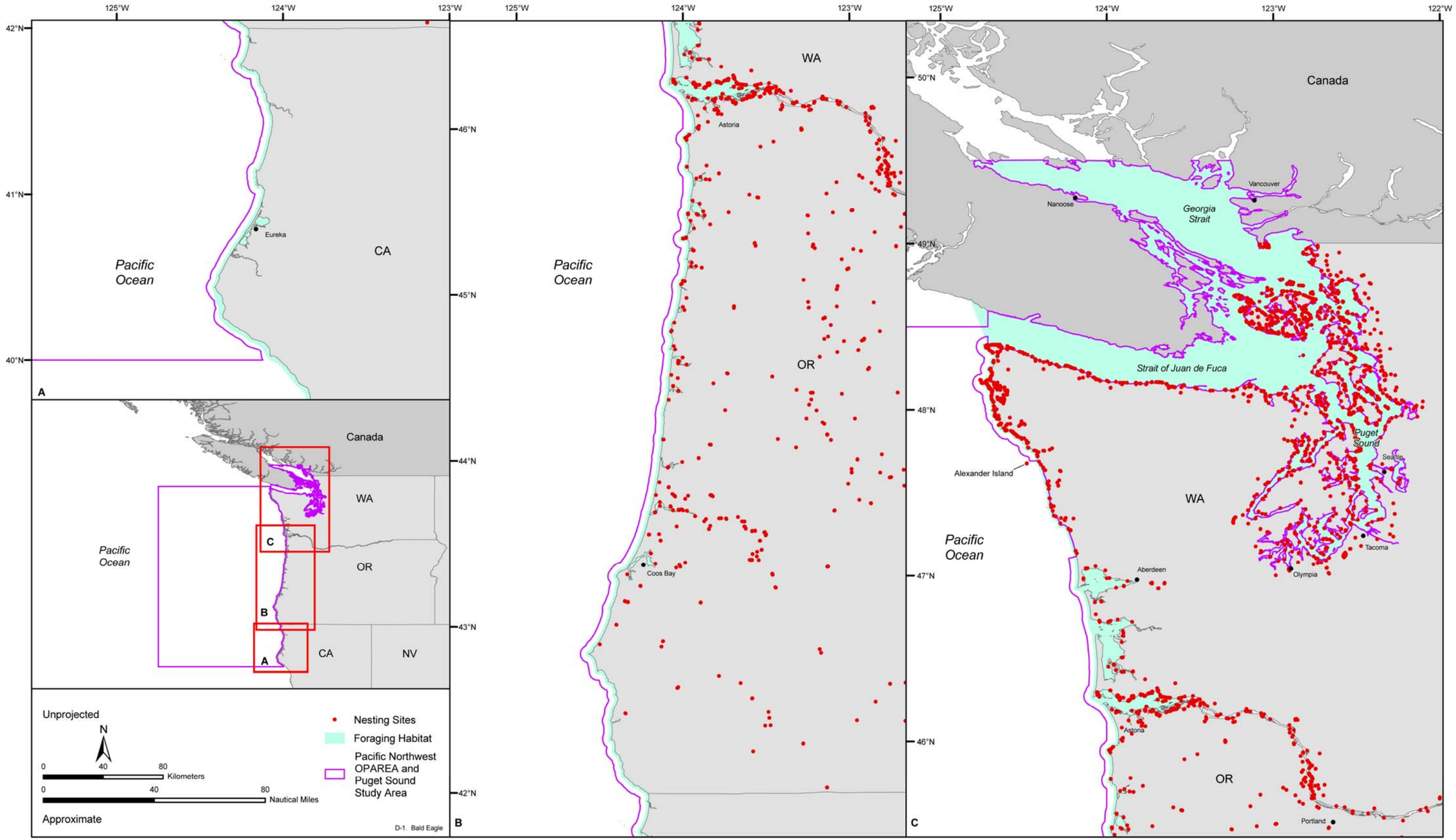

Figure D-1. Foraging habitat and nesting sites of the bald eagle in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: Isaacs and Anthony (2004).

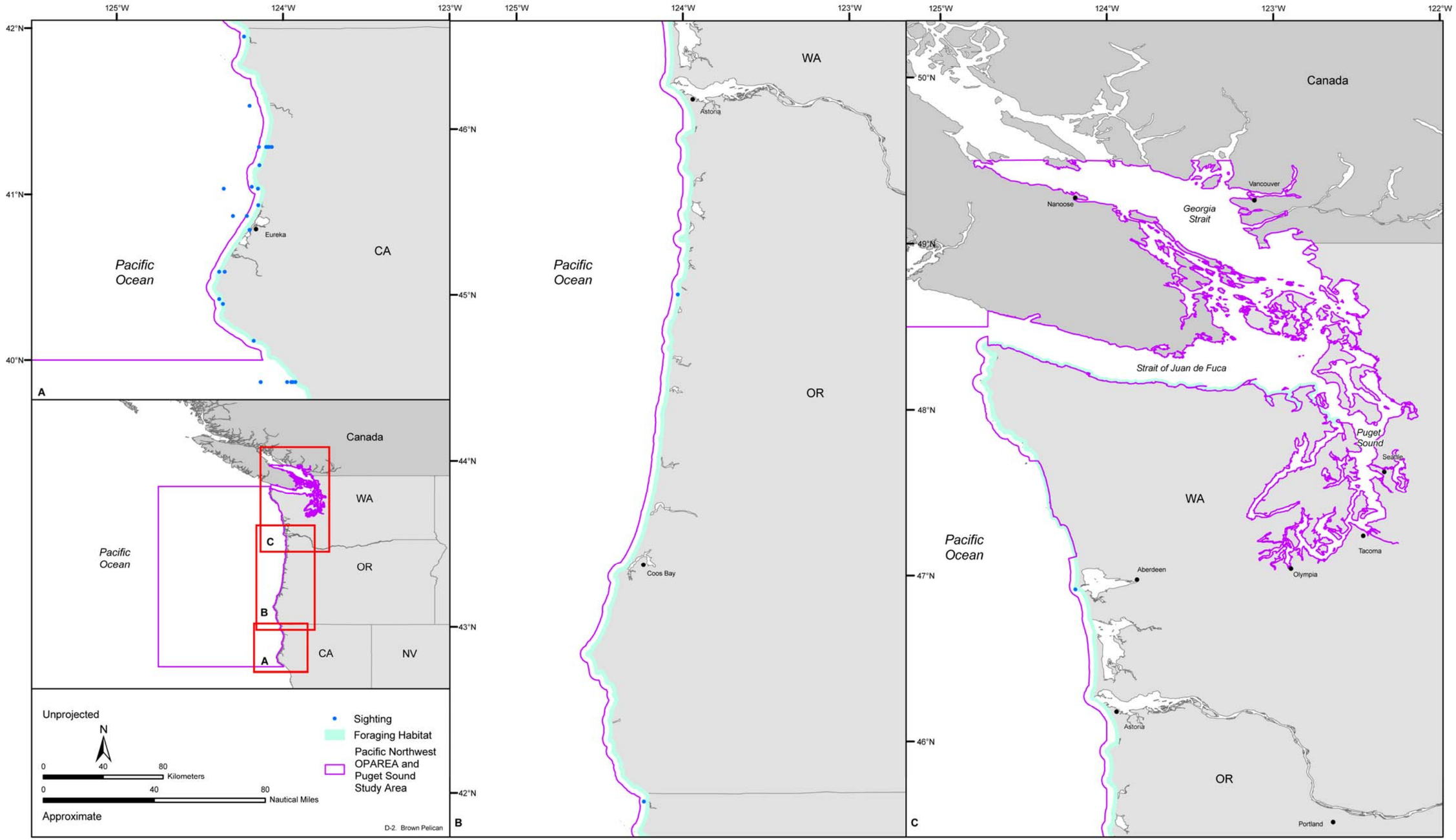

Figure D-2. Foraging habitat and recorded sightings of the brown pelican in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.

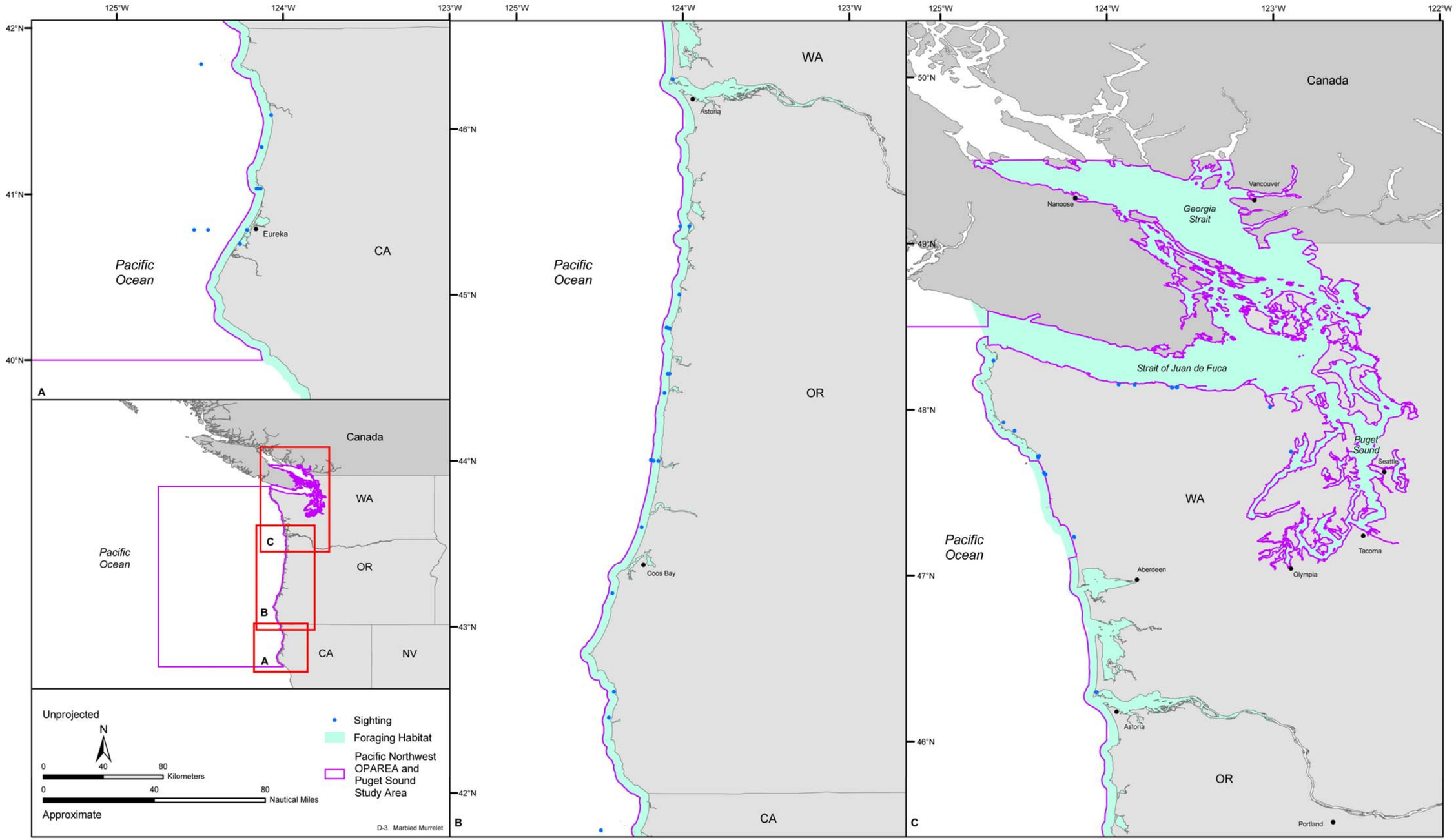

Figure D-3. Foraging habitat and recorded sightings of the marbled murrelet in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.

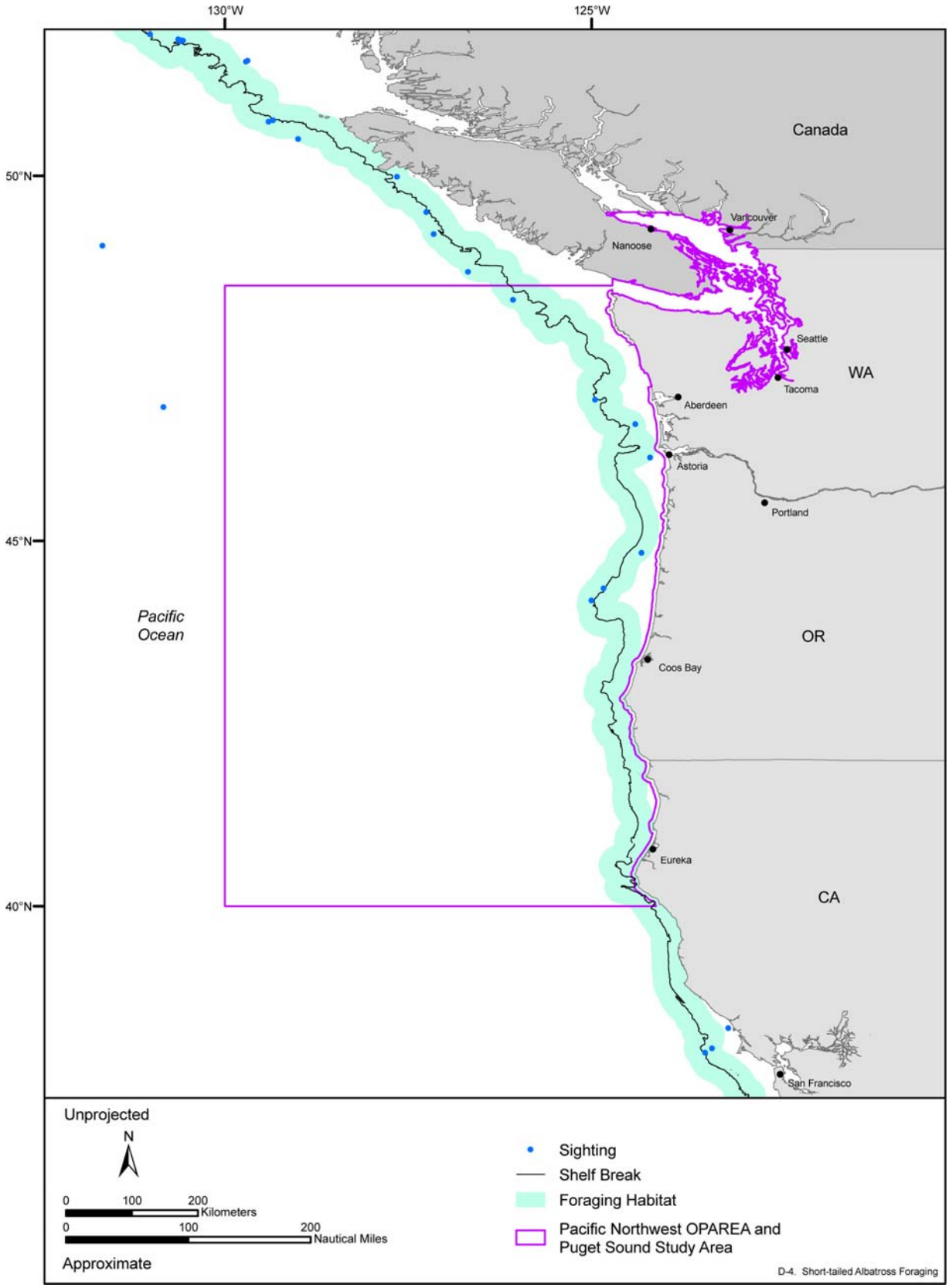

Figure D-4. Foraging habitat and recorded sightings of the short-tailed albatross in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: NPPSD (2005a, 2005b).

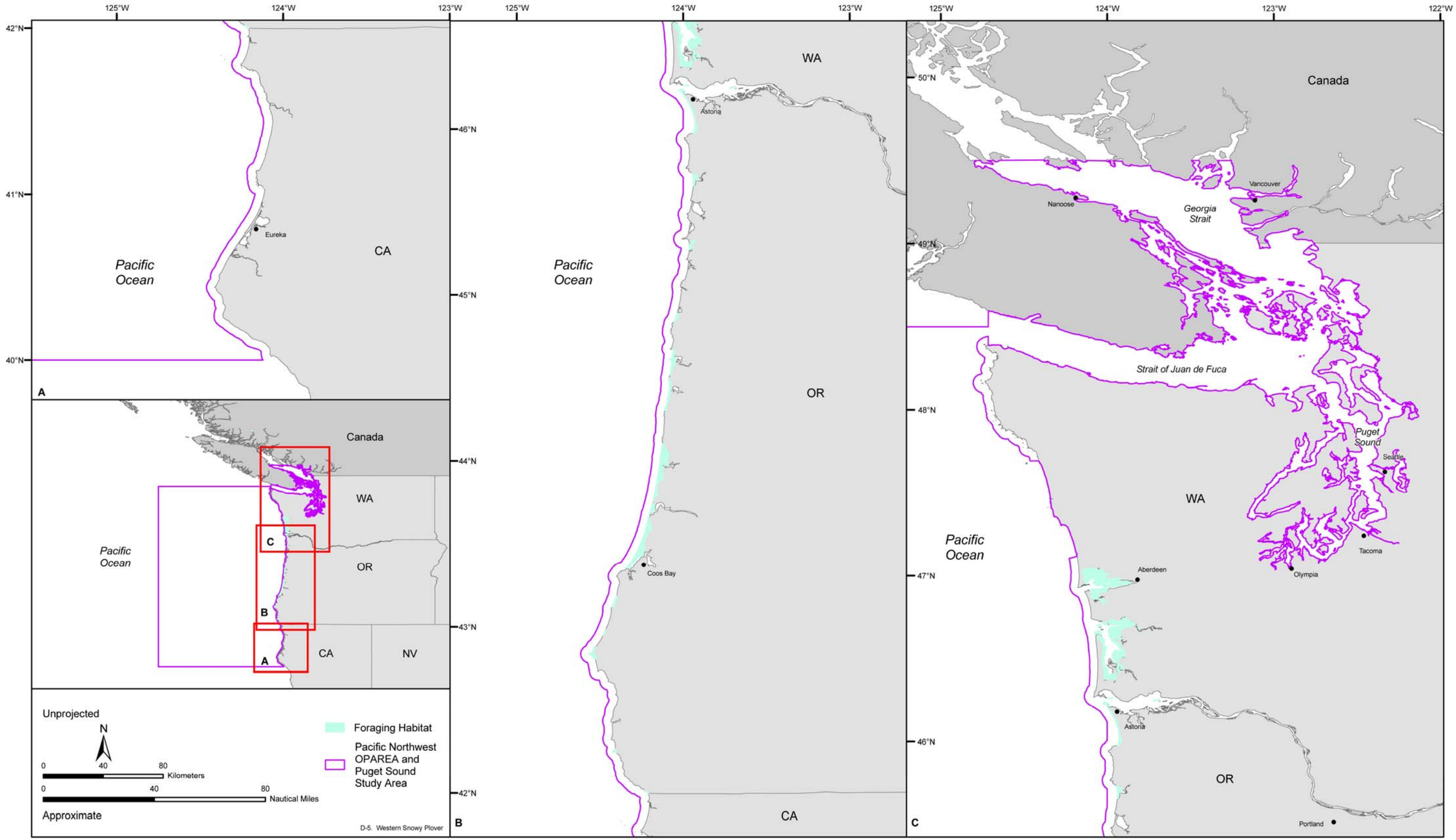

Figure D-5. Foraging habitat of the western snowy plover in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.

APPENDIX E: FISH

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E-3	Essential habitat for *Euphasia pacifica* and *Thysanoessa spinifera* in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
E-4	EFH designated for areas with 100% of the area with a Habitat Suitability Probability (HSP) greater than zero and any additional areas with seafloor depths of 3,500 meters or less in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity.
E-5	EFH for the adult (73 m to 127°W longitude north of the Mendocino Escarpment and 73 to 3,475 m south of the Mendocino Escarpment) lifestage of the common thresher shark designated in the Pacific Northwest OPAREA and vicinity.
E-6	EFH for the adult (1,463 m to EEZ) lifestage of the bigeye thresher shark designated in the Pacific Northwest OPAREA and vicinity.
E-7	EFH for the neonate/small juvenile (1,829 to 3,658 m south of Cape Mendocino and 1,829 m to EEZ north of Cape Mendocino) and large juvenile/subadult/adult (1,829 m to EEZ) lifestages of the shortfin mako shark designated in the Pacific Northwest OPAREA and vicinity.
E-8	EFH for all (1,829 m to EEZ) lifestages of the blue shark designated in the Pacific Northwest OPAREA and vicinity.
E-9	EFH for the juvenile/adult (183 m to EEZ) lifestages of the albacore tuna designated in the Pacific Northwest OPAREA and vicinity.
E-10	EFH for the juvenile (183 m to EEZ) lifestage of the northern bluefin tuna designated in the Pacific Northwest OPAREA and vicinity.
E-11	EFH for the juvenile/adult (1,829 m to EEZ) lifestages of the broadbill swordfish designated in the Pacific Northwest OPAREA and vicinity.

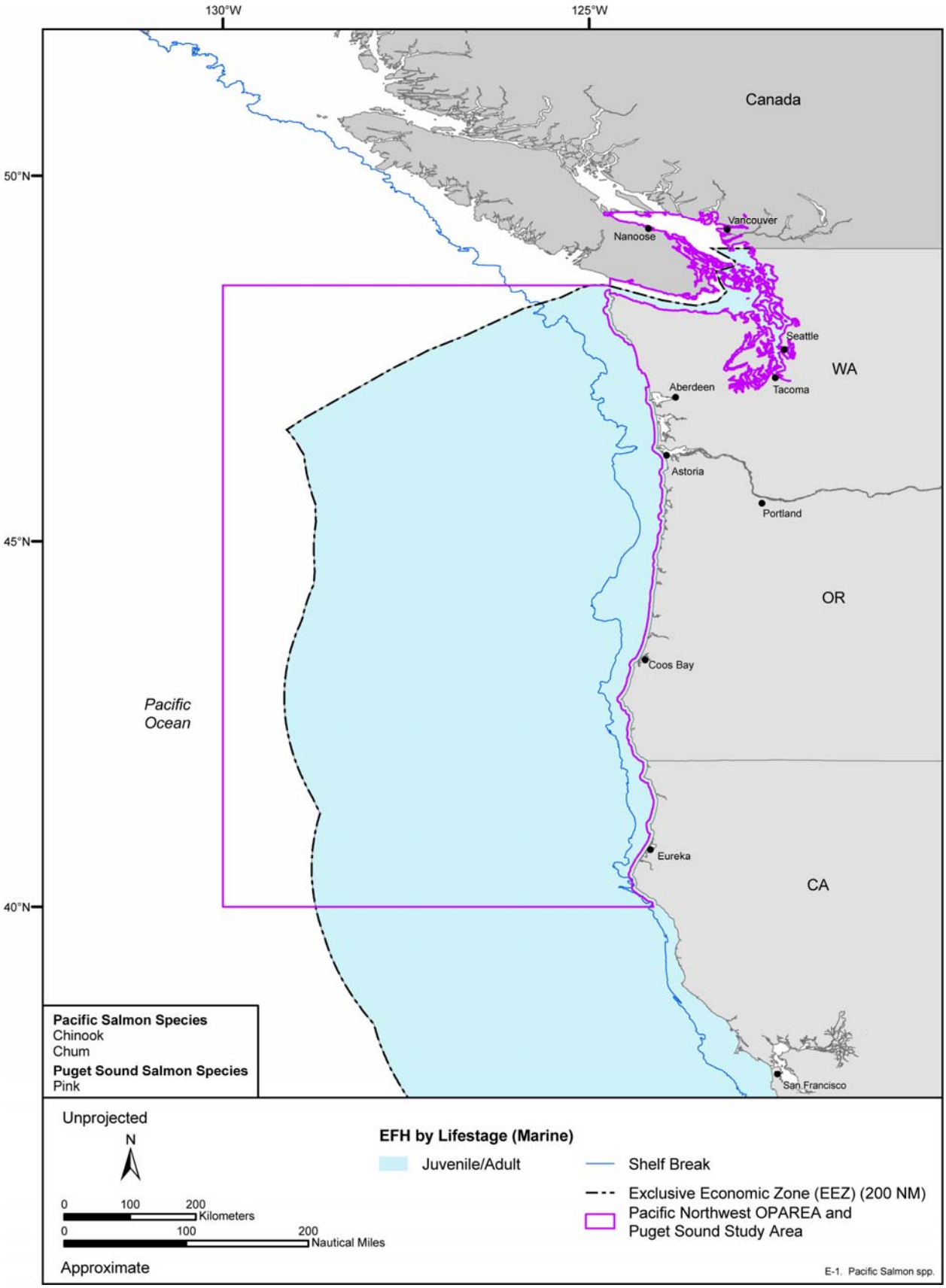

Figure E-1. EFH for all marine lifestages of Pacific salmon designated in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Map adapted from: PFMC (2000).

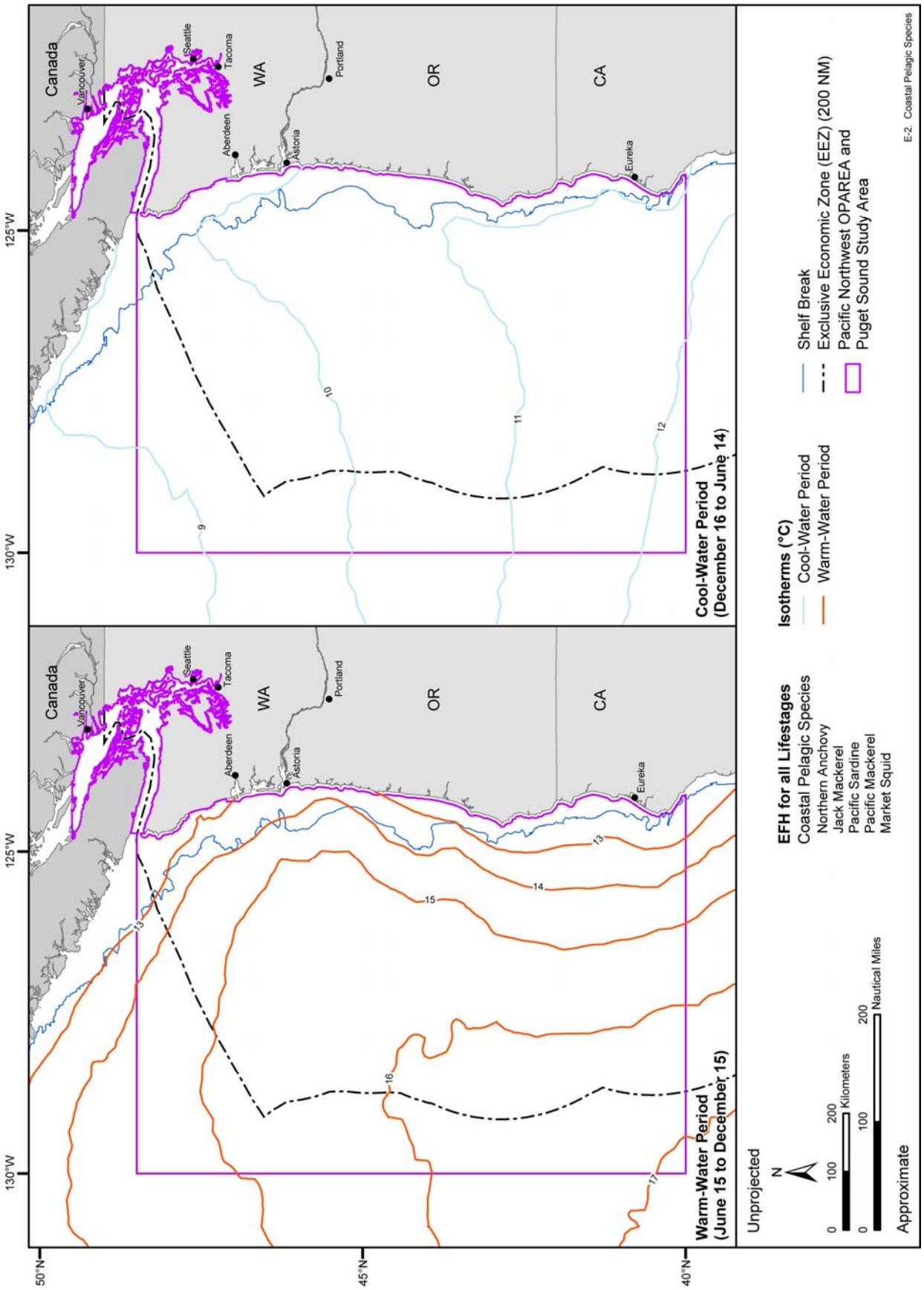

Figure E-2. Estimated EFH for all lifestages of coastal pelagic species designated Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity based on warmest and coldest year averages from 1982 through 2001. Source data: NASA.[1] Source information: PFMC (1998a).

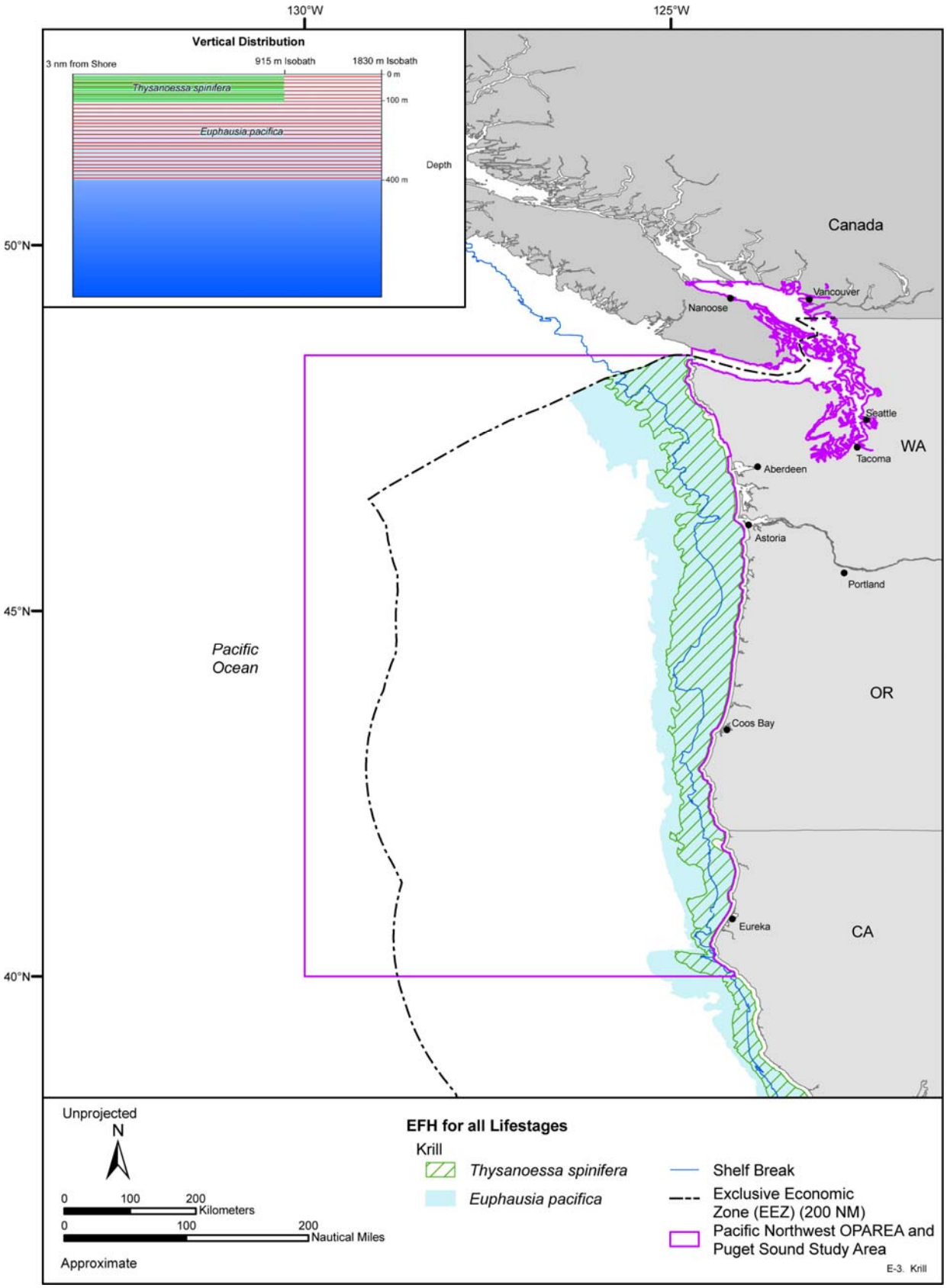

Figure E-3. Essential habitat for *Euphasia pacifica* and *Thysanoessa spinifera* in the Pacific Northwest OPAREA and vicinity. Source information: NMFS-SWR (2006).

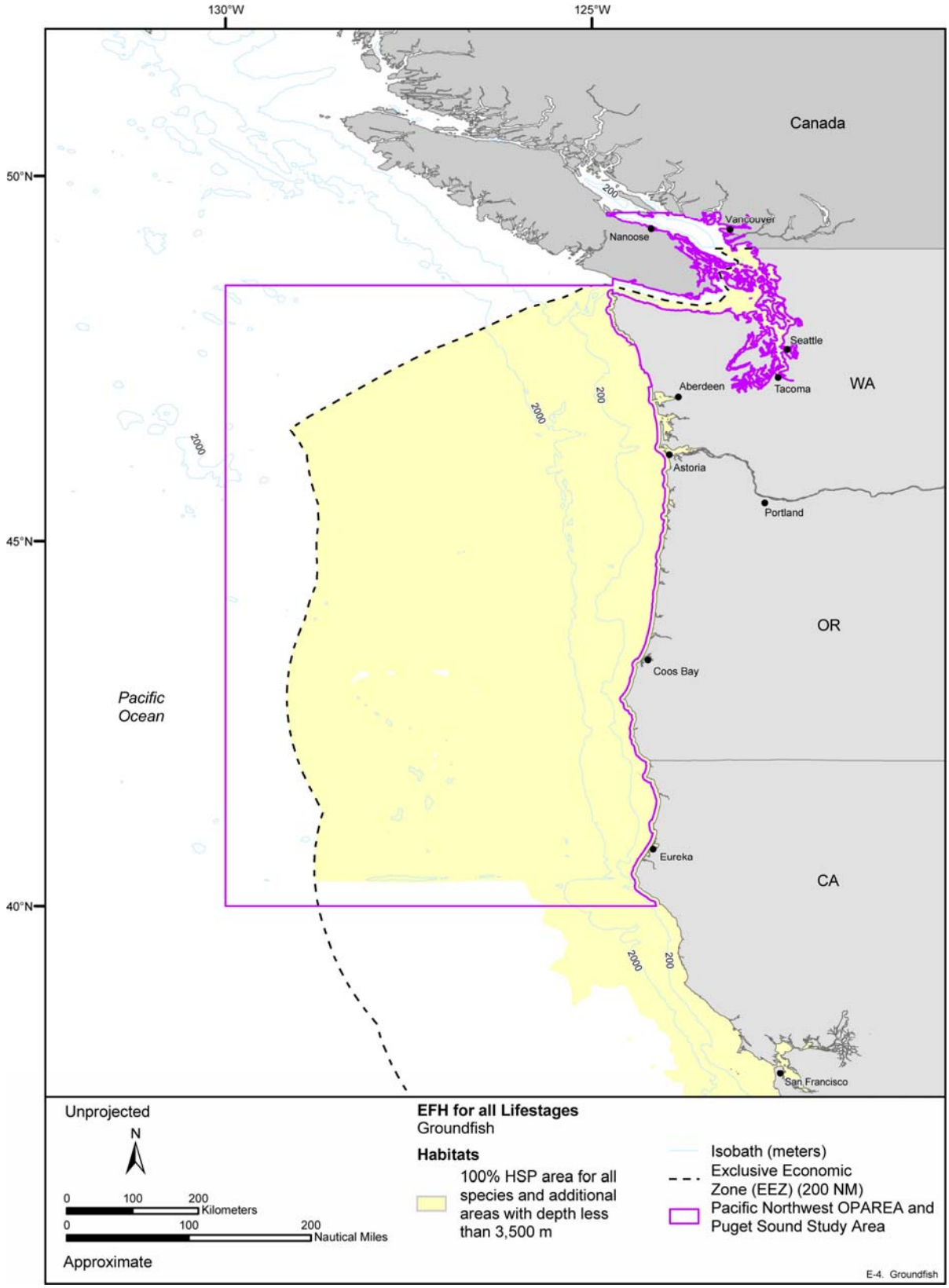

Figure E-4. EFH designated for areas with 100% of the area with a Habitat Suitability Probability (HSP) greater than zero and any additional areas with seafloor depths of 3,500 meters or less in the Pacific Northwest OPAREA, Puget Sound Study Area, and vicinity. Source data: Terralogic GIS, Inc. (2005e).

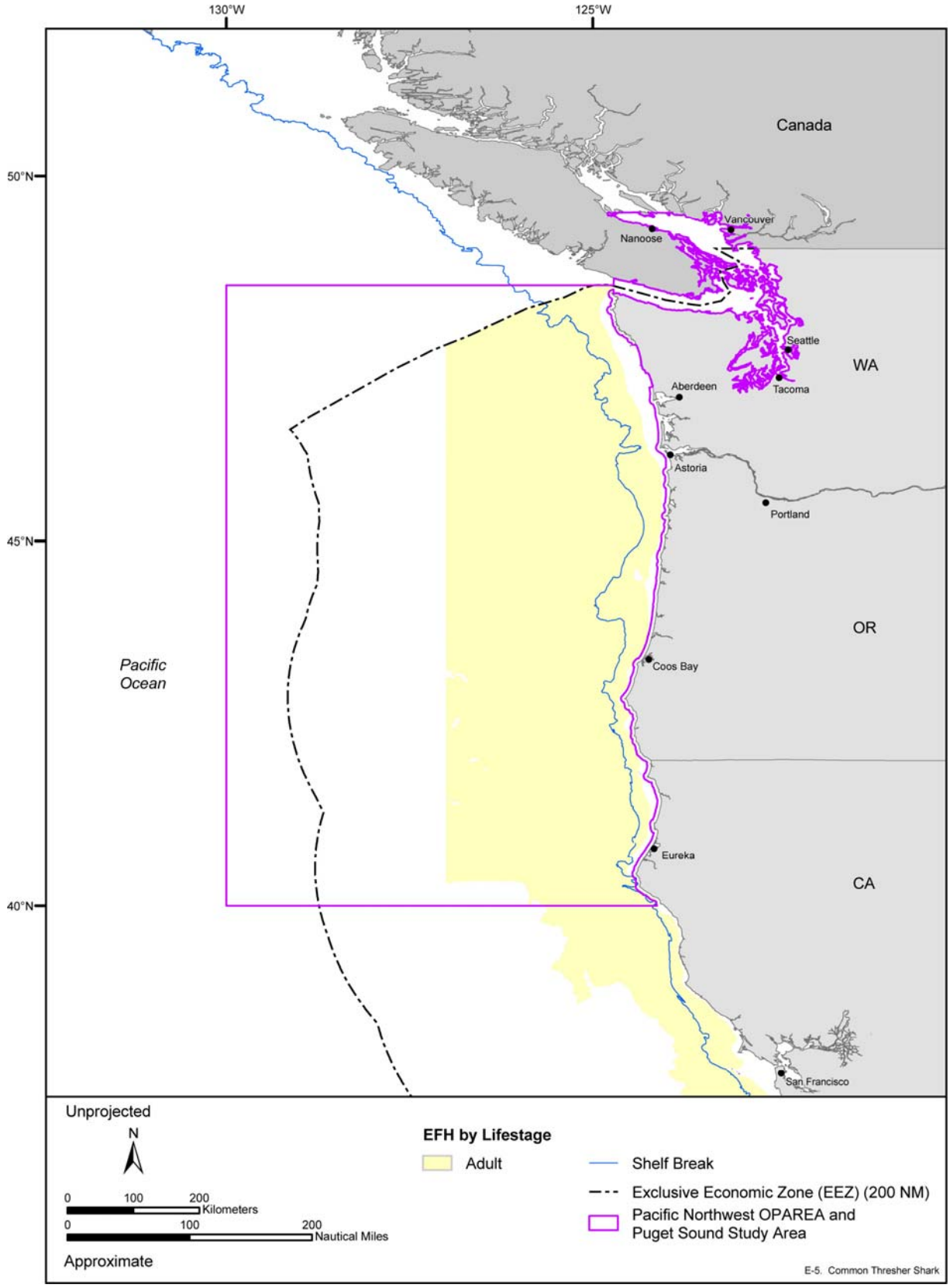

Figure E-5. EFH for the adult (73 m to 127°W longitude north of the Mendocino Escarpment and 73 to 3,475 m south of the Mendocino Escarpment) lifestage of the common thresher shark designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: Shepard and Emery (1941) and PFMC (2003b).

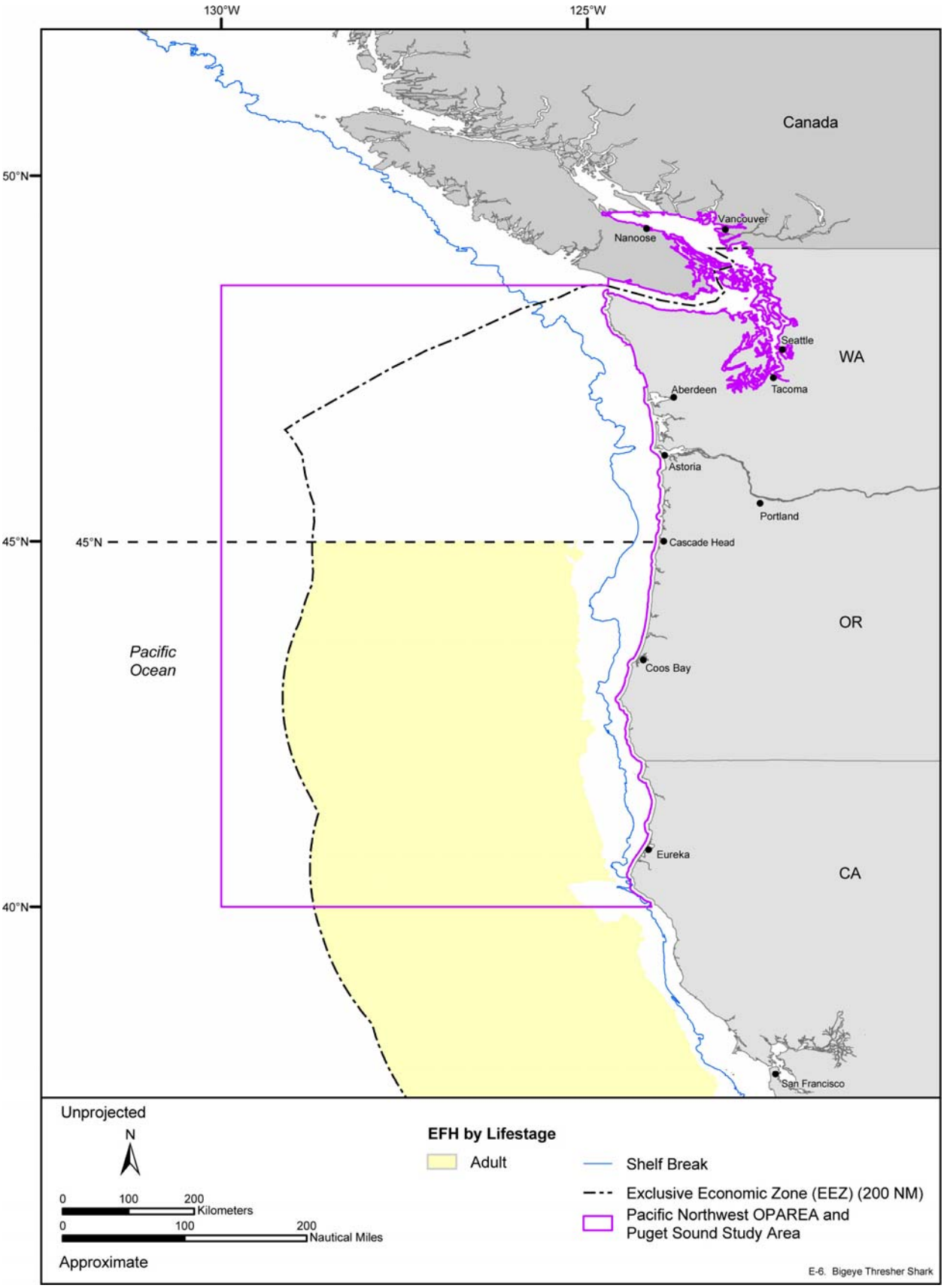

Figure E-6. EFH for the adult (1,463 m to EEZ) lifestage of the bigeye thresher shark designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: PFMC (2003b).

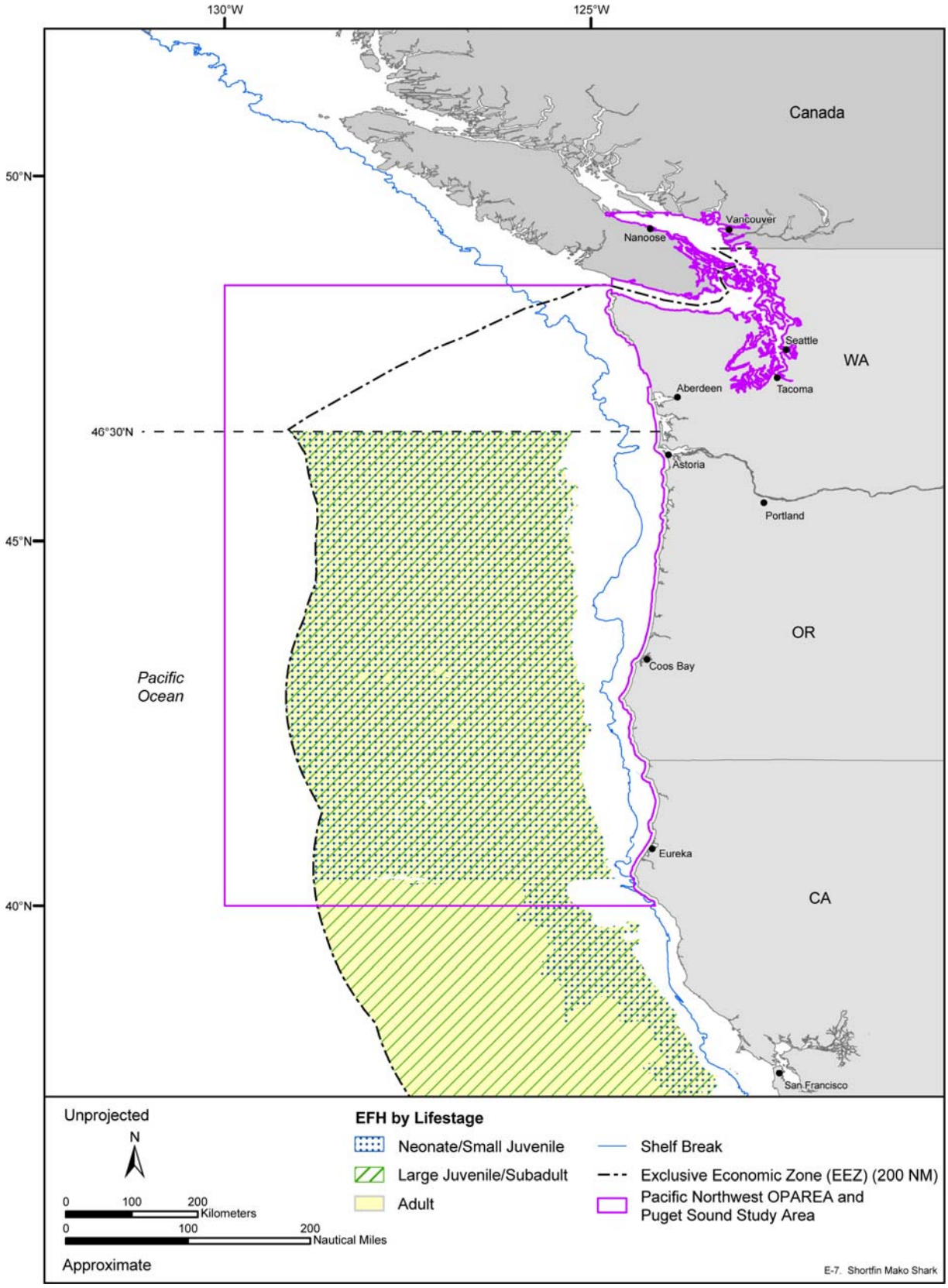

Figure E-7. EFH for the neonate/small juvenile (1,829 to 3,658 m south of Cape Mendocino and 1,829 m to EEZ north of Cape Mendocino) and large juvenile/subadult/adult (1,829 m to EEZ) lifestages of the shortfin mako shark designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: Shepard and Emery (1941) and PFMC (2003b).

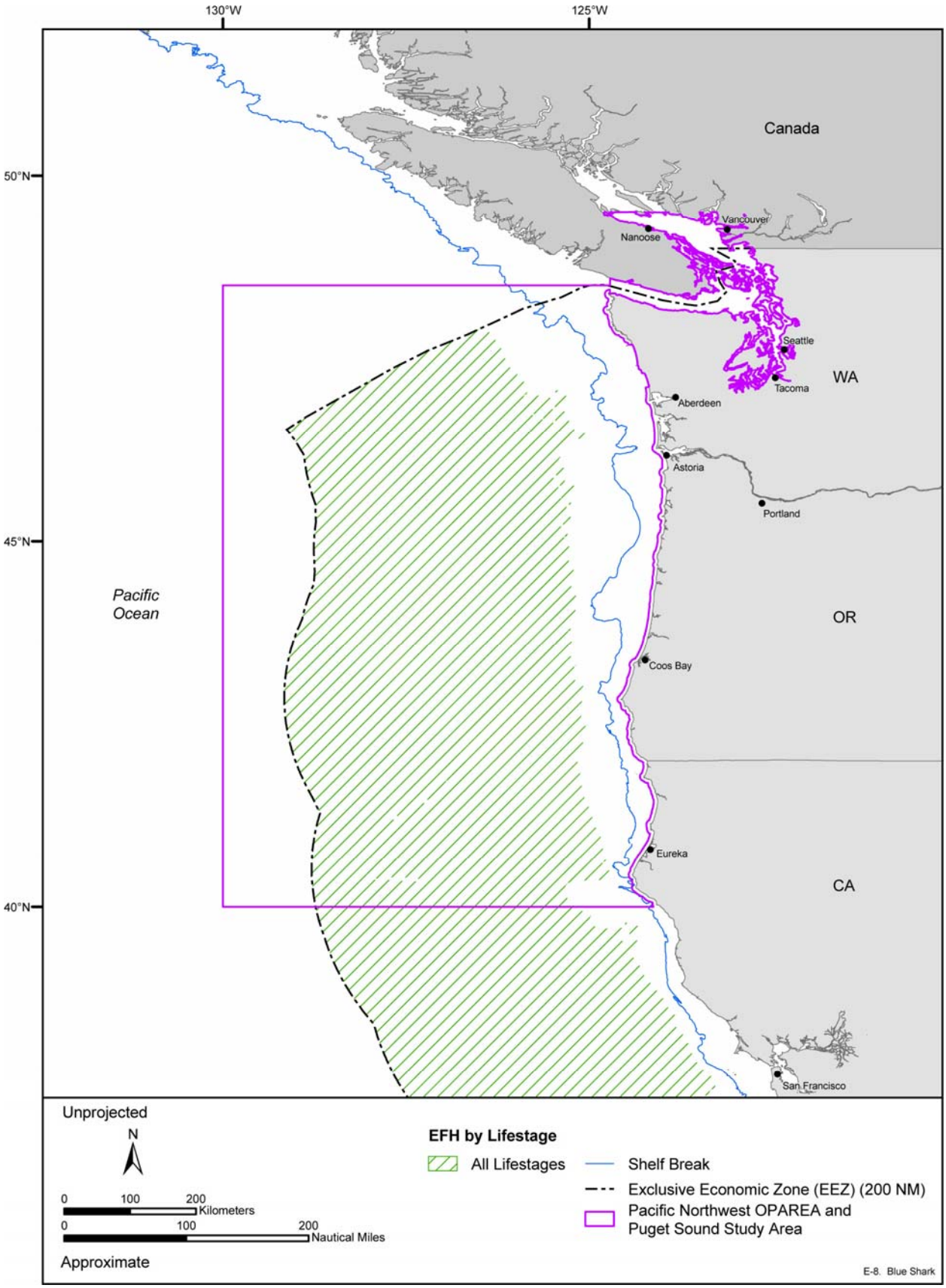

Figure E-8. EFH for all (1,829 m to EEZ) lifestages of the blue shark designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: PFMC (2003b).

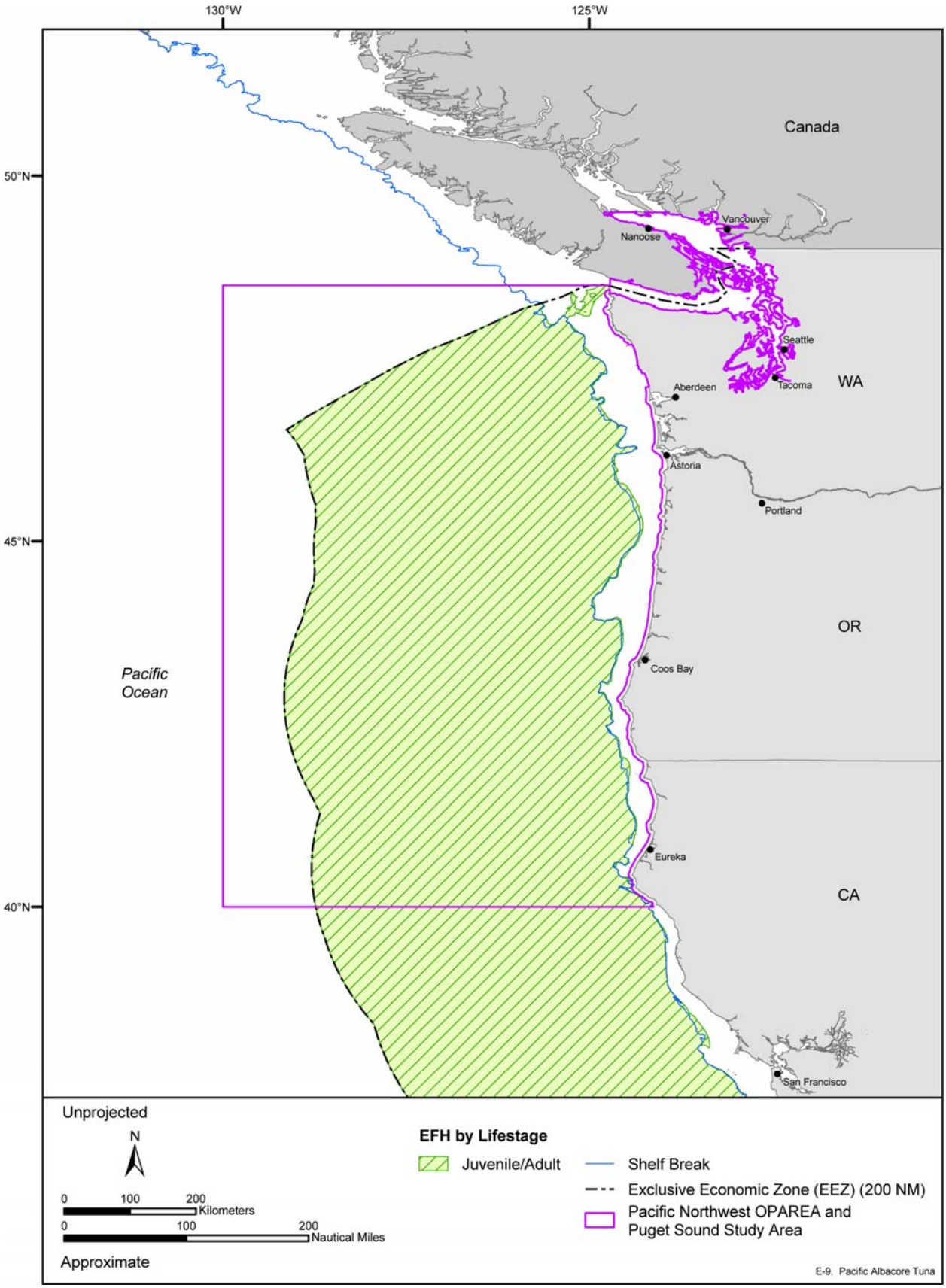

Figure E-9. EFH for the juvenile/adult (183 m to EEZ) lifestages of the albacore tuna designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: PFMC (2003b).

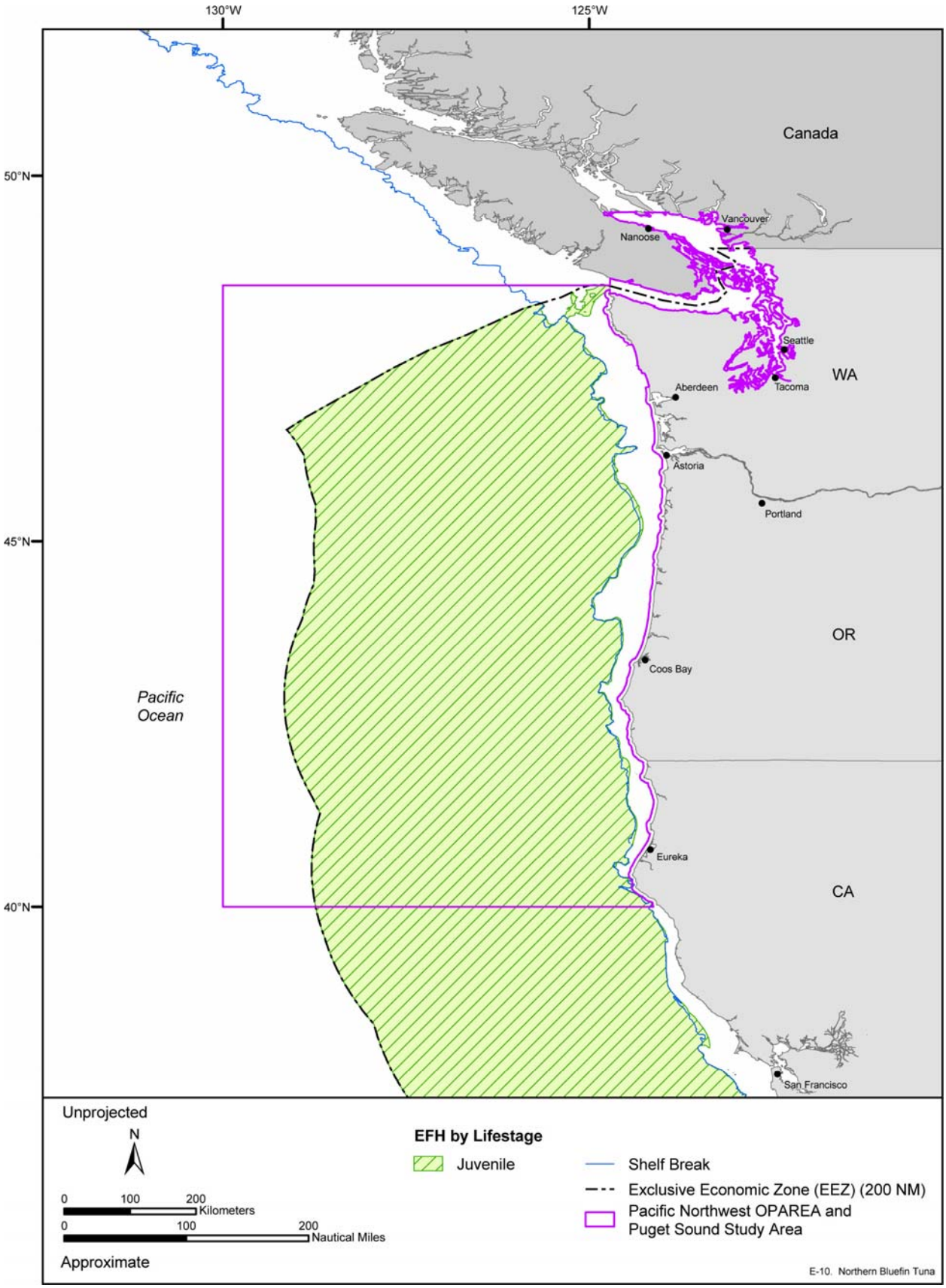

Figure E-10. EFH for the juvenile (183 m to EEZ) lifestage of the northern bluefin tuna designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: PFMC (2003b).

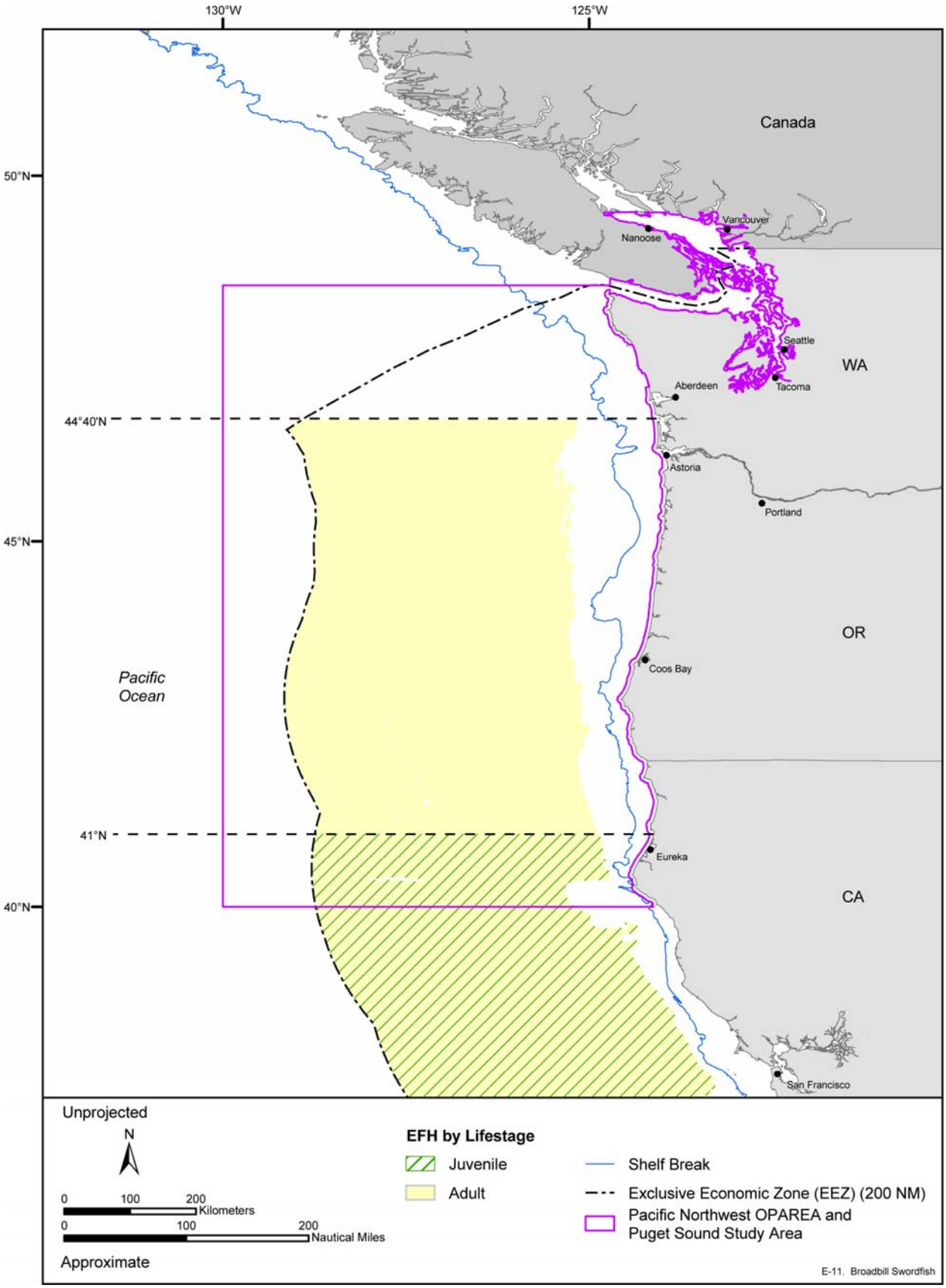

Figure E-11. EFH for the juvenile/adult (1,829 m to EEZ) lifestages of the broadbill swordfish designated in the Pacific Northwest OPAREA and vicinity. Map adapted from: PFMC (2003b).