MARINE RESOURCES ASSESSMENT FOR THE SOUTHERN CALIFORNIA AND POINT MUGU OPERATING AREAS

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

CONTRACT NUMBER: N62470-02-D-9997 TASK ORDER: 120

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FINAL REPORT
OCTOBER 2008

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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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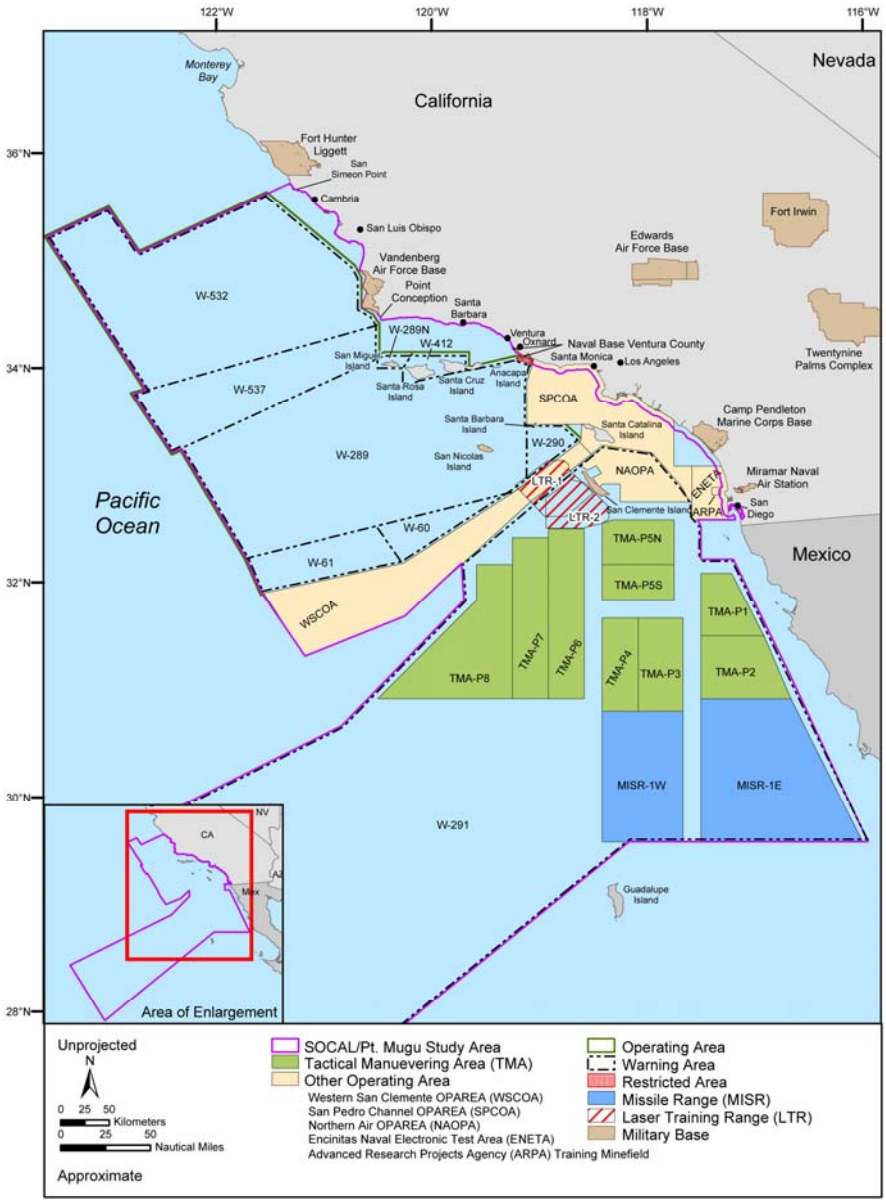
EXECUTIVE SUMMARY

The Department of the Navy (DoN) is committed to demonstrating environmental stewardship while executing its national defense mission. The United States (U.S.) Navy (Navy) is responsible for compliance with a suite of federal environmental and natural resources laws and regulations that apply to the marine environment, including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), the Magnuson-Stevens Fishery Conservation and Management Act/Sustainable Fisheries Act (MSFCMA/SFA), and Executive Order (EO) 13089 on Coral Reef Protection. The Navy Commander, U.S. Pacific Fleet (COMPACFLT) implemented the marine resources assessment (MRA) program to develop a comprehensive compilation of data and literature concerning the protected and managed marine resources found in its various operating areas. The information in this Marine Resource Assessment (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 in the vicinity of the Southern California (SOCAL) and Pt. Mugu Operating Areas (OPAREAs). An overview of the Pacific Ocean marine environment found off the southwest U.S. 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 protected marine mammals, sea turtles, birds, fishes, and invertebrates that may occur in the SOCAL/Pt. Mugu 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 communities such as kelp beds, seagrasses, and salt marshes have been assessed. Oceanic habitats including deep rocky and artificial habitats are also described and mapped. An overview of the fish assemblages associated with the waters of the SOCAL/Pt. Mugu Study Area as well as fishing activities (commercial and recreational) are reviewed and their occurrences noted. Fish

species for which essential fish habitat (EFH) has been designated 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, navigable waters, marine managed areas, self-contained underwater breathing apparatus (SCUBA) diving sites, sailing regattas, and oil and gas platforms in proximity to the SOCAL/Pt. Mugu OPAREAs.

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 for these protected and managed species. Predictions of the densities or 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 SOCAL/Pt. Mugu 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. Over 138 GIS-generated map figures are included in this assessment; data layers associated with these maps comprise bathymetry, sea surface temperature, protected and managed species' occurrences, essential fish habitats, 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 SOCAL/Pt. Mugu OPAREAs is provided in both paper and electronic form.

REPORT ORGANIZATION

This report consists of eight chapters and four 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 and Biological Environment—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);

Chapter 3 Species of Concern—covers protected marine mammals, sea turtles, birds, fishes, and invertebrates found in the vicinity of the SOCAL/Pt. Mugu 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 and recreational), and EFH for managed species that occur within the SOCAL/Pt. Mugu Study Area;

Chapter 5 Additional Considerations—provides information on maritime boundaries, navigable waters, marine managed areas, SCUBA diving locations, sailing regattas, and oil and gas platforms;

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 report;

Chapter 8 Glossary—includes definitions of the terms used in the 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 SOCAL/Pt. Mugu OPAREAs MRA;

Appendix B—marine mammal occurrence maps;

Appendix C—sea turtle occurrence maps; and

Appendix D—EFH maps.

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ACKNOWLEDGMENTS

We are grateful to the many people who provided scientific data, literature, and information needed for this assessment.

We are especially grateful to the personnel with the Southwest Fisheries Science Center (NMFS-SWFSC) for providing recent shipboard survey data and expertise in order to determine marine mammal and sea turtle occurrence patterns in the Southern California and Point Mugu Operating Areas. In particular, we acknowledge the efforts of Dr. Lisa Balance, Dr. Peter Dutton, and Dr. Karin Forney.

We would also like to thank Dr. John Hildebrand (Scripps Institute of Oceanography [SIO]), Mr. Brian Hatfield (U.S. Geological Survey [USGS]), and Dr. Peter Tyack (Woods Hole Oceanographic Institution [WHOI]), for providing marine mammal occurrence data sets and records and Ms. Michelle Berman (Santa Barbara Museum of Natural History) for providing marine mammal stranding records.

Occurrence data sets and reports for seabirds were collected and provided by Ms. Tiffany Shepherd (Naval Facilities Engineering Command, Southwest [NAVFAC SW]) and Mr. Steve Schwartz (Naval Air Systems Command, Mugu [NAVAIR, Mugu]).

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percent
‘	Minute(s)
°	Degree(s)
°C	Degree(s) Celsius
µg/L	Microgram(s) Per Liter
µm	Micron(s)
µs	Microsecond
2D	Two-Dimensional
3D	Three-Dimensional
AB	Assembly Bill
ABR	Auditory Brainstem Response
ac	Acre(s)
AM	Amplitude-Modulated
ARPA	Advanced Research Projects Agency
ASBS	Area of Special Biological Significance
ASW	Anti-Submarine Warfare
atm	Atmosphere(s)
AVHRR	Advanced Very High-Resolution Radiometer
BLM	Bureau of Land Management
CADDIS	Cetacean Acoustic Detection and Dive Interval Studies
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CalFish	California Cooperative Anadromous Fish and Habitat Data Program
CAMMS	California Marine Mammal Survey
CCA	California Coastal Act/Cowcod Conservation Area/Critical Coastal Area
CCC	California Coastal Commission
CCCA	California Clean Coast Act
CCL	Curved Carapace Length
CCLME	California Current Large Marine Ecosystem
CCNW	California Coastal National Monument
CCS	California Current System
CCSA	California Coastal Sanctuary Act
CDBW	California Department of Boating and Waterways
CDFG	California Department of Fish and Game
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERES	California Environmental Resources Evaluation System
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
Chl *a*	Chlorophyll *a*
CINMS	Channel Islands National Marine Sanctuary
cm	Centimeter(s)
cm/d	Centimeter(s) Per Day
cm/s	Centimeter(s) Per Second
cm^2/hr	Square Centimeter(s) Per Hour
CMMSN	California Marine Mammal Stranding Network
CNMI	Commonwealth of the Northern Mariana Islands
CNO	Chief of Naval Operations
COMPACFLT	Commander, United States Pacific Fleet
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPFV	Commercial Passenger Fishing Vessel
CPS	Coastal Pelagic Species
CRANE	Cooperative Research and Assessment of Nearshore Ecosystems

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

CRCA	Coral Reef Conservation Act
CRFS	California Recreational Fisheries Survey
CSA	Council of Sailing Associations
CSCAPE	Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem
CSLC	California State Lands Commission
CUD	Coastal Upwelling Domain
CVN	Carrier Vessel Nuclear
CWA	Clean Water Act
CZCS	Coastal Zone Color Scanner
CZMA	Coastal Zone Management Act
d	Day(s)
DA	Domoic Acid
dB re 1 μPa-m	Decibels with a Reference Pressure of One Micropascal at One Meter
dB	Decibel(s)
DBN	Delta Beach North
DBS	Delta Beach South
DCM	Deep Chlorophyll Maximum
DDT	Dichloro-Diphenyl-Trichloroethane
DFO	Department of Fisheries and Oceans
DNA	Deoxyribonucleic Acid
DoAF	Department of the Air Force
DoD	Department of Defense
DoN	Department of the navy
DoS	Department of the State
DoT	Department of Transportation
DPS	Distinct Population Segment
DSL	Deep Scattering Layer
E	East
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EFL	“Eye-to-Fork” Length
EIS	Environmental Impact Statement
ENETA	Encinitas Electronic Test Area
ENSO	El Niño/Southern Oscillation
EO	Executive Order/Environmental Opinion
EPA	Environmental Protection Agency
EPO	Eastern Pacific Ocean
EPR	East Pacific Rise
ERA	Estuary Restoration Act
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
ESRI	Environmental Systems Research Institute, Inc.
ESU	Evolutionary Significant Unit
ETP	Eastern Tropical Pacific
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization
FCMA	Fishery Conservation and Management Act
FL	Fork Length
FM	Frequency-Modulated
FMC	Fishery Management Council
FMP	Fishery Management Plan

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

FR	Federal Register
ft	Foot(Feet)
FWPCA	Federal Water Pollution Act
gC/m^2	Gram(s) of Carbon Per Square Meter
$gC/m^2/yr$	Gram(s) of Carbon Per Square Meter Per Year
GIS	Geographic Information System
GMI	Geo-Marine, Inc.
GPS	Global Positioning System
gt	Gross Ton(s)
ha	Hectare(s)
HAB	Harmful Algal Bloom
HABHRCA	Harmful Algal Bloom and Hypoxia Research and Control Act
HAPC	Habitat Area of Particular Concern
HICEAS	Hawaiian Islands Cetacean and Ecosystem Assessment Survey
HMS	Highly Migratory Species
HPAS	Harbor Porpoise Aerial Survey
hr	Hour(s)
hr/d	Hour(s) Per Day
HSP	Habitat Suitability Probability
HTML	Hyper Text Markup Language
Hz	Hertz
IATTC	Inter-American Tropical Tuna Commission
IMO	International Maritime Organization
in.	Inch(es)
INRMP	Integrated Natural Resources Management Plan
IOS	Indian Ocean Sanctuary
IPOA	International Plan of Action
ISE	Independent Steaming Exercise
IUCN	International Union for Conservation of Nature and Natural Resources
IUSS	Integrated Undersea Surveillance System
IWC	International Whaling Commission
JFL	“Tip of Jaw to Fork” Length
kg	Kilogram(s)
kHz	Kilohertz
km	Kilometer(s)
km/d	Kilometer(s) Per Day
km/hr	Kilometer(s) Per Hour
km^2	Square Kilometer(s)
km^3	Cubic Kilometer(s)
LA	Los Angeles
LODS	Longline Observer Data System
LOS	Law of the Sea
LST	Landing Ship Tank
LTR	Laser Training Range
m	Meter(s)
m/s	Meter(s) Per Second
m^2	Square Meter(s)
m^3	Cubic Meter(s)
m^3/s	Cubic Meter(s) Per Second
MAB	Man and the Biosphere
MARINe	Multi-Agency Rocky Intertidal Network
MARPOL	International Convention for the Prevention of Pollution from Ships
MBNMS	Monterey Bay National Marine Sanctuary

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

MBTA	Migratory Bird Treaty Act
MCB	Marine Corps Base
MEHRA	Marine Environmental High Risk Area
mg	Milligram(s)
mg/L	Milligram(s) Per Liter
mg/m^3	Milligram(s) Per Cubic Meter
$mgC/m^2/d$	Milligram(s) of Carbon Per Square Meter Per Day
MHHW	Mean Higher High Water
mi	Mile(s)
mi^2	Square Mile(s)
min	Minute(s)
MISR	Missile Range
mL	Milliliter(s)
mL/L	Milliliter(s) Per Liter
MLLW	Mean Lower Low Water
MLMA	Marine Life Management Act
MLPA	Marine Life Protection Act
mm	Millimeter(s)
mm/yr	Millimeter(s) Per Year
MMA	Marine Managed Area
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
mo	Month(s)
MOA	Arcsecond
MOPS	Monitoring of Porpoise Stocks
MOU	Memorandum of Understanding
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
ms	Millisecond(s)
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
MSY	Maximum Sustainable Yield
mt	Metric Ton(s)
MTR	Mine Training Range
N	North
NAB	Naval Amphibious Base
NALF	Naval Auxiliary Landing Facility
NAOPA	Northern Air Operating Area
NAS	Naval Air Station
NASA	National Aeronautic and Space Administration
NASNI	Naval Air Station North Island
NAWCWPNS	Naval Air Warfare Center Weapons Division
NB	Naval Base
NCCPA	Natural Community Conservation Planning Act
NDAA	National Defense Authorization Act
NDBC	National Data Buoy Center
NEP	National Estuary Program
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

NERRS	National Estuarine Research Reserve System
NFEA	National Fishing Enhancement Act
NGA	National Geospatial-Intelligence Agency
NGO	Non-Governmental Organization
NISC	National Invasive Species Council
NM	National Monument
nm	Nautical Mile(s)/Nanometer(s)
nm^2	Square Nautical Mile(s)
NMBCA	Neotropical Migratory Bird Conservation Act
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NMS	National Marine Sanctuary
NMSA	National Marine Sanctuaries Act
NMSP	National Marine Sanctuary Program
NOAA	National Oceanic and Atmospheric Administration
NOLF	Naval Outlying Landing Field
NOP	National Observer Program
NOS	National Ocean Service
NOSC	Naval Ocean Systems Center
NP	National Park
NPS	National Park Service/Nonpoint Source
NPSG	North Pacific Subtropical Gyre
NPTZ	North Pacific Transition Zone
NRFCC	National Recreational Fisheries Coordination Council
NRKW	Northern Resident Killer Whale
NRL	Naval Research Lab
NRRF	Naval Radio Receiving Facility
NSFS	Naval Surface Fire Support
NSHEP	Nearshore Sportfish Habitat Enhancement Program
NWFSC	Northwest Fisheries Science Center
NWR	National Wildlife Refuge
NWRS	National Wildlife Refuge System
OBIS-SEAMAP	Ocean Biogeographic Information System - Spatial Ecological Analysis of Megavertebrate Populations
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
OCSLAA	Outer Continental Shelf Lands Act Amendments
OLF	Outlying Landing Field
OMZ	Oxygen Minimum Zone
OPA	Oil Pollution Act
OPAREA	Operating Area
ORCAWALE	Oregon, California, and Washington Line-Transect Expeditions
OS	Ocean Sanctuary
OSPR	Oil Spill Prevention and Response
OSTR	Outer Sea Test Range
P.L.	Public Law
PacFIN	Pacific Coast Fisheries Information Network
PAR	Pendleton Artificial Reef
PCE	Primary Constituent Element
PCFA	Pacific Coast Feeding Aggregation
PDF	Portable Document Format
PDO	Pacific Decadal Oscillation
PFMC	Pacific Fishery Management Council

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

PIFSC	Pacific Islands Fisheries Science Center
PIR	Pacific Islands Region
PODS	Population of *Delphinus* Stocks
POP	Platforms of Opportunity
ppm	Part(s) Per Million
ppt	Part(s) Per Thousand
PSMFC	Pacific States Marine Fisheries Commission
PSSA	Particularly Sensitive Sea Area
psu	Practical Salinity Unit(s)
Pt. Mugu	Point Mugu
RFRCP	Recreational Fishery Resources Conservation Plan
RSA	Regional Sailing Associations
s	Second(s)
S	South
S.D.	Standard Deviation
SAR	Stock Assessment Report
SCB	Southern California Bight
SCIUR	San Clemente Island Underwater Range
SCORE	Southern California Offshore Range
SCUBA	Self-Contained Underwater Breathing Apparatus
SCYA	Southern California Yachting Association
SD	San Diego
SDBTA	San Diego Bay Training Area
SE	Standard Error
SEAL	Seal, Air, and Land
SECDEF	Secretary of Defense
SFA	Sustainable Fisheries Act
SHOBA	Shore Bombardment Area
SIO	Scripps Institute of Oceanography
SL	Standard Length
SLA	Submerged Lands Act
SLC	State Lands Commission
SLP	Sea Level Pressure
SMCA	State Marine Conservation Area
SMR	State Marine Reserve
SMRMA	State Marine Recreational Management Area
SOAR	Southern California Anti-Submarine Warfare Range
SOCAL	Southern California
SOSUS	Sound Surveillance System
SPCOA	San Pedro Channel Operating Area
SPSV	San Pedro Sea Valley
SRKW	Southern Resident Killer Whale
SSABA	Silver Strand Amphibious Beaching Area
SST	Sea Surface Temperature
SWAT	Special Warfare Training Area
SWFSC	Southwest Fisheries Science Center
SWQPA	State Water Quality Protection Area
SWR	Southwest Regional Office
SWRCB	State Water Resources Control Board
T&E	Threatened/Endangered
Tg	Terragram(s)
TIN	Triangular Irregular Network
TL	Total Length

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

TMA	Tactical Maneuvering Area
TZCF	Transition Zone Chlorophyll Front
U.N.	United Nations
U.S.	United States
U.S.C.	United States Code
UNCLOS	United Nations Convention on the Law of the Sea
UNEP-WCMC	United Nations Environment Programme-World Conservation Monitoring Centre
UNESCO	United National Educational, Scientific, and Cultural Organization
UNIA	United Nations Agreement on the Conservation and management of Straddling Fish Stocks and High Migratory Fish Stocks
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USMC	United States Marine Corps
USSR	Union of Soviet Socialist Republics
USVI	United States Virgin Islands
VAB	Vandenberg Air Force Base
VDS	Variable Depth Sonar
W	West
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	West-Central Pacific Ocean
WHOI	Woods Hole Oceanographic Institute
WIDECAST	Wider Caribbean Sea Turtle Conservation Network
wk	Week(s)
WS	Withering Syndrome
WSCOA	Western San Clemente Operating Area
WS-RLP	Withering Syndrome-Rickettsiales-like Prokaryote
WWI	World War One
WWII	World War Two
XML	Extensible Markup Language
yr	Year(s)
YRUSC	Yacht Racing Union of Southern California
ZTA	Zevenbergen and Thorn Algorithm

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1.0 INTRODUCTION

The United States (U.S.) Navy's (Navy) Commander, U.S. Pacific Fleet (COMPACFLT) contracted this marine resources assessment (MRA) to initiate collection of data and information concerning the protected and commercial marine resources found in the U.S. Pacific Fleet's (Fleet) Southern California (SOCAL) and Point Mugu (Pt. Mugu) Operating Areas (OPAREA).

For the purposes of this MRA, the SOCAL OPAREA refers to the airspace, ocean surface and subsurface training areas offshore and nearshore to within 3 nautical miles (nm) of the coast from Oxnard, California, to the U.S./Mexico border, including San Diego Bay; offshore regions extend further south off of Mexico (Figure 1-1). Inside San Diego Bay, the OPAREA includes all waters to the mean higher high water mark. The Pt. Mugu OPAREA refers to the airspace and associated ocean surface offshore from near San Simeon Point to the Los Angeles area, where it abuts the northern boundary of the SOCAL OPAREA. The Pt. Mugu OPAREA includes the nearshore waters to the mean higher high water mark, and includes the waters of Mugu Lagoon (Figure 1-1). These two areas together may be referred to as either the "SOCAL/Pt. Mugu Study Area" or "study region" or just "Study Area."

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 SOCAL/Pt. Mugu Study Area. This MRA includes a discussion of the physical environment, habitats (coastal and oceanic), and protected species found in the Study Area and surrounding region. Also addressed in this assessment are essential fish habitat (EFH) designations, commercial and recreational fisheries, and other areas of interest (e.g., marine managed areas [MMA], Self-Contained Underwater Breathing Apparatus [SCUBA] diving sites, and oil and gas structures) that occur off central and southern California. The identification of data gaps and the prioritization of recommendations for future research in the Study Area are additional components of this assessment.

The Department of the Navy (DoN) is responsible for organizing, training, and equipping naval forces for combat. The mission of the SOCAL OPAREA is to support Navy and U.S. Marine Corps (USMC) tactical training by maintaining and operating facilities, and providing services, arms and material to support Fleet forces, USMC Forces Pacific, and other operating forces. Similarly, the Pt. Mugu OPAREA, part of the Naval Air Warfare Center Weapons Division (NAWCWPNS) and supported by Naval Air Station (NAS) Pt. Mugu, provides defined sea and air space in support of U.S. and allied military tests and operational training, including weapon systems testing and realistic training activities that ensure operational readiness (DoN 2002a). Section 4.1.1 of Department of Defense (DoD) Instruction 4715.3 (1996), "Environmental Conservation Program" states that "all DoD conservation programs shall work to guarantee continued access to our land, air, and water resources for realistic military training and testing while ensuring that natural and cultural resources are sustained in a healthy condition for scientific research, education, and other compatible uses by future generations." The marine resources information assembled in this MRA will serve as a baseline from which the Navy may evaluate its operations and their potential impacts on the marine environment while balancing the requirement to provide trained and ready forces with the obligations of sound resource stewardship. This assessment will contribute to the Fleet's integrated long-range planning process and represents an important component in the Fleet's ongoing compliance with U.S. federal mandates that aim to protect and manage resources in the marine environment. All species and habitats potentially affected by the Navy's maritime exercises and protected by U.S. federal or state legislation 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 protected species, and the distribution of EFH and other Navy concerns in the SOCAL/Pt. Mugu Study Area and vicinity. To describe the physical environment and habitats of the Study Area, physiographic, bathymetric, geologic, hydrographic, and oceanographic data were compiled and the locations of estuarine, seagrass, kelp bed, deep rocky, and artificial habitats were identified. Comprehensive sighting, stranding, incidental fisheries

bycatch, satellite tracking, and haulout data for marine mammals and sea turtles were collected and analyzed to qualitatively predict the areas of occurrence for these protected species in the Study Area. Marine mammal and sea turtle areas of occurrence were 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, fishes, and invertebrates. Occurrence maps were 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 off central and southern California. Also reviewed were commercial and recreational fishing activities, EFH, U.S. maritime boundaries, commercially navigable waterways, MMAs, SCUBA diving sites, sailing regattas, and oil and gas structures.

1.2 LOCATION OF THE SOUTHERN CALIFORNIA/POINT MUGU STUDY AREA

1.2.1 Location of the Southern California Operating Area

The SOCAL OPAREA is located in the eastern North Pacific Ocean off the coasts of southern California (U.S.) and Baja California (Mexico) (**Figure 1-1**). Covering 411,644 square kilometers (km^2) of ocean and estuarine area, the SOCAL OPAREA consists of specific ranges with defined air, ocean surface, and subsurface OPAREAs (DoN 2005a; 2005b; **Table 1-1**). These ranges extend more than 960 kilometers (km) southwest into the Pacific Ocean and are discussed in great detail in DoN documents (DoN 2005b; 2005a).

The SOCAL OPAREA includes both a nearshore and an offshore component. The nearshore component of the OPAREA encompasses ocean waters along the southern California coast, from Oxnard to a point just north of the U.S./Mexico border, as well as all of San Diego Bay. Navy training areas comprising the nearshore component include the Advanced Research Projects Agency (ARPA) Training Minefield, Encinitas Electronic Test Area (ENETA), Northern Air OPAREA (NAOPA), and San Pedro Channel OPAREA (SPCOA). Within San Diego Bay and its near vicinity are the San Diego Bay Training Area (SDBTA), Silver Strand Amphibious Beaching Area (SSABA), and several Navy installations including Naval Amphibious Base (NAB) Coronado, Naval Base Point Loma, Naval Station San Diego, and the Silver Strand Training Complexes (**Figure 1-2**). Naval Outlying Landing Field (NOLF) Imperial Beach lies just south of San Diego Bay near the U.S./Mexico border.

The offshore component of the SOCAL OPAREA is one of the most important Navy training areas in the Pacific Ocean. It consists of Warning Area W-291, the Western San Clemente OPAREA (WSCOA), two missile ranges (MISRs), and nine tactical maneuvering areas (TMAs or Papa Areas) (**Figure 1-1**). Warning Area W-291 is an extensive special use airspace that runs from the northeast to the southwest out to waters beyond 125 degrees (°) West (W) longitude. It is by far the largest component of the SOCAL OPAREA. The San Clemente Island Range Complex, which includes two laser training ranges (LTRs), is also found within the offshore component of the SOCAL OPAREA.

The San Clemente Island Range Complex is the cornerstone of the tactical training ranges that support the SOCAL OPAREA. The primary purpose of the complex is to provide readiness training for units and personnel who deploy overseas to meet the national strategy of forward presence and global engagement. The complex consists of land, air, and sea training ranges as well as designated OPAREAs to the south and west of San Clemente, which are controlled by a single command and control system on the island. The ranges on and around San Clemente Island are owned entirely by the Navy and accommodate naval surface fire support (NSFS), air-to-ground ordnance delivery operations, and special operations. San Clemente Island is the only NSFS range on the U.S. west coast and, with the closure of the Navy's bombing range at Vieques Island, Puerto Rico, in 2003 is also the Navy's last ship-to-shore live-fire range. More than a dozen ranges and OPAREAs are clustered within a 100-km radius of the island, including the San Clemente Island Underwater Range (SCIUR), Southern California Anti-Submarine Warfare (ASW) Range (SOAR), Variable Depth Sonar (VDS) Area, Shore Bombardment Area (SHOBA), and several special warfare training areas (SWATs) and mine training ranges (MTRs) (**Figure 1-3**). Naval Auxiliary Landing Facility (NALF) San Clemente Island is located at the northwest corner of

the island. The *San Clemente Island Integrated Natural Resources Management Plan* (DoN 2002d) provides an extensive amount of information on San Clemente Island and the surrounding marine environment.

One of the most highly studied areas of the SOCAL OPAREA is San Diego Bay. A natural, nearly enclosed embayment, San Diego Bay is an exceptional harbor because of its deep entrance and protected conditions. San Diego Bay and its environs are home to the largest complex of naval installations in the Fleet. Per the directives of the *San Diego Integrated Natural Resources Management Plan* (DoN 2000a), the Navy has initiated an aggressive campaign to fully catalog the natural resources of San Diego Bay, including baseline data collection on eelgrass, waterfowl, and fishes. An abundance of information on this embayment and the naval activities that occur there is contained in the following documents: *San Diego Bay Integrated Natural Resources Management Plan* (DoN 2000a), *Naval Base San Diego Integrated Natural Resources Management Plan* (DoN 2002c), and *Naval Base Coronado Integrated Natural Resources Management Plan* (DoN 2002b).

Outside of San Diego Bay, much of the SOCAL OPAREA is located in the Southern California Bight (SCB). The SCB is a highly complex marine ecosystem situated off the southern California coast between Point Conception and a point just south of the U.S./Mexico border. The SCB occurs where the mainland coastline turns abruptly eastward and is an area of convergence between southward flowing cold water and northward flowing warmer waters. This convergence zone provides a diversity of habitats that contain a rich and varied assemblage of marine life and consequently is one of the most heavily human-used marine resource areas on earth (Hood 1993). California's Channel Islands, three of which lie inside the SOCAL OPAREA (Santa Barbara, Santa Catalina, and San Clemente Islands), also are located within the SCB and provide additional suitable habitat for a number of marine organisms year-round. These islands serve as a breeding ground for marine birds and possess protected shorelines that are used regularly by seals, sea lions, and sea otters. Distributed between the southern California mainland and the Channel Islands (and beyond) are a series of embayments, submarine canyons, ridges, banks, basins, and seamounts that provide yet more unique habitats in the SCB (Dailey et al. 1993b; DoN 2000a).

Further from the coast, southern California's offshore ecosystem consists of open ocean environments over deeper parts of the continental shelf, the continental slope, and ocean basins. In contrast to the richer nearshore waters of the SCB, which are dominated by upwelling and terrestrial nutrient sources that create high levels of productivity, the offshore waters of the SOCAL OPAREA and surrounding area become less productive as the distance from shore increases.[1] Despite a relative decrease in primary productivity, the offshore ecosystem provides important habitat for groundfish species (shelf and slope rockfish, flatfish, sablefish, and Pacific whitings); coastal pelagic species (CPS) (sardines, anchovies, mackerels, and squids); salmonids (during the ocean phase of their life cycle); highly migratory species (HMS) (tunas, billfishes, and pelagic sharks); marine mammals; sea turtles; pelagic seabirds (including albatrosses and shearwaters); phytoplankton; and zooplankton (including euphausids, copepods, salps, and red crabs) (Wolf 2001).

1.2.2 Location of the Point Mugu Operating Area

The Pt. Mugu OPAREA is located in the eastern North Pacific Ocean off the coast of central and southern California directly north of the SOCAL OPAREA (**Figure 1-1**). Covering 93,200 km^2 of ocean and estuarine area, the Pt. Mugu OPAREA controls special use airspace over the open ocean and San Nicolas and Santa Cruz Islands within the OPAREA boundaries, as well as facilities on the mainland. The Pt. Mugu OPAREA parallels the California coast for approximately 320 km, from near San Simeon Point in San Luis Obispo County southward to the Los Angeles area, where it abuts the northern boundary of the SOCAL OPAREA. The Pt. Mugu OPAREA extends more than 290 km seaward into the Pacific Ocean (DoN 2002a).

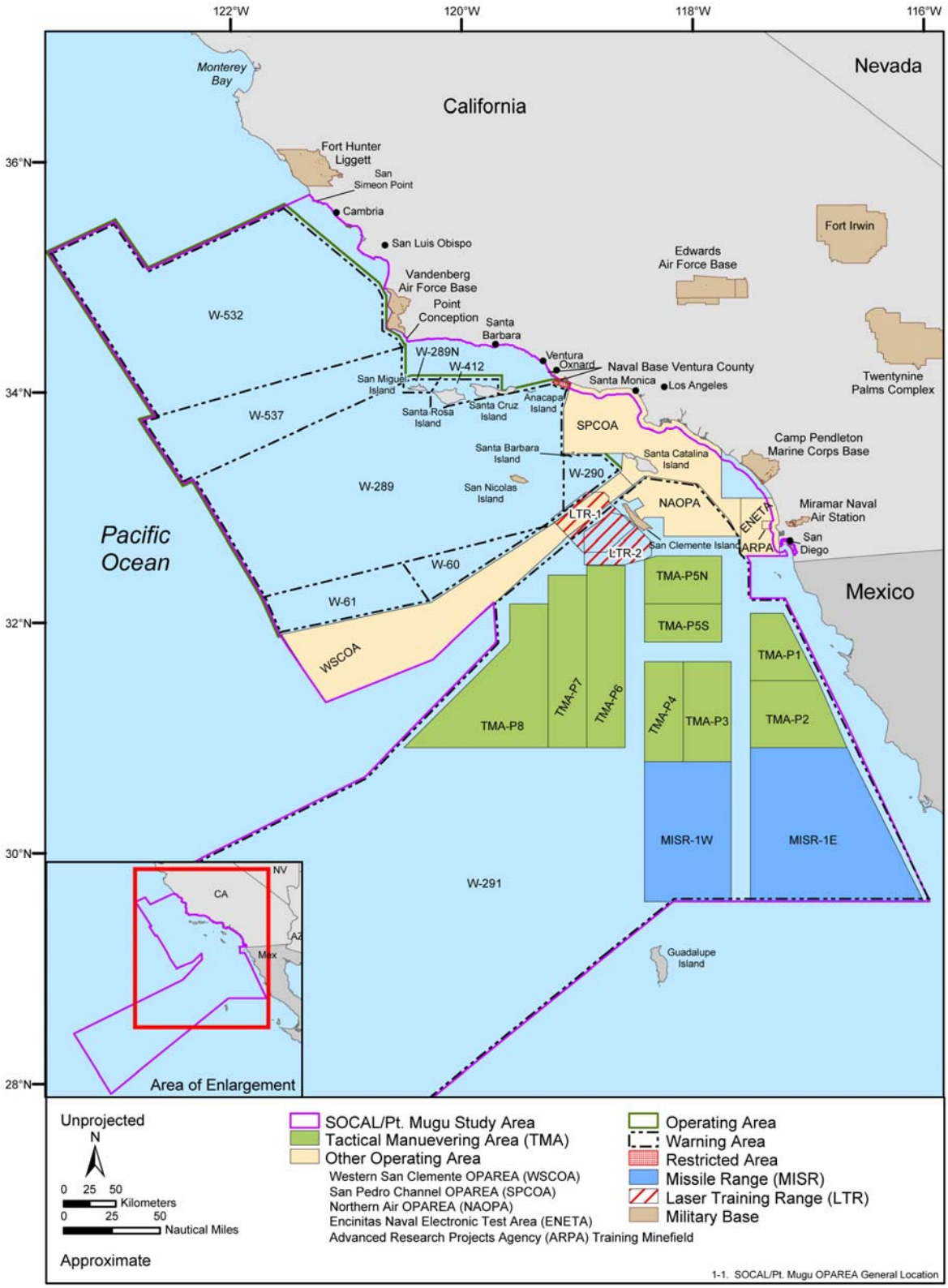

Figure 1-1. The Study Area encompassing the SOCAL and Pt. Mugu OPAREAs is located in the eastern North Pacific Ocean off southern California, U.S. The portion of the Study Area south of the U.S./Mexico border lies off Baja California, Mexico. Source data: SRS Technologies, Inc. (2003).

Table 1-1. Major components of the SOCAL OPAREA and their descriptions.

OPAREA Component	Description
Advanced Research Projects Agency (ARPA) Training Minefield	The ARPA Training Minefield lies within the ENETA and extends from the ocean bottom to the surface. Exercises conducted are mine detection and avoidance. No towing operations are permitted below a water depth of 162 meters (m).
Encinitas Naval Electronic Test Area (ENETA)	The ENETA is located about 37 km northwest of NAB Coronado (formerly NAS North Island). The area extends from the ocean bottom up to 213 m above mean sea level (MSL). Exercises conducted include fleet training and independent steaming exercises (ISEs). Ordnance use is not permitted.
Laser Training Ranges (LTR-1 and LTR-2)	LTR-1 and LTR-2 are water ranges located northwest and southwest of San Clemente Island. They extend from the surface up to 1,524 m above MSL. These areas were developed to test the laser-guided Hellfire missile. Lasers are employed against targets that are either towed or remotely controlled.
Missile Range One East/West (MISR-1E/MISR-1W)	Both MISR-1E and MISR-1W are located about 111 km south-southwest of NAB Coronado. They extend from the ocean bottom up to 24,380 m above MSL. Exercises conducted include rocket and missile firing, ASW, carrier and submarine operations, fleet training, ISE, and surface and air gunnery. Conventional ordnance is permitted.
Northern Air Operating Area (NAOPA)	The NAOPA is located east of San Clemente Island and is approximately 167 km west of NAB Coronado. It extends from the ocean bottom to 24,380 m above MSL. Exercises conducted here include fleet training, multi-unit exercises, and individual unit training. Torpedo and anti-submarine rocket exercises using conventional ordnance are permitted.
San Pedro Channel Operating Area (SPCOA)	The SPCOA is an open ocean area located about 111 km northwest of NAB Coronado. The area extends from the ocean bottom to 305 m above MSL (213 m above MSL south of 33°15 minutes (′) North [N]). The area lies outside of the boundaries of W-291. Exercises conducted here include fleet training, mining, mine countermeasures, and ISE.
Tactical Maneuvering Areas (Papa Areas: TMA-P1 through TMA-P8)	The Papa Areas are open ocean air operating areas that extend from 1,524 m MSL up to 12,190 m above MSL (P2 and P3 extend to 7,620 m above MSL for air-to-air guns). Exercises conducted include air combat maneuvering (except in P4), air intercept control aerobatics, and air-to-air gunnery. Air-to-air gunnery exercises use 20-millimeter (mm) cannon fire and are limited to TMAs P2, P3, and P5.
Warning Area W-291	W-291 is a large, special use air, surface, and subsurface, open ocean area located off of the southern California coastline. It extends from the ocean bottom to 24,380 m above MSL and encompasses several other OPAREAs. Air, surface, and submarine units exercise in this major area. Operations include all weather flight training, drone flights, refueling, test flights, rocket and missile firing, bombing, fleet training, independent unit training, ASW, aircraft carrier, and ship and submarine operations, and anti-air and surface gunnery. Conventional ordnance is permitted.
Western San Clemente Operating Area (WSCOA)	The WSCOA is located about 333 km west of NAB Coronado. It extends from the ocean bottom up to 1,524 m above MSL and lies along the northern boundary of W-291. Exercises conducted include ISE and fleet training. Ordnance use is not permitted.

Source: (DoN 2005b; 2005a)

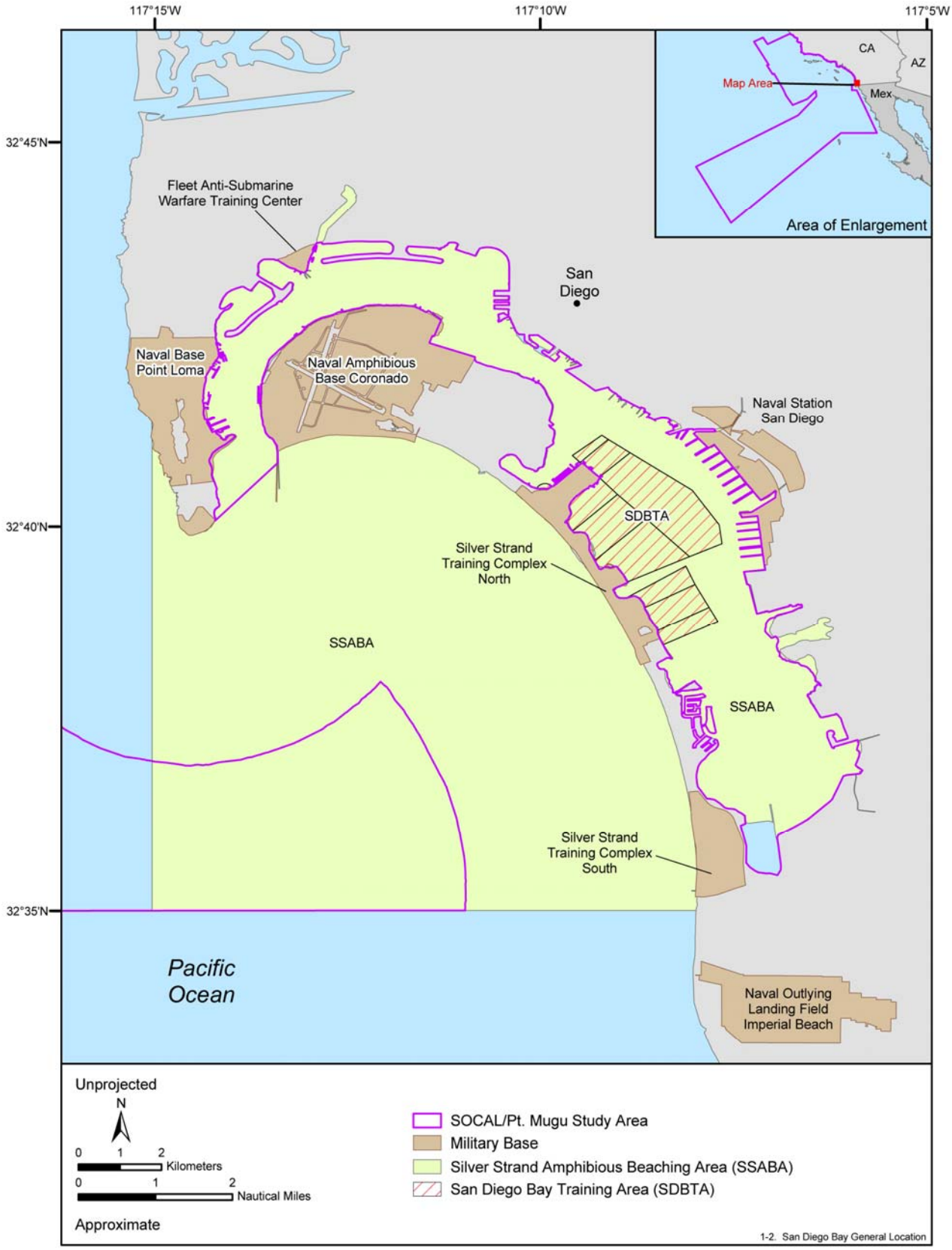

Figure 1-2. Naval OPAREAs and installations around San Diego Bay. Source data: DoN (2000a) and SRS Technologies, Inc. (2003).

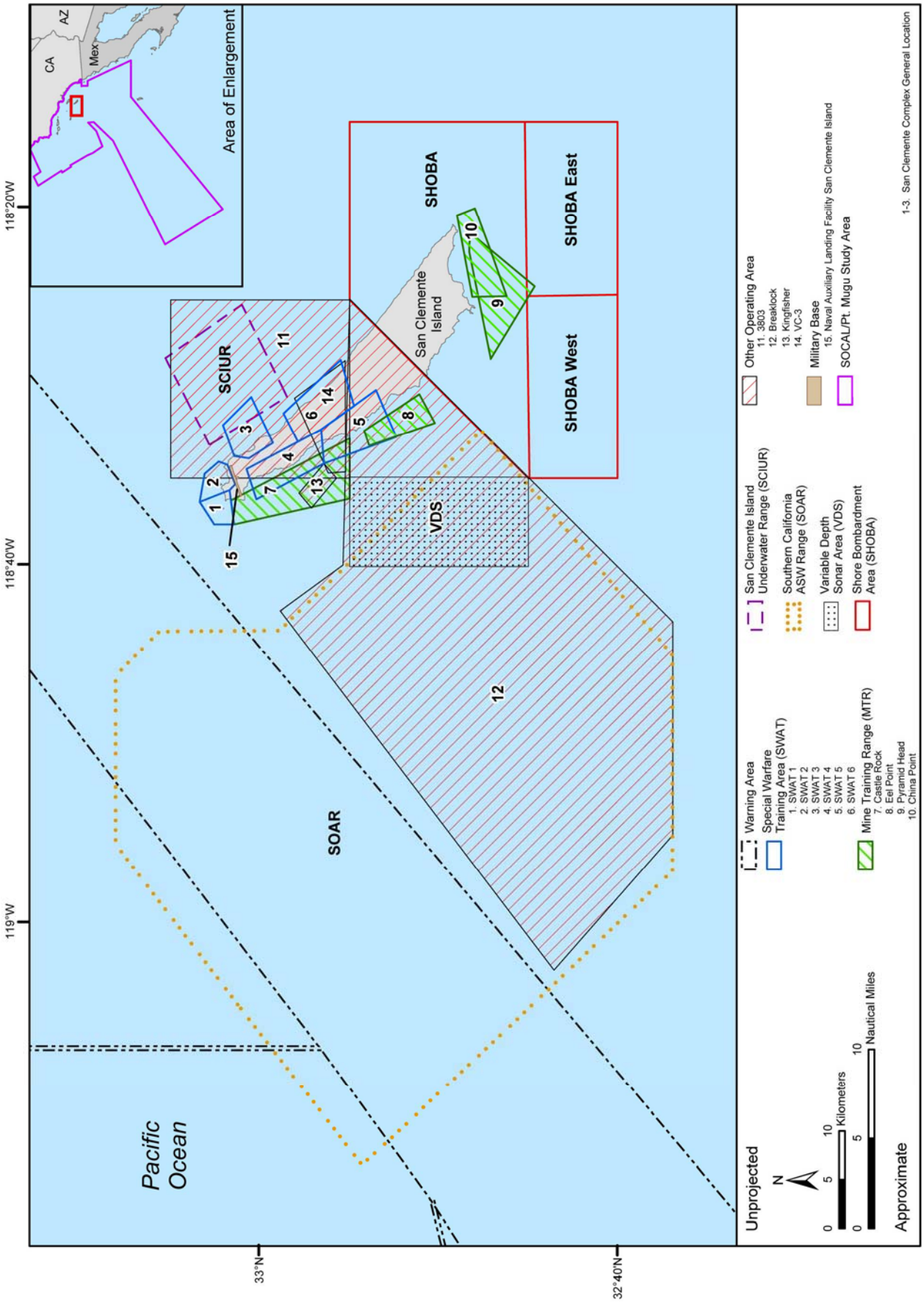

Figure 1-3. Naval OPAREAs and installations around San Clemente Island. Source data: SRS Technologies, Inc. (2003).

The Pt. Mugu OPAREA consists of coastal and open ocean waters overlaid by special use airspace that includes both restricted and warning areas extending from the ocean surface to an unlimited altitude (DoN 2000b). The Pt. Mugu OPAREA is roughly divided into inner and outer portions via an imaginary line that passes through San Miguel Island in the north to San Nicolas Island in the south (**Figure 1-1**). The Pt. Mugu OPAREA is associated with NAS Pt. Mugu, a part of Naval Base Ventura County located approximately 80 km northwest of Los Angeles. NAS Pt. Mugu provides support services for the NAWCWPNS test and evaluation and operational training activities that occur on the base, within the sea range, and at the offshore facilities located on San Nicolas and Santa Cruz Islands. NAS Pt. Mugu operates an air terminal, an air traffic control center, and provides airfield services but does not provide port facilities nor does it allow docking for vessels of any size (DoN 2002a).

One of the most important components of the Pt. Mugu OPAREA is San Nicolas Island. San Nicolas, one of the Channel Islands, is owned by the Navy and comprises 14,230 acres (ac) located far offshore, approximately 105 km southwest of the NAS on the boundary between the inner and outer portions of the OPAREA. Its location makes it ideal for simulation of shipboard missile and target launches. In addition to supporting operations in the immediate vicinity of the island, the equipment and facilities on San Nicolas Island support operations throughout the OPAREA and include radar, telemetry, and communications instrumentation, missile launching stands, target facilities, and the San Nicolas Island Outlying Landing Field (OLF).

The nearshore environments of Pt. Mugu host a diversity of habitats, including the estuarine habitats associated with Mugu Lagoon on NAS Pt. Mugu. Mugu Lagoon occupies approximately 350 ac and is part of a larger 2,500-ac wetland designated as a significant ecological resource (DoN 2002a). Mugu Lagoon provides habitat for a variety of marine species, including macrophytes, invertebrates, and fishes. The lagoon supports roosting and foraging habitat for protected seabirds including endangered California brown pelicans, threatened Western snowy plovers, and endangered California least terns (Jaques et al. 1996; Strong and Jaques 2003; USFWS 2005). Other protected birds, such as the endangered light-footed clapper rail, may also be found at NAS Pt. Mugu.

The nearshore open waters of the Pt. Mugu OPAREA are split biogeographically between cold northern waters and the warmer southern waters found within the SCB, an ecologically unique area of warm and cold-water convergence that is less thermally constrictive than the colder waters that dominate the northern portion of the Pt. Mugu OPAREA (Airamé et al. 2003). North of Point Conception, the open ocean and coastal environs are dominated by the cold water of the California Current. While overall there is less diversity here than in the convergence zone to the south, the nearshore zone north of Point Conception is an important upwelling area producing a region of well-mixed, highly productive waters (Fiedler et al. 1998) that are home to many species of fishes, cetaceans, pinnipeds, sea otters, and sea turtles (Dailey et al. 1993a; Eckert 1993; Allen and Pondella 2006). The portion of the Pt. Mugu OPAREA south of approximately 35° North (N) latitude is also an extremely productive and diverse area located within the SCB. The high level of diversity, the productive nature of these waters, and the proximity of several high-density population centers result in a region containing some of the highest levels of human use anywhere in the world (Hood 1993). In addition, the protected shorelines of California's Channel Islands, five of which lie within the boundary of the Pt. Mugu OPAREA (San Miguel, Santa Rosa, Santa Cruz, San Nicolas and Anacapa) serve as a breeding ground for marine birds and as breeding and/or haulout sites for seals, sea lions, and sea otters.

1.3 APPLICABLE LEGISLATION

The primary environmental laws that govern Navy activities in the marine environment include the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). In addition to these federal acts, there are several other federal mandates, executive orders, and presidential proclamations that deal with resource conservation and management in ocean waters under U.S. jurisdiction and in foreign waters (**Table 1-2**). Relevant environmental laws for California are also discussed since the SOCAL/Pt. Mugu Study Area encompasses a number of coastal and estuarine areas that are under state jurisdiction.

1.3.1 Federal Resource Laws

1.3.1.1 General

- The **National Environmental Policy Act** (NEPA) of 1969 (42 U.S. Code [U.S.C.] §§ 4321-4370[f]) establishes national policies and goals for the protection of the environment. The NEPA aims to encourage harmony between people and the environment, to promote efforts to prevent or eliminate damage to the environment and the biosphere, and to enrich the understanding of ecological systems and natural resources important to the country. To this end, the NEPA stipulates that environmental factors must be given appropriate consideration in all decisions made by federal agencies. This includes all major federal actions, including state or private actions which benefit from federal funding, that occur within the U.S. (its lands, territories, and possessions out to 12 nautical miles [nm] from the coastline).

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

  Section 102(2) of the NEPA contains "action-forcing" provisions that ensure that federal agencies act according to the letter and the spirit of the law. These procedural requirements direct all federal agencies to give appropriate consideration to the environmental effects of their decision-making by evaluating the environmental impact, irreparable environmental effects, alternatives, and short-term and long-term impacts of the proposed action. Where a determination of significant impact (or potential significant impact) to the human environment is made, the NEPA requires federal agencies take a hard look at the environmental consequences of the proposed action, usually through the preparation of an environmental impact statement (EIS). Section 102(2) also requires the development and evaluation of alternatives to the proposed action.

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

- Congress passed the **Rivers and Harbors Appropriation Act** of 1899 (33 U.S.C. § 403) to restrict the building of structures over or in U.S. navigable waterways. Under Section 9, no bridge, dam, dike, or causeway may be constructed without 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 the U.S. Army Corps of Engineers (USACE) 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 construction and excavation in navigable waters.

- The **Submerged Lands Act** (SLA) of 1953 (43 U.S.C. §§ 1301-1315) grants to coastal states and territories jurisdiction over the offshore lands within their historic boundaries. Texas, the gulf coast of Florida, and the territory of Puerto Rico lay claim to the seabed underlying waters within 9 nm of shore, while the rest of U.S. coastal states and territories hold 3-nm claims. It also grants the rights to the natural resources on or in these lands. The federal government relinquishes its claims to the lands and resources, but maintains the right to regulate offshore activities for national defense, international affairs, navigation, and commerce.

Table 1-2. Timeline detailing the passage of federal resource laws, executive orders, and presidential proclamations affecting marine resources in the SOCAL/Pt. Mugu Study Area.

1899	**Rivers and Harbors Appropriation Act** restricts the building of structures over or in the navigable waterways of the U.S.
1918	**Migratory Bird Treaty Act** prohibits the taking, transporting, and harming of migratory birds
1953	**Submerged Lands Act** grants to coastal states and territories jurisdiction over submerged offshore lands within 3 nm (9 nm for Texas, the gulf coast of Florida and the territory of Puerto Rico)
1953	**Outer Continental Shelf Lands Act** (and its amendments of 1978) grants to the federal government jurisdiction over the resources of submerged lands seaward of state waters
1960	**Sikes Act** provides for the conservation of fish and wildlife resources on U.S. military lands
1969	**National Environmental Policy Act** establishes national policies and goals for the protection of the environment within U.S. jurisdiction
1972	**Marine Mammal Protection Act** establishes protection for marine mammals under U.S. jurisdiction
1972	**Marine Protection, Research, and Sanctuaries Act** establishes guidelines for the dumping of toxic materials into the ocean and for the designation and regulation of marine sanctuaries
1972	**Coastal Zone Management Act** establishes a voluntary national program through which U.S. states and territories may develop and implement coastal zone management plans
1973	**Endangered Species Act** establishes protection for threatened and endangered species and the ecosystems upon which they depend, as well as guidelines for conservation and recovery of these species
1976	**Fishery Conservation and Management Act (FCMA)** establishes management scheme for the sustainable use of fishery resources
1977	**Executive Order (EO) 11990 on Protection of Wetlands** issued to guide federal agencies on their use of wetlands throughout the U.S.
1977	**Clean Water Act** takes the first step toward establishing a comprehensive solution to the country's serous water pollution problems
1979	**EO 12114 on Environmental Effects Abroad of Major Federal Actions** extends the principles of the NEPA to federal actions occurring outside U.S. territory
1984	**National Fishery Enhancement Act** recognizes the social and economic value of artificial reefs in enhancing fishery resources
1987	**Marine Plastic Pollution Research and Control Act** prohibits the discharge of any plastic materials into the ocean and regulates the discharge of other refuse
1990	**Oil Pollution Act** details new policies for oil spill prevention and clean-up
1992	**National Marine Sanctuaries Act** authorizes the Secretary of Commerce to designate and manage areas of the marine environment with nationally significant aesthetic, ecological, historical, or recreational value as national marine sanctuaries
1995	**EO 12962 on Recreational Fisheries** promotes the protection and enhancement of recreational fisheries
1996	**Sustainable Fisheries Act** amends the FCMA, renaming it the **Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)**, and mandates the identification of EFH for each federally managed species
1996	**National Invasive Species Act** addresses the movement of invasive species into the lands and waters of the U.S. and outlines methods for mitigation, monitoring, and restoration of damaged ecosystems
1998	**EO 13089 on Coral Reef Protection** seeks to protect the biodiversity and health of coral reefs as well as the social and economic value reefs possess
1998	**Harmful Algal Bloom and Hypoxia Research and Control Act** is passed in response to growing harmful algal bloom (HAB) and hypoxia problems, mandating national assessments on the effects of HABs and hypoxia in U.S. waters
1999	**EO 13112 on Invasive Species** is issued to further recognize and address the economic, ecologic, and human health problems of invasive species, both terrestrial and aquatic
2000	**Presidential Proclamation 7264** establishes the California Coastal National Monument
2000	**EO 13158 on Marine Protected Areas** creates a framework for a national system of MPAs
2000	**Neotropical Migratory Bird Conservation Act** increases the protection of migratory bird species
2000	**Estuary Restoration Act (ERA)** increases estuary protection and creates interagency council to develop national strategy for wetland restoration
2000	**Coral Reef Conservation Act** sets in motion the development of a national coral reef action strategy
2001	**EO 13189 on the Responsibilities of Federal Agencies to Protect Migratory Birds** directs executive departments and agencies to increase protection of migratory birds

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

1.3.1.2 Protected Species

- The **Marine Mammal Protection Act** (MMPA) of 1972 (16 U.S.C. §§ 1361-1407) established a moratorium on the taking of marine mammals in waters or on lands under U.S. jurisdiction. Marine mammals as defined by the MMPA are cetaceans (whales, dolphins, and porpoises), pinnipeds (walruses, seals, and sea lions), sirenians (manatees and dugongs), sea otters, and polar bears. The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) jointly administer the MMPA, each with responsibility over certain of the marine mammals; the NMFS is charged with managing cetaceans and pinnipeds and the USFWS manages manatees, sea otters, 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[3][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 (USFWS) or the Secretary of Commerce (NMFS).

  In the 1994 amendments to the MMPA, two levels of harassment were defined. Level A 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 B harassment is defined as 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. **The National Defense Authorization Act for Fiscal Year 2004** (P.L. 108-136) altered these definitions of 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 (16 U.S.C. § 1362[3][18][B]). The National Defense Authorization Act for Fiscal Year 2004 also allows for military readiness exemptions from the MMPA. See **Section 1.4.2**.

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

- The **Endangered Species Act** (ESA) of 1973 (16 U.S.C. §§ 1531-1599) establishes 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 and the USFWS jointly administer the ESA and are responsible for the listing (i.e., the labeling of a species as either threatened or endangered) of all candidate species. A candidate species is one that is the subject of either a petition to list or status review, and for which the NMFS or USFWS has determined that listing may be or is warranted (NMFS 2004). The NMFS is further charged with the listing of all species of concern that fall under its jurisdiction. A species of concern is one about which the NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA (NMFS 2004). Neither listing as candidate nor informal status such as species of concern provides protection under the ESA; such protection comes only from formal threatened or endangered status.

  The NMFS and the USFWS may also propose distinct population segments (DPSs) for listing under the ESA. A DPS is a subset of a given species that meets certain criteria and may be protected by the ESA regardless of the status of the remainder of that particular species. In this case, the term "species" as used in the ESA may refer to all individuals of a species or to a subset of individuals defined as a DPS by federal rule. Listing as a DPS is the driver behind the NMFS' designation of certain subsections of Pacific salmonids as Evolutionary Significant Units (ESUs). An ESU is a federally-designated subset of a Pacific salmonid species deemed to be valuable to the species as a whole such that particular protection under the ESA is warranted for that population alone.

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

  The major responsibilities of the NMFS and the 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).

  Section 4 of the ESA provides for 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 (primary constituent elements [PCEs]) are included in the habitat designation. Designation of critical habitat affects only federal agency actions and federally funded or permitted activities. Certain military lands may be exempt from critical habitat designation (see **Section 1.4.2**). It is also possible under section 3(5)(A)(i) of the ESA for lands other than military lands to be exempted on the basis of an already established management plan if the Secretary of the Interior determines that the management plan benefits the species for which critical habitat designation is sought (i.e., the area does not need "special management considerations or protection").

  There are 46 marine mammals (36 cetaceans, 9 pinnipeds, and 1 sea otter), 5 sea turtles, and a multitude of birds, fishes, and invertebrates with known or potential occurrence in the study region. Of these, nine marine mammals, five sea turtles, six birds, two fishes, and two invertebrates are listed as either an endangered, threatened, or candidate species under the ESA (**Table 1-3**). 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 or hauled out individuals). The USFWS has sole jurisdiction over the birds while the NMFS has sole jurisdiction over both white and black abalone. The NMFS and USFWS share jurisdiction over the steelhead trout, 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 USFWS has sole jurisdiction over the tidewater goby.

- The **Migratory Bird Treaty Act** (MBTA) of 1918 (16 U.S.C. §§ 703-712) 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 addressing the protection of migratory birds. Provisions from later conventions with Mexico, Japan, and the former Soviet Union are also implemented as amendments to the MBTA. The USFWS has the authority to enforce the act's provisions, which includes determining periodically when the taking of migratory birds may occur. Federal agencies, including the military, must obtain take permits if their actions have the potential to harm birds as defined in the MBTA. 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 (16 U.S.C. § 708).

  In 2000, Congress furthered the protection of migratory birds by passing the **Neotropical Migratory Bird Conservation Act** (NMBCA) (16 U.S.C. §§ 6101-6109). This act sets aside funds used to finance projects that assist in the conservation of North American migratory birds in the U.S., Latin America, and the Caribbean. Project proposals are submitted to the Secretary of the Interior who determines which projects will receive federal funding. Not more than 25 percent (%) of a project's funds can come from the federal government. At least 75% of the funds must be used on projects outside the U.S. Congress may appropriate as much as $5 million each year for use in NMBCA initiatives (16 U.S.C. § 6109).

- Congress passed the **Coral Reef Conservation Act** (CRCA) of 2000 (16 U.S.C. §§ 6401-6409) in recognition of the importance of coral species and in furtherance of Executive Order (EO) 13089. The purpose of the CRCA is to advance the conservation and restoration of coral reef ecosystems through the application of sound science, sustainable use management, and support and financing to programs and organizations in both the governmental and private sectors. Responsibility for the CRCA is vested in the Administrator of the National Oceanic and Atmospheric Administration (NOAA), who was ordered to produce a national coral reef action strategy in consultation with the Coral Reef Task Force established per EO 13089 (NOAA 2005). The CRCA is currently in the process of reauthorization.[2]

1.3.1.3 Fisheries

- The **Fishery Conservation and Management Act** (FCMA) of 1976 (16 U.S.C. §§ 1801-1882), 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 (FMCs). The FMCs are comprised of federal and state officials who 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. A substantial portion of fishery resources in offshore waters had been allocated for foreign harvest, so these foreign allocations were reduced as domestic fish harvesting and processing industries expanded under the domestic preference authorized by the FCMA. Exclusive federal management authority over U.S. domestic fisheries resources is vested in the NMFS.

Table 1-3. ESA-designated species with known or potential occurrence in the SOCAL/Pt. Mugu Study Area and vicinity.

Taxonomic Group	Scientific Name	ESA Status
Marine Mammals		
North Pacific right whale	*Eubalaena japonica*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Guadalupe fur seal	*Arctocephalus townsendi*	Threatened
Steller sea lion	*Eumetopias jubatus*	Threatened
California sea otter	*Enhydra lutris nereis*	Threatened[a]
Sea Turtles		
Leatherback turtle	*Dermochelys coriacea*	Endangered
Green turtle	*Chelonia mydas*	Threatened[b]
Loggerhead turtle	*Caretta caretta*	Threatened
Olive ridley turtle	*Lepidochelys olivacea*	Threatened[c]
Hawksbill turtle	*Eretmochelys imbricata*	Endangered[d]
Birds[e]		
Short-tailed albatross	*Phoebastria albatrus*	Endangered
Marbled murrelet	*Brachyramphus marmoratus marmoratus*	Threatened
Xantus's murrelet	*Synthliboramphus hypoleucus*	Candidate[f]
California brown pelican	*Pelecanus occidentalis californicus*	Endangered[g]
California least tern	*Sterna antillarum browni*	Endangered
Western snowy plover	*Charadrius alexandrinus nivosus*	Threatened
Fishes		
Tidewater goby	*Eucyclogobius newberryi*	Endangered
Steelhead trout	*Oncorhynchus mykiss*	Endangered[h]
Invertebrates		
Black abalone	*Haliotis cracherodii*	Candidate[i]
White abalone	*Haliotis sorenseni*	Endangered

[a] The San Nicolas sea otter population is listed as "Experimental Population, Non-Essential" under the ESA; however, under Public Law 99-625, sea otters within the translocation zone (San Nicolas Island) receive the standard protections of the ESA for threatened species. Note that with respect to defense-related activities, sea otters within the translocation zone are treated as a species that is proposed to be listed [50 CFR §17.84(d)(4)(iv)].

[b] Although the species as a whole is listed as threatened, the Mexican Pacific nesting stock of the green turtle is listed as endangered. A risk-averse approach requires the assumption that at-sea animals encountered in the Study Area come from the Mexican Pacific population and are therefore endangered.

[c] Although the species as a whole is listed as threatened, the Mexican Pacific breeding stock of the olive ridley turtle is listed as endangered. A risk-averse approach requires the assumption that at-sea animals encountered in the Study Area come from the Mexican Pacific population and are therefore endangered.

[d] The hawksbill is a circum-tropical species thought not to venture beyond 30° latitude except in rare, warm-water situations such as an El-Niño event. A risk-averse approach requires the assumption that the hawksbill occurs in the Study Area, however, as there have been documented sightings of the hawksbill off of southern California.

[e] Six avian species that occur in the SOCAL/Pt. Mugu Study Area and have populations that are listed as either threatened or endangered will not be addressed in this report. They are mentioned only to indicate they were not overlooked in the SOCAL/Pt. Mugu Study Area seabird assessment. These species are the Hawaiin petrel (*Pterodroma sandwichensis*), Newell's shearwater (*Puffinus auricularis*), light-footed clapper rail (*Rallus longirostris levipes*), black storm-petrel (*Oceanodroma homochroa*), and Cassin's auklet (*Ptychoramphus aleuticus*).

[f] This species is currently a candidate for federal listing with a priority number of 5 (on a 1 to 12 scale) as of October, 2007. The California Fish and Game Commission determined that the Xantus' murrelet should be listed as a threatened species under the California Endangered Species Act (CESA); it was listed as a state threatened species on December 22, 2004 (CDFG 2007).

[g] The California brown pelican is proposed for delisting from the Federal List of Endangered and Threatened Wildlife and Plants pursuant to section 4(b)(3) of the Endangered Species Act of 1973, as amended (Act).

[h] The southern California ESU of the steelhead trout, which includes all naturally spawned populations of steelhead (and their progeny) in streams from the Santa Maria River to Malibu Creek, California, is listed as an endangered species. There are 14 other steelhead trout ESUs found along the U.S. Pacific coast, each with its own status under the ESA.

[i] On October 18, 2006 the NMFS officially added the black abalone to its candidate list (71 FR 61021).

In 1996, the FCMA was reauthorized, renamed the MSFCMA, and amended by the **Sustainable Fisheries Act** (SFA) (P.L. 104-297). Authority to implement the SFA is given to the Secretary of Commerce through the NMFS. The SFA provides a new habitat conservation tool in the form of the EFH mandate. The EFH mandate requires that the regional FMCs, through federal Fishery Management Plans (FMPs), describe and identify EFH for each federally managed species, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitats. Congress defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. § 1802[10]). The term "fish" is defined in the SFA as "finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds." The regulations for implementing EFH define "waters" as aquatic areas and their biological, chemical, and physical properties, while "substrate" refers to the associated biological communities that make these areas suitable fish habitat (50 CFR § 600.10). Habitats used at any time during a species' life cycle (i.e., during at least one of its life stages) must be accounted for when describing and identifying EFH (NMFS 2002). The identification must include descriptive information on the geographic range of the EFH for all life stages, along with maps of the EFH for life stages over appropriate temporal and spatial scales. Habitat requirements also must be identified, described, and mapped for all life stages of each species. The NMFS and regional FMCs determine the species distributions by life stage and characterize associated habitats, including habitat areas of particular concern (HAPCs). 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 NMFS issued a final rule that simplified EFH regulations (NMFS 2002). Significant changes delineated in this final rule are: (1) clearer standards for identifying and describing EFH, such as the inclusion of the geographic boundaries and a map of the EFH, as well as guidance for the FMCs to distinguish EFH from other habitats; (2) more guidance for the FMCs on evaluating the impact of fishing activities on EFH and clearer standards for deciding when FMCs should act to minimize the adverse impacts; and (3) clarification and reinforcement of the EFH consultation procedures (NMFS 2002). The process by which federal agencies can integrate MSFCMA EFH consultations with ESA Section 7 consultations is also included in the final rule (NMFS 2002).

The authority to place observers on commercial fishing and processing vessels operating in specific geographic areas is also provided by the MSFCMA (16 U.S.C. § 1881b[403]). 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 (16 U.S.C. § 1826[206][b][3]).

The MSFCMA was amended most recently in 2007; these amendments include measures to maintain sustainable fish stocks and mitigate the effects of overfishing. The amendments mandate annual catch limits by 2010 for stocks classified as "overfished" and by 2011 for all other stocks (16 U.S.C. § 1853[303 note][1][A-B]) as well as limited access programs to promote market-based management throughout U.S. fisheries (16 U.S.C. § 1853a[303A]). In addition, the 2007 amendments will improve enforcement of the MSFCMA to mitigate illegal, unreported and unregulated fishing practices (16 U.S.C. § 1826j[609]); NMFS is developing certification procedures to help prevent the import into the U.S. of products from unsustainable or poorly managed international fisheries.

- In 1984, Congress passed the **National Fishing Enhancement Act** (NFEA) (33 U.S.C. §§ 2101-2106) 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 responsible 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 can enhance

the habitat and diversity of these fishery resources. The NARP, which underwent revision in 2007, was implemented in November 1985 to provide guidance and criteria on various aspects of artificial reef use, including types of construction materials and planning, siting, designing, permitting, installing, maintaining, and managing artificial reefs (NOAA 2007). One of the most significant recommendations in the NARP encourages the development of state-specific artificial reef plans (Gordon 1993).

1.3.1.4 Management

- The **Sikes Act of 1960** (16 U.S.C. § 670[a]-670[o]) directs the Secretary of Defense to carry out a program for the cooperative development and implementation of Integrated Natural Resources Management Plans (INRMPs) to provide for the conservation and rehabilitation of fish and wildlife resources on U.S. military installations. The main purpose of an INRMP is to integrate conservation of natural resources on military lands with military operations and to ensure consistency with both the spirit and the letter of federal resource laws. 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 **Coastal Zone Management Act** (CZMA) of 1972 (16 U.S.C. §§ 1451-1466) establishes a voluntary national program through which U.S. states and territories can develop and implement coastal zone management plans. The NOAA, under the Secretary of Commerce, administers this act. States and territories use coastal zone management plans "to manage and balance competing uses of and impacts to any coastal use or resource" (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 defined boundaries of the coastal zone, the uses of the area that the state or 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.[3] California's coastal zone management program received federal approval from the NOAA in 1977 (CCC 1999).
  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. These effects may be direct or indirect, adverse or not and must be evaluated for consistency regardless of whether they originate within state waters. Consistency reviews may be integrated with NEPA procedures. The federal consistency requirement was enacted as a mechanism to address coastal effects, to ensure adequate federal consideration of state and territory coastal management programs, and to avoid conflicts between states or territories and federal agencies by fostering early consultation and coordination (NOAA 2000). Within each state or territory's coastal zone management plan is a list of the federal agency activities for which consistency determinations must be prepared. California's coastal management agency, the California Coastal Commission (CCC), has regulatory authority over all federal activities, permits, licenses, and funding approvals for projects that affect the state's coastal zone resources (CCC 2003).

- The **Marine Protection, Research, and Sanctuaries Act** (MPRSA) (33 U.S.C. §§ 1401-1445), often referred to as the "Ocean Dumping Act," was enacted in 1972. The MPRSA regulates the dumping of toxic materials beyond U.S. territorial waters and provides guidelines for the designation and regulation of marine sanctuaries. Titles I and II prohibit persons or vessels subject to U.S. jurisdiction from transporting any material out of the 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 (33 U.S.C. 1402[f]).

  During the reauthorization of the MPRSA in 1992, Title III of the MPRSA was designated the **National Marine Sanctuaries Act** (NMSA) (16 U.S.C. §§ 1431-1445[c]). Title III authorizes the Secretary of Commerce to designate and manage areas of the marine environment with nationally significant aesthetic, ecological, historical, or recreational value as national marine sanctuaries (NMSs). 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. NMSs are similar to underwater parks and are managed according to management plans prepared by the NOAA on a site-by-site basis. The NOAA is the agency responsible for administering the National Marine Sanctuary Program.

- The **National Invasive Species Act** of 1996 (16 U.S.C. §§ 4701-4751) was in large part a result of concern over the spread of zebra mussels throughout the inland waters of the U.S., especially the Great Lakes. This act outlines specific guidelines for identifying ways in which non-native species enter the lands and waters of the U.S., as well as methods for mitigation, restoration, and monitoring of invasive species and the degree to which they have or will spread. Sections 4711 et seq. particularly addresses aquatic invasive species; section 4713 mandates that the DoD, in cooperation with the International Maritime Organization (IMO), develop and implement a ballast water management program for its seagoing vessels to minimize the potential for introduction of non-native species via ballast water discharge and exchange.

- The federal government increased estuary protection by passing the **Estuary Restoration Act** (ERA) of 2000 (33 U.S.C. §§ 2901-2909). This act establishes the Estuary Habitat Restoration Council, a federal interagency council that was ordered to develop a national estuary habitat restoration strategy, published in 2002. Private entities propose projects to the council, which then makes recommendations to the USACE; projects are selected for implementation based on specific criteria. The federal government pays up to 65% of the project costs, excluding operation and maintenance costs. These projects are tracked in an online database developed and maintained by the NOAA. The ultimate goal of the act is to restore one million acres of estuary habitat by 2010.[4]

1.3.1.5 Pollution

- In 1977, Congress addressed heightening concern over water pollution by amending the **Federal Water Pollution Control Act** (FWPCA) of 1948 as the **Clean Water Act** (CWA) (33 U.S.C. §§ 1251-1376). For a synopsis of initiatives prior to 1977, see the USFWS *Digest of Federal Resource Laws* entry for the FWPCA.[5]

  The CWA took the first step towards establishing a comprehensive solution to the country's serious water pollution problems.[6] 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 319 of the CWA describes the control of nonpoint source (NPS) pollution, assigning to states the responsibility to implement best management practices for the control of NPS pollution. States also are granted the authority to ensure that federal activities are consistent with state programs. 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. 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. navigable waters at specified disposal sites. The USACE, through issuance of CWA Section 401 and 404 permits, is the regulatory agency that approves all discharge of dredge or fill material into U.S. waters, especially water bodies with high resource value such as wetlands, riparian areas, and headwaters.

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 **Act to Prevent Pollution from Ships** of 1980, as amended by the **Marine Plastic Pollution Research and Control Act** of 1987 **(MPPRCA)**, (33 U.S.C. §§ 1901-1915) implements the provisions set forth in Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL). Like the CWA, the MPPRCA 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 meters (m) in length, as well as all manned, fixed, or floating platforms subject to U.S. jurisdiction, keep records of garbage discharges and disposals.

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

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

- In response to growing harmful algal bloom (HAB) and hypoxia problems, Congress passed the **Harmful Algal Bloom and Hypoxia Research and Control Act** (HABHRCA) of 1998 (P.L. 105-383). This statute formed the Interagency Task Force on Harmful Algal Blooms and Hypoxia. The task force was instructed to compose a national assessment on the ecological and economic impacts of HABs, the same type of assessment for hypoxia, and a separate assessment for hypoxia in the Gulf of Mexico. These assessments include recommendations for mitigation and detail the

socioeconomic consequences of such solutions. The act appropriates a certain amount of funds to the Secretary of Commerce to use for 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 HABHRCA was reauthorized in 2004 with new mandates for research and vertical integration of management efforts.[7]

1.3.2 Executive Orders and Presidential Proclamations

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

- **EO 11990 on Protection of Wetlands** (42 FR 26961) was issued in 1977 in furtherance of NEPA. The order aims to mitigate both short and long-term effects on wetlands resulting from destruction or modification and to limit new construction in wetlands. Federal agencies are ordered to preserve wetlands, take specific action to minimize impacts to them and to avoid new construction where there is a practicable alternative. In taking action to minimize destruction and degradation of wetlands, agencies are ordered to consider relevant socioeconomic and ecologic factors. Pursuant to this order, the federal government implemented its policy of "no net loss" of wetlands.

- **EO 12962 on Recreational Fisheries** (60 FR 30769) was issued in 1995 to ensure that federal agencies strive to improve the "quantity, function, sustainable productivity, and distribution of U.S. aquatic resources" so that recreational fishing opportunities nationwide can increase. The overarching goal of this order is to promote 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.[8]

- **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 establishes the interagency U.S. Coral Reef Task Force, co-chaired by the Secretary of the Interior and the Secretary of Commerce through the Administrator of the NOAA.

- **EO 13158 on Marine Protected Areas** (MPAs) (65 FR 34909) of 2000 is a furtherance of EO 13089. It creates the framework for a national system of MPAs. MPAs are defined in EO 13158 as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." This EO strengthens governmental interagency cooperation in protecting the marine environment. It also calls for strengthening management of these existing areas, creating new ones, and preventing harm to marine ecosystems by federally approved, conducted, or funded activities (Agardy 2000). Currently, the NOAA is redefining the criteria used to designate MPAs and has recently reclassified all existing MPAs as "marine managed areas." A timeline and in-depth discussion on the process of redefining MPAs are included in **Chapter 5**.

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

- **EO 13186 on the Responsibilities of Federal Agencies to Protect Migratory Birds** (66 FR 3853) was issued in 2001 to support the efforts of the MBTA and other acts. The 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 important to migratory birds. The departments and agencies have 2 yr 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. The 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 on 11 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 California sea otters, elephant seals, 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). This designation does not include those offshore lands owned by the DoN (DoN 2002a).

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.[9]

- The **California Endangered Species Act** (CESA) of 1970, amended 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.[10]

- The **California Coastal Act** (CCA) of 1976 was developed in accordance with the federal CZMA to provide long-term protection of California's 1,760 km coastline for the benefit of current and future generations. This act creates 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).

- California's **Marine Life Management Act** (MLMA) of 1998 regulates the management of commercial and recreational fisheries within state waters, as well as the ecosystems and habitats upon which the target species depend. The MLMA calls for regulatory action to preserve the sustainability of local fisheries and utilizes a precautionary, science-based approach to protect and restore depleted stocks. Data collection on relevant fish stocks, their associated ecosystems, and catch per effort are mandated to inform the fishery management plans required by the MLMA. The MLMA also transfers the bulk of the authority for state fisheries management from the legislature to the California Fish and Game Commission.[11]

- The **Marine Life Protection Act** (MLPA) of 1999 is 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 use sound scientific guidelines to develop clearly defined objectives, effective management measures, and adequate enforcement. 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.[12]

- In 2005, the state legislature passed the **California Clean Coast Act** (CCCA) which regulates discharges into state waters from passenger vessels or oceangoing vessels over 300 gross tons (gt) that call on a California port.[13] The CCCA prohibits the discharge of waste or oily bilgewater, sewage, and graywater into state waters or marine sanctuary waters. The CCCA also sets forth a system for reporting violations to both the SWRCB and the State Lands Commission (SLC).

- In 2004, the California congress enacted legislation, under **Assembly Bills (ABs) 2093 and 2672**, to mandate stricter pollution control for cruise ships in state waters. AB 2093 prohibits graywater discharge and AB 2672 prohibits the discharge of sewage, treated or untreated, into state waters.

1.4 DEPARTMENT OF DEFENSE ENVIRONMENTAL COMPLIANCE

1.4.1 At-Sea Compliance

Chapter 22–Environmental Compliance Afloat—of the U.S. Navy's *Environmental and Natural Resources Program Manual* (OPNAVINST 5090.1C) applies to U.S. Navy ships and floating drydocks worldwide and, as appropriate, to the boats and other craft carried by these ships (DoN 2007). Chapter 22 lays out Navy policy for environmental stewardship and compliance for its vessels operating both within U.S. waters and abroad. The discharge of waste, including blackwater, graywater, hazardous and medical wastes, plastics and other trash, as well as procedures for oil spill response and ballast water control are included in this chapter along with relevant regulatory drivers. The U.S. Navy is required to comply with U.S. federal policy when operating within U.S. waters or on the high seas. This includes abiding by relevant international agreements to which the U.S. is a signatory or conforming to international agreements if it is the practice of the U.S regardless of whether the U.S. has officially ratified the agreement. The Navy is required to assess the impacts of its actions both within U.S. waters and abroad per the mandates of the NEPA and EO 12114. It is the policy of the Navy to provide for national defense in a manner consistent with federal environmental policy and to utilize the systematic approach of the NEPA as an effective decision-making tool. To this end, NEPA processes are integrated with U.S. Navy and USMC actions as early as possible to protect, enhance, and restore environmental quality within a framework consistent with the mission of the Navy, stated national policy and security requirements.

Due to the protection afforded marine mammals by the MMPA, Navy vessels are prohibited from deliberately harassing a marine mammal. Per Navy policy, vessels must report all instances of shipstrikes (i.e., the collision between a vessel and a marine mammal for any reason) to the Chief of Naval Operations (CNO). Navy policy also mandates that those in authority plan and act to protect marine mammals during operations (DoN 2007). The Navy employs monitoring and mitigation activities during its operations to guard against adverse effects to marine mammals; these activities do not cease upon invocation of a military readiness exemption.

1.4.2 Federal Agency Exemptions

Federal agencies are required to comply with environmental legislation. However, there are provisions within several major federal resource laws for the exemption of certain DoD lands or activities if such exemption is necessary for national security. These exemptions come either from wording in the original legislation or from amendments and are related primarily to protected species laws. Military readiness exemptions most relevant to the marine environment are authorized by the **National Defense Authorization Act for Fiscal Year 2004** (NDAA) (P.L. 108-136). The NDAA includes specific exemptions from the MMPA and the ESA for DoD lands and activities.

The MMPA affords protection to all marine mammals as defined in 16 U.S.C. § 1372(6), prohibiting the take of marine mammals by any person or vessel under U.S. jurisdiction. The MMPA allows for the issuance of incidental take permits for both levels of harassment defined in section 1372(6)(A-D). The

NDAA modified these definitions for actions involving military readiness. The NDAA also empowers the Secretary of Defense (SECDEF) to exempt actions involving military readiness from compliance with the MMPA when the SECDEF determines an exemption necessary for national security. The exemption can apply to a single action or to a group of actions, and may be applied to the same action more than once. The duration of a military readiness exemption from the MMPA is determined by the SECDEF, but cannot be longer than 2 yr. The SECDEF must submit the details of and reasons for the exemption to the House and Senate Armed Services Committees within 30 days (d) of the issuance of an exemption. The NDAA also strikes certain language in the MMPA in relation to take authorizations for military readiness activities such that there is no restriction on the geographic scope of the authorization. As of early 2008, the military readiness exemption from the requirements of the MMPA has been invoked twice – once for a period of 6 months (mo) and once for a period of 2 yr.

Exemptions to the ESA for military activities exist in two forms. The first pertains to military lands and the designation of critical habitat as mandated by section 4(3) of the ESA. The Sikes Act of 1960 and the Sikes Act Improvement Act of 1997 (see **Section 1.3.1.4**) mandate the development of INRMPs to provide for the conservation and rehabilitation of fish and wildlife resources on U.S. military installations. Section 318 of the NDAA allows an INRMP to substitute for critical habitat designation if that INRMP provides a "benefit" to the species. This "benefit" must be determined in writing by the Secretary of the Interior. Section 318 also orders the Secretary of the Interior to take into account the impacts on national security before making a critical habitat determination. Military lands within the SOCAL/Pt. Mugu Study Area that have been exempted from critical habitat designation based upon either INRMP status or national security impacts include:

- Naval Base Ventura County (includes NAS Point Mugu)
- Vandenberg Air Force Base
- San Nicolas Island
- NAB Coronado
- Silver Strand Training Complex
- Naval Station San Diego
- Fleet ASW Training Center
- Naval Base Point Loma

Critical habitat exemptions for DoD lands and activities do not affect the obligation to comply with the NEPA or with interagency consultation required by Section 7 of the ESA.

The second type of exemption from the requirements of the ESA applies to federal agency actions related to national defense and is found in the language of the ESA. Section 7(j) of the ESA directs the Endangered Species Committee to exempt federal agency actions from Section 7 consultation if the SECDEF determines that an exemption is necessary for national security. Such an exemption, when granted, will not trigger the NEPA process except in certain situations. This clause has never been invoked.

Two other of the major pieces of environmental legislation that govern federal agency actions have an escape clause. Under certain circumstances, the President is authorized to exempt specific activities from the federal consistency requirement of the CZMA if (s)he determines that the activities are in the paramount interest of the U.S. (16 U.S.C. § 1456[a][1][B]). Under the CEQ's implementing regulations for the NEPA, federal agency actions with significant environmental impact and occurring under "emergency circumstances" may proceed without NEPA review (40 C.F.R. § 1506.11).

1.5 METHODOLOGY

1.5.1 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 used in the assessment: journals, periodicals, bulletins, monographs of scientific and professional societies, theses, dissertations, project reports, endangered species recovery plans, stock assessment reports (SARs), Environmental Assessments (EAs), EISs, FMPs, 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 SOCAL/Pt. Mugu Study Area (all of which are mentioned below). Although the southeastern portion of the Study Area extends into Mexico's Exclusive Economic Zone (EEZ), data were not specifically obtained to characterize the marine resources off Baja California.

To investigate the physical environment and habitats of the Study Area; to summarize the occurrence patterns of protected species; to determine the locations of EFH; to describe the region's recreational and commercial fisheries; and to ascertain the distribution of maritime boundaries, shipping lanes, MMAs, and other concerns, information was collected from the following sources:

- Academic and educational/research institutions (Blue Ocean Institute, BirdLife International, California Coastkeeper Alliance, California Sea Grant, California State University, Cascadia Research, Center for Biological Diversity, Coastal Conservancy, College of William and Mary, Cooper Ornithological Society, Duke University, Harvey Mudd College, Humboldt State University, International Society for Bird Preservation, Johns Hopkins University, Los Angeles County Museum of Natural History, Marine Conservation Biology Institute, Monterey Bay Aquarium, Moss Landing Marine Laboratory, National Audubon Society, Oak Ridge National Laboratory, Ocean Conservation Society, Old Dominion University, San Diego Society of Natural History, San Diego State University, Scripps Institution of Oceanography, Texas A&M University, Texas A&M University at Galveston, Universidad Autónoma de Baja California, University of Arizona, University of California at Berkeley, University of California at Santa Barbara, University of California at Davis, University of California at Los Angeles, University of California at Santa Cruz, University of Colorado, University of Hawai'i, University of North Texas, University of Rhode Island, University of Texas at Dallas, Virginia Institute of Marine Science, Wider Caribbean Sea Turtle Conservation Network (WIDECAST), WILDCOAST, Woods Hole Oceanographic Institute);

- The Internet, including various databases and related websites (NOAA, NMFS, Ocean Biogeographic Information System - Spatial Ecological Analysis of Megavertebrate Populations [OBIS-SEAMAP], U.S. Geological Survey [USGS], Pacific Fishery Management Council [PFMC], Channel Islands National Marine Sanctuary [CINMS], National Park Service [NPS], National Estuary Program, National Wildlife Refuge System, Commondreams.org, Elsevier, Allen Press, Blackwell-Synergy, FishBase, ReefBase, Reef Environment Education Foundation, Food and Agriculture Organization [FAO], FR, seaturtle.org, University of Florida Sea Turtle Bibliography, National Sea Grant Library, California Diving Adventures, North Pacific Pelagic Seabird Database);

- U.S. Federal agencies (DoD; DoN; Department of the Air Force [DoAF]; USMC; U.S. Coast Guard [USCG]; Department of State [DoS]; Department of Transportation [DoT]; Naval Research Lab [NRL]; Marine Mammal Commission [MMC]; MMS; National Aeronautic and Space Administration [NASA]; National Geospatial-Intelligence Agency [NGA]; NMFS: Alaska Region, CINMS, National Marine Mammal Laboratory [NMML] and Library, Office of Habitat Protection, Office of Protected Resources, PFMC, NMFS-Northwest Fisheries Science Center [NWFSC], NMFS-Southwest Fisheries Science Center [SWFSC], NMFS-Southwest Regional Office [SWR]; NOAA: National MPA Center, National Ocean Service [NOS], National Weather Service, National Data Buoy Center (NDBC); USFWS Field Offices; NPS; USGS, U.S. Department of Agriculture [USDA]);

- California state agencies (CCC, CDFG, California Environmental Resources Evaluation System [CERES], California Geological Survey, California State Lands Commission [CSLC], California Cooperative Oceanic Fisheries Investigations [CalCOFI], California Cooperative Anadromous Fish and Habitat Data Program [CalFish], California State Water Resources Control Board); and

- International agencies and commissions (Canada Department of Fisheries and Oceans [DFO], Committee on the Status of Endangered Wildlife in Canada [COSEWIC], Canadian Wildlife Services, United Nations Environment Programme-World Conservation Monitoring Centre [UNEP-WCMC]).

1.5.2 Spatial Data Representation—Geographic Information System

The geographical representation of marine resource occurrences in the SOCAL/Pt. Mugu 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 common to all data sets allowed the widely dissimilar data to be visualized in a meaningful manner.

A Geographic Information System (GIS) was used to store, manipulate, analyze, and display the spatial data and information accumulated for the SOCAL/Pt. Mugu Study Area. For this project, Environmental Systems Research Institute, Inc.'s (ESRI) ArcGIS® Version 9.2 software was used to create the majority of the map figures and metadata. ArcGIS® was chosen for this project due to Naval use, industry-standard status, and broad functionality.

The geographic locations of important marine resources in the SOCAL/Pt. Mugu 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 available in coordinate form. For example, maps displaying non-coordinate data, information given via personal communication, or information extracted from a literature description are referenced as source information. In certain cases, source maps and/or information had to be interpreted to be usable in the GIS environment. Maps displaying geographic information that was interpreted or altered from the original source map/information are noted in the figure caption as being “adapted from” with a corresponding source name.

The source type and associated references for all marine resource data presented in the map figures are listed in each figure’s caption. The full reference citations for map source data or information may be found in the Literature Cited section of each MRA chapter. The two primary types of spatial information used in the SOCAL/Pt. Mugu 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 is 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 data set 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 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 warm-water period (15 June through 15 December) and cool-water period (16 December through 14 June). These divisions were determined by scientists with the NMFS-SWFSC and are based on general oceanographic conditions in the study region.

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.

1.5.2.1 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 2002) were sampled at 3 arcsecond (MOA) resolution and extracted at 15-MOA resolution to obtain a smaller and more usable file size. Bathymetric data from Scripps Institution of Oceanography (SIO 2005) 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, and 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 SOCAL/Pt. Mugu Study Area, triangular irregular networks (TINs), which interpolate intermediate data values between surveyed data points, were created using the available bathymetry data and processing those data in the ArcGIS® 3D Analyst extension. The 2-min bathymetric sounding data sampled from Scripps Institution of Oceanography (SIO 2005) were used to create the TIN, which depicts the 3D bathymetry of the SOCAL/PT. Mugu Study Area and vicinity (**Figure 2-1**). The TINs were viewed in the ArcGIS® 9.2 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 SOCAL/Pt. Mugu Study Area was derived using the detailed vector bathymetry contours that were adapted from NOAA (2002) and Scripps Institution of Oceanography (SIO 2005) 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 Study Area. An analytical unit composed of three grid cells by three grid cells was repetitively analyzed throughout the rectangular depth grid to derive a digital depth model. ArcGIS 9.2® 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 sea surface temperature (SST) were compiled from weekly averaged Advanced Very High-Resolution Radiometer (AVHRR) satellite data, which contain multi-channel SST pixel data (NASA 2000). Seasons were defined with the same monthly derivations used throughout the MRA report (cool-water period: 16 December through 14 June, warm-water period: 15 June through 15 December). Data for the SOCAL/Pt. Mugu 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:

$$\text{SST (°C)} = 0.15 * \text{DN} - 2.1$$

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 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 Study Area (NASA 2000; NASA 2005). Pixel data for the SOCAL/Pt. Mugu Study Area extent from 1978 to 1986 were extracted and converted to chl *a* values using MATLAB® and the provided function:

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

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. The seasonal range of chl *a* concentrations (in milligrams [mg] per cubic meters [m^3]) is visualized on the MRA map figures as a color spectrum with chl *a* concentrations increasing from red to blue.

Habitat Data—Multiple sources of data and information were used in the creation of maps for the coastal and oceanic habitats located in the SOCAL/Pt. Mugu Study Area and vicinity. The maps displaying estuarine, seagrass, kelp bed, deep rocky, and artificial habitats (see **Chapter 2.0**) are all examples of multiple data sources used in the creation of a single map. These maps were created using scanned images, coordinate data, GIS shapefiles, and other information available in the scientific literature and technical reports.

1.5.2.2 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 SOCAL/Pt. Mugu Study Area. An overview of known marine mammal and sea turtle data sources for the waters off California 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 SOCAL/Pt. Mugu Study Area. Of greatest utility were sightings collected during NMFS aerial and shipboard surveys of the Study Area and 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 of the records 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 Study Area. 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 five 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 Study Area. **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 designated by the NMFS and maps of pinniped haulout sites in the Study Area, 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. **Section 3.2** of this MRA includes a map summarizing the developmental migration path of loggerhead turtles as they move from nesting beaches in the western Pacific to juvenile developmental habitats in the eastern Pacific and back to foraging/breeding areas in the western Pacific as adults. This map allows the reader to better visualize and understand the life history and migration patterns of this species in the North Pacific Ocean. **Section 3.2** also includes maps of both the NMFS-designated conservation zones that are located in the eastern Pacific Ocean (EPO). These area closures are designed to protect loggerhead and leatherback sea turtles. The conservation zone for the leatherback is located to the north of the Study Area; the conservation zone for the loggerhead overlays the SOCAL/Pt. Mugu Study Area south of Point Conception.

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.

1.5.2.3 Biological Resource Maps—Essential Fish Habitat

Maps displaying the EFH for all lifestages of salmon, coastal pelagic, groundfish, and highly migratory species found within the SOCAL/Pt. Mugu 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 D**.

1.5.2.4 Maps of Additional Considerations

Information regarding the locations of U.S. maritime boundaries, navigable waters, MMAs, SCUBA diving sites, and oil and gas platforms in the SOCAL/Pt. Mugu Study Area was gathered from a wide array of sources. Maps displaying the major commercial shipping lanes and MMAs off central and southern California were created from data available at U.S. government agency websites. Federal and state level sites that are currently listed in the MMA Inventory are displayed in **Figures 5-4** and **5-5**. SCUBA diving sites in the SOCAL/Pt. Mugu Study Area and vicinity were depicted using geographic data, maps, and information available from local and state SCUBA diving, artificial reef, and shipwreck websites or from fish/dive chart makers. Geographic locations of oil and gas structures, including both islands and platforms, were acquired from the MMS and the CSLC.

1.5.2.5 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 consists of properties

and process documentation. Properties are derived from the data source, while documentation is entered manually. ESRI ArcCatalog® creates metadata in extensible markup language (XML) format, so the same metadata can be viewed in many different ways using different styles. Metadata created to accompany this MRA report are provided in both XML and 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.

1.5.3 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 (Würsig et al. 1998; Barlow 1999). Beaked whales are often solitary individuals, which makes their sightability much different from a species that regularly occurs in large groups, such as dolphins in the genus *Stenella* (Scott and Gilbert 1982).

Ambient conditions also affect the ability to sight 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 relatively small size, diving behavior, and startle responses to vessels and aircraft make smaller sea turtles difficult to sight or visually observe from a ship. The youngest age-classes 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 eastern 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. 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 and sighting frequency is often a direct result of the level of survey effort expended in a given area.

1.5.4 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*.

1.6 REPORT ORGANIZATION

This report consists of eight major chapters and four 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 and Biological Environment and Habitats describes the physical environment of the Study Area, including the marine geology (physiography, bathymetry, and bottom sediments), physical oceanography (circulation and currents), hydrography (surface temperature and salinity), biological oceanography (plankton), and habitat complexity. It also discusses the distribution of estuarine habitats (e.g., marshes, sandy beaches, and salt flats), seagrasses, kelp beds, and artificial habitats (e.g., artificial reefs, shipwrecks, and fish aggregating devices [FADs]) in the Study Area and vicinity. Marine managed areas and marine protected areas are also discussed in this chapter. Chapter 3—Species of Concern covers all protected species found in the Study Area: marine mammals, sea turtles, birds, fish, and one invertebrate. 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 discusses the fish, EFH, and fishing activities (commercial and recreational) that occur within the Study Area. Chapter 5—Additional Considerations provides information on U.S. maritime boundaries, navigable waterways and commercial shipping lanes, SCUBA diving sites, sailing regattas, and oil and gas structures. Chapter 6—Recommendations suggests future avenues of research that may fill the data gaps identified in this project and prioritizes research needs from a cost-benefit approach. Chapters 7 and 8 are the List of Preparers and Glossary, respectively. Appendix A includes supplementary materials referred to in Chapter 1 (including the marine mammal and sea turtle data sources) while Appendices B and C contain occurrence map figures that are described or referenced in the marine mammal and sea turtle sections (3.1 and 3.2, respectively) of Chapter 3. Appendix D includes maps for all fish species that have designated EFH (for at least one life stage) within the Study Area.

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

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2.0 PHYSICAL AND BIOLOGICAL ENVIRONMENT

2.1 INTRODUCTION

Much of the marine environment located within the SOCAL and Pt. Mugu OPAREAs is enclosed within the SCB. The SCB is the offshore region bounded between Point Conception in the north and Cabo Colnett in the south. It includes the coast of southern California, the Channel Islands, and the local Pacific Ocean environment (Kennett 1982; Hickey 1992). The SCB is the major geological province occurring within the SOCAL and Pt. Mugu OPAREAs. This predominantly north-south trending region is defined as a bight because of the prominent curvature or indentation of the southern California coastline (**Figure 2-1**). The SCB covers almost 96,000 km^2 of ocean habitat (NRC 1990) and is characterized by complex current circulation patterns and geologic features (Hickey 2000). It is composed of a variety of habitats, spanning shallow coastal areas to deepwater pelagic environments, which support a diverse assortment of marine organisms (Emery 1960).

About half of the Pt. Mugu OPAREA lies just to the north of the SCB between Point Conception and Point Piedras Blancas and includes San Luis Obispo Bay as well as other marine and geologic features. Prominent components of this region (e.g., submarine canyons and bays) will be included in the description of the physical environment; however, the descriptions of many features (e.g., climate and currents) that focus on the SCB are also relevant to the northern half of the Pt. Mugu OPAREA.

2.2 CLIMATE

The climate in the southern California region, including the SOCAL and Pt. Mugu OPAREAs, is characterized by a semi-arid, Mediterranean climate (Zedler 1982; NRC 1990; DoN 2000; DoN 2002a) similar to the climates found along the Mediterranean coast, in South Africa, and in subtropical Australia (DoN 2002a). A Mediterranean climate is, in particular, characterized by a well-defined cool, wet season (Duarte et al. 1999; Moody 2000). The climate in the SCB 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 fog, hazy afternoon sunshine, and daytime onshore breezes (Hannes 1975; DoN 2000; DoN 2002a).

Average annual daily temperatures along the coast of the SOCAL/Pt. Mugu Study Area range from 15°C in Santa Barbara to 21°C in San Diego (Zedler 1982; DoN 2002a). Summer months tend to be warm and dry with temperatures surpassing 27°C and rates of evaporation often exceeding precipitation (Zedler 1982; DoN 2000; DoN 2002b). In fact, summers are often completely dry with little to no recorded rainfall (NRC 1990; DoN 2002a; DoN 2002b). Temperatures are relatively stable throughout the year with average winter temperatures only slightly cooler (by approximately 5°C) than summer temperatures. The temperature rarely drops low enough to form frost (Zedler 1982; DoN 2002a). Winter also tends to be more humid than summer throughout the California coast; humidity (in San Diego) averages 70% annually (DoN 2002a). The majority of rainfalls occur during late winter through early spring (November through March) when the oceanic high-pressure system is weakest (MMS 2001). Annual precipitation along the coast ranges from 5 to 40 centimeters (cm) with the amount of rainfall decreasing from north to south (Zedler 1982; NRC 1990; DoN 2000; DoN 2002a). The SCB is occasionally affected by mid-latitude winter storms (DoN 2000; DoN 2002a; DoN 2002b), the remnants of tropical storms, and hurricanes (Dorman 1982).

Climactic conditions within the offshore OPAREAs follow a similar pattern, although offshore air temperatures are generally cooler throughout the year. A long-term record of atmospheric and oceanographic conditions at several sites within the SOCAL and Pt. Mugu OPAREAs is available from oceanographic buoys maintained by the NOAA's NDBC.[1] Air temperature measured over a 22-yr period (1980 through 2001) in the northern part of the Pt. Mugu OPAREA, 21 nm northwest of Port Arguello, California, averaged 13.5°C, with the warmest temperatures occurring in September (15.2°C) and the coolest in April (12.2°C) (NDBC 2003a). Farther south, near the border separating the SOCAL and Pt. Mugu OPAREAs, a buoy located 121 nm west of San Diego, California, recorded an annual mean temperature of 15.1°C, averaged over an 11-yr period from 1991 through 2001 (NDBC 2003b).

The warmest month on average was September with a mean temperature of 17.1°C, and the coolest month was April with a mean temperature of 13.5°C. The vast majority of the SOCAL OPAREA is located farther south and west than the location of this data buoy; however, no long-term historical data are available from the NDBC in these offshore regions. Even though the latitudinal distance between the two data buoys represents only about half of the north-south span of the SOCAL and Pt. Mugu OPAREAs, a distinct difference in air temperature is observed. The average annual temperature in the south is about 1.5°C warmer and the warmest month (September in both locations) is nearly 2.0°C warmer. The coolest month (April in both locations) is 1.3°C warmer at the southern buoy. A primary reason for the difference in air temperature at the two locations is the influence of the local SST. The northern buoy is located within the cold, southward flowing California Current and the southern buoy is located within the warm, northward flowing California Countercurrent (see **Section 2.5.1.2** below).

2.2.1 Seasons

In the SCB, there is very little seasonal climatic variability; however, the year can be divided into two distinct seasons based on averages of SST (DoN 2002a; DoN 2002b). A warm-water period is defined as extending from mid-June to mid-December and is characterized by little or no rainfall (NRC 1990; DoN 2002a; DoN 2002b; Reid et al. 2003; Zutta 2003). A corresponding cool-water period extends from mid-December to mid-June, and it is the season when the majority of the rainfall for the year occurs. Because of the small seasonal variations, many climactic or environmental changes are better described in reference to long-term, low frequency, interannual patterns than with seasonal cycles (NRC 1990). Two examples of long-term patterns that affect the general climate and oceanography in southern California are the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO).

2.2.2 ENSO—El Niño/Southern Oscillation

El Niño (the little boy or Christ Child in Spanish) was originally defined by fishermen from the western coast of South America with the influx of unusually warm waters along the coast near Christmas. ENSO is the result of interannual changes in sea level pressures (SLPs) between the eastern and western hemispheres of the tropical Pacific (Conlan and Service 2000). These events can initiate large shifts in the global climate, atmospheric circulation, and oceanographic processes (Jacobs et al. 1994). ENSO conditions typically last 6 to 18 mo although they can persist for longer periods of time (Barber and Chavez 1983; Lynn et al. 1998; Durazo et al. 2001; Schwing et al. 2002); they are the main indicators of global change over time scales of months to years (Philander 1983). During normal, non El Niño conditions, trade winds blow from east to west across the tropical Pacific and cause warm water to pile up in the western Pacific, resulting in ~0.5 m sea surface height difference between Indonesia and Ecuador (Conlan and Service 2000).[2,3] The equatorward flow of the Peru Current along the coast of South America and the California Current along the coast of North America, coupled with the easterly trade winds, create a net offshore transport of cool surface water (the Ekman layer) (Pickard and Emery 1990).[3] This transport can be visualized in maps of SST (see **Section 2.4.1.1**) as a large, cool “tongue” of surface water extending westward across the Equatorial Pacific. The surface water advected westward is replaced by cold nutrient-rich water upwelled from below the thermocline. This newly upwelled water enhances primary productivity and maintains an abundance of higher trophic level animals (e.g., kelp, fish, and marine mammals). Under these normal conditions, rainfall is heavy over the warm waters of the western Pacific, and rainfall in the eastern Pacific is low.

El Niño conditions occur when unusually high atmospheric pressure develops over the western tropical Pacific and Indian Oceans, and low SLP develop in the eastern tropical Pacific (Trenberth 1997; Conlan and Service 2000). During El Niño conditions, the easterly trade winds weaken in the central and western Pacific causing the normal east to west surface water transport across the tropical Pacific to reverse. The influx of warm surface water into the central and eastern Pacific lowers the thermocline resulting in drastically reduced upwelling along the coasts of North and South America (Donguy et al. 1982; Open University 2001). Without the influx of nutrients from below the thermocline, surface waters in the region

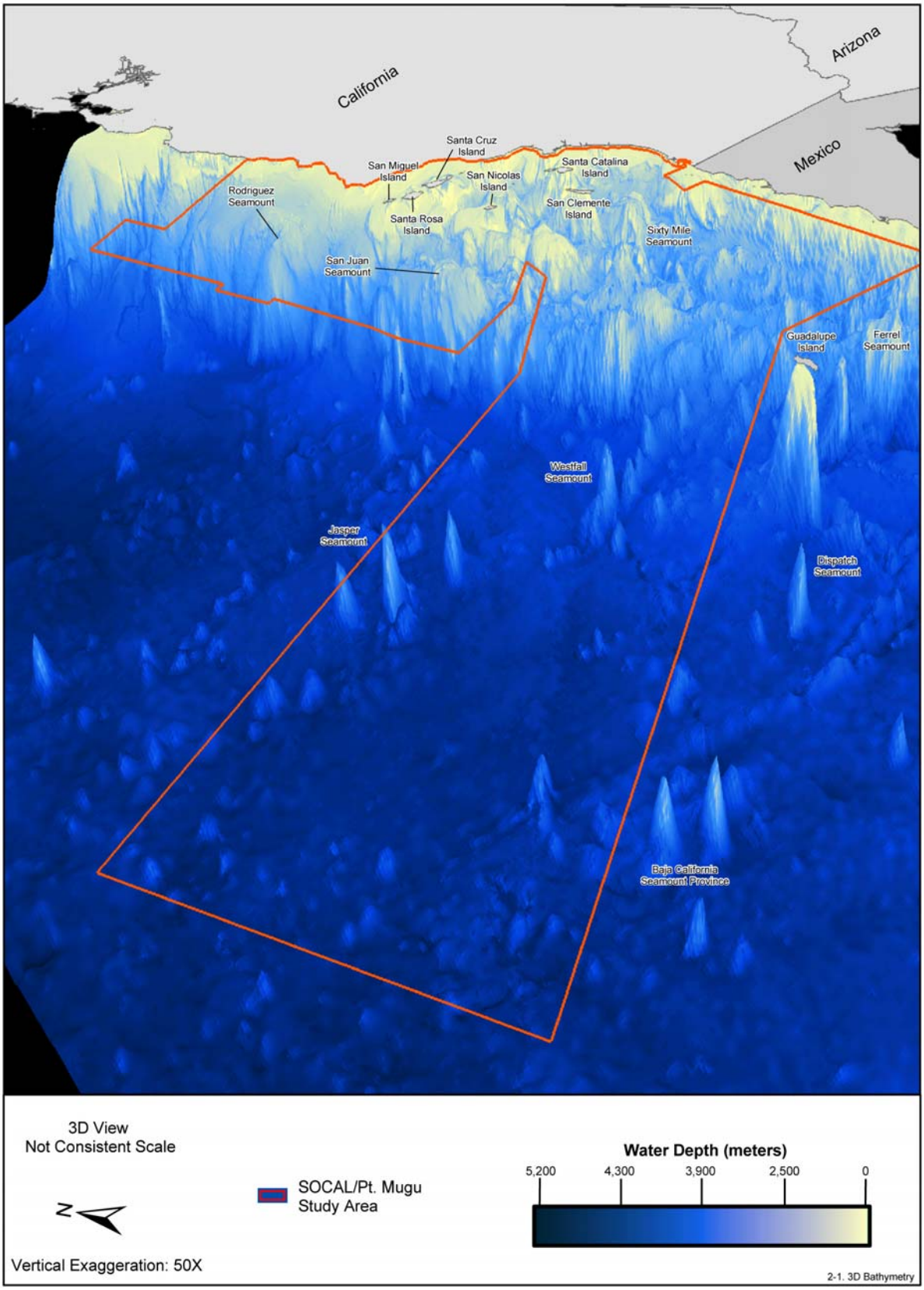

Figure 2-1. Three-dimensional (3D) bathymetry of the SOCAL and Pt. Mugu OPAREAs and vicinity. Source data: Smith and Sandwell (1997) and NOAA (2002). Source information: NGA (2007).

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become oligotrophic and marine life becomes relatively scarce. 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; Open University 2001). Historically, strong El Niño events have been documented in 1940, 1958, 1983, 1992, and 1997 to 1998 (Hayward 2000; Leet et al. 2001).

La Niña is the companion phase of El Niño in the ENSO cycle, and La Niña conditions are generally opposite those experienced during El Niño events (Open University 2001).[2] La Niña events are characterized by stronger than average easterly trade winds that push the warm surface waters of the tropical Pacific to the west, and enhanced upwelling along the eastern Pacific coastline (Schwing et al. 2000). Under these conditions, the thermocline in the western Pacific deepens and the thermocline in the eastern Pacific becomes shallower than normal. This shift results in abnormally cold SST moving westward along the equatorial Pacific. The most recent significant La Niña event occurred from 1998 through 2000, and as of January 2008, conditions similar to those in 1998 are being observed, suggesting that a strong La Niña is developing (NWS 2008). Although El Niño events are most closely associated with negative environmental impacts, strong La Niña events can also have severe environmental consequences.

The Study Area experiences considerable changes during El Niño and La Niña events (Millán-Núñez et al. 1997; Hernández de la Torre et al. 2004). During an El Niño, atmospheric temperatures increase along with corresponding increases in coastal rainfall, local sea level, SST, the strength of the California Countercurrent, and local populations of warm-water fishes. Concurrently, the trade winds weaken, upwelling and primary production decrease, and local kelp beds are severely impacted. (Barber and Chavez 1983; Barber et al. 1985; Jackson 1986; Hayward 2000; Leet et al. 2001; Allen et al. 2002); however, it should be noted that on occasion droughts have been recorded in the region during El Niño events (NRC 1990). During a La Niña event, opposite climactic patterns emerge. The trade winds strengthen, coastal upwelling and primary productivity increase, the California Current strengthens, and populations of cold water fishes increase. At the same time, a decrease in coastal rainfall (drought-like conditions) and a decline in local sea level and SST are observed (Schwing et al. 2000).

2.2.3 Pacific Decadal Oscillation

The PDO is a long-term climatic pattern capable of altering SST, surface wind, and SLP (Mantua 2002; Mantua and Hare 2002). The PDO is often described as a long-lived El Niño-like pattern of Pacific climate variability (Mantua 2002; Mantua and Hare 2002; Norman and Taylor 2003); however, the PDO has three main characteristics distinguishing it from ENSO events. First, PDO events can persist for 20 to 30 yr. Second, climatic effects of the PDO are more prominent in ecosystems outside the tropics. Third, the mechanisms controlling the PDO are unknown (Mantua and Hare 2002). The PDO has both warm and cool phases. During warm phases of the PDO, the western tropical Pacific experiences increased SLP, SST in the eastern North Pacific is warmer, and the Aleutian Low moves southwest into the western North Pacific (Miller 1996; Norman and Taylor 2003). During cold phases the tropical Pacific experiences decreased SLP, the Aleutian Low weakens, El Niño events tend to be less intense, and La Niña events tend to be stronger (Norman and Taylor 2003). In the SCB, the warm phase of the PDO is driven by a basin-scale change in wind stress (Ekman pumping), which causes a deepening of the thermocline off California (Miller 1996); however, no significant differences in the strength of the California Current have been observed in conjunction with the change in the depth of the thermocline (Miller 1996). In the SOCAL/Pt. Mugu Study Area, warmer periods of the PDO have been documented from 1938 to 1945, 1957 to 1961, and from 1977 to 1998, whereas colder periods have occurred before 1925, from 1946 to 1956, and from 1962 to 1976 (Leet et al. 2001). The PDO has been predominantly positive from 1980 to the present, with the most notable exception being from mid 1998 through mid 2002.[4]

2.2.4 Winds

Coastal winds occurring along the U.S Pacific coast are linked to basin-scale wind patterns (Schwing et al. 2000). These winds are forced by a subtropical high-pressure system stationed offshore of the SCB (Dorman 1982) producing weak and highly variable onshore winds (DoN 2000).[5] The winds produced via

this high-pressure system have average wind speeds of 10 to 15 kilometers per hour (km/hr) before reaching the coast and are classified as moderate-typical (Dailey et al. 1993; Wang et al. 1998). As they encounter the coastline and move onshore, their average wind speeds diminish by half. Although these winds are typically weak in the SCB region, stronger winds may occur during winter storms or during the occasional tropical storm (Dailey et al. 1993).

The coastal mountain ranges and islands in the SCB are capable of altering the strength and direction of winds both locally and regionally (Dailey et al. 1993). For example, San Miguel Island frequently blocks the wind flowing to the southeast along the California coastline and produces strong onshore winds along the northern side of the Channel Islands (Dailey et al. 1993). Winds blow out of the northwest over most of the islands in the SCB throughout the year and are particularly strong over San Miguel, Santa Rosa, San Nicolas, and Santa Barbara islands (Moody 2000). San Nicolas Island, the most desert like of all the islands, experiences winds up to 7.2 meters per second (m/s) nearly every day of the year (Moody 2000).

During summer, a low-pressure region creates a diurnal land breeze over the deserts 10 to 40 km east of the SCB, in a region known as the Great Basin; however, on occasion a high-pressure system settles over the Great Basin between the Sierra Nevada and the Rocky mountains, and a low pressure system lingers off the coast.[6] This shift in the position of the two pressure systems reverses the typical pressure gradient and generates strong, dry, gusty offshore winds known as the Santa Ana winds (Lynn and Svejkovsky 1984; Dailey et al. 1993; DoN 2000; Castro et al. 2003).

Santa Ana Winds—Santa Ana winds are strong winds (in excess of 46 km/hr) that blow from the desert regions northeast of the California coast. They occur most often between September and June when weather conditions exhibit high temperatures, low humidity (less than 10%), and clear skies (Sommers 1978; DoN 2002a; DoN 2002b).[6] The duration of wind events is relatively short (~3 d) and the monthly frequency peaks in December at 3.5 events per month (Castro et al. 2003; Finley and Raphael 2007). Santa Ana winds can have dramatic effects on the regional oceanography including surface currents, upwelling, air-sea heat exchange, and the input of nutrients (Castro et al. 2003). The complex topography of southern California and the Baja Peninsula (e.g., mountains and canyons) strongly influences the direction and characteristics (warm and dry) of the winds, which warm adiabatically as they descend the hills and mountains adjacent to the California coast (Castro et al. 2003; Finley and Raphael 2007). Although the Santa Ana winds are short-lived, they transport large quantities of sand and dust hundreds of kilometers out to sea (Castro et al. 2003). During droughts, the high winds and low humidity associated with Santa Ana conditions can produce extreme fire hazards in the foothills, mountains, and canyons of southern California; brush fires fed by these winds can spew plumes of soot and ash into the adjacent sea and coastal plain (Sommers 1978; NRC 1990; Finley and Raphael 2007).

2.3 MARINE GEOLOGY

2.3.1 Geologic Setting

Southern California has a dynamic geologic history that continues to unfold today, often quite dramatically. Mountains, valleys, deserts, and coastal lowlands characterize the terrain consisting of endless varieties of rocks, geologic structures (e.g., faults and folds), and surficial geologic materials.[7] The region offshore of southern California generally consists of northwest oriented ridges, banks, and basins (Emery 1960). The ridge and basin structure is a part of the dynamic San Andreas Fault system, which experiences approximately 52±2 millimeters per year (mm/yr) of horizontal shear between the Pacific and North America plates. As much as 20% (10 to 11 mm/yr) of the relative motion occurs along offshore faults (DeMets and Dixon 1999). The vertical deformation that occurs along coastal and offshore faults is directly responsible for the uplift of coastal and island marine terraces (Borrero et al. 2004). The geological formation of the SOCAL and Pt. Mugu OPAREAs is the result of volcanism, erosion, subsidence, and sea level rise. The OPAREAs encompass the continental shelf, continental borderland (Shepard and Emery 1941), the continental slope and rise at the Patton Escarpment, and at their farthest offshore reaches, the abyssal plains.

2.3.2 Physiography and Bathymetry

The seafloor beneath the SOCAL and Pt. Mugu OPAREAs is comprised of a series of unique basins, escarpments, and troughs that extend seaward for over 250 km. The submarine topography is essentially and extension of the terrestrial topography of Southern California with three notable differences: fewer canyons are present below sea level making the bathymetry simpler than the terrestrial topography, submarine basins extend deeper below their surroundings than those found on land, and the tops of the submarine mountain ranges are much flatter than those exposed on land (Shepard and Emery 1941). The broad irregular region extending seaward of the continental shelf has been termed the "continental borderland" to differentiate it from the shelf which is very narrow and close to shore (Shepard and Emery 1941; Uchupi and Emery 1963). The continental borderland has complex bathymetry comprised of submarine canyons, submerged basins, elevated submarine banks, seamounts, and steep escarpments, and extends seaward to the Patton Escarpment (Shepard and Emery 1941). The maximum water depths in the Study Area are found over the abyssal plain in the SOCAL OPAREA and exceed 5,000 m (**Figure 2-2**).

2.3.2.1 Continental Margins

Active continental margins, including those located along the majority of the U.S. Pacific coast, are often associated with trenches, volcanism, active mountains, and seismic activity (Kennett 1982). They mark the boundaries between two converging plates and are also referred to as seismic margins. Active margins are characterized by shallow, intermediate, and deep earthquakes resulting in the deformation or destruction of the earth's crust typically by subduction (Kennett 1982). The Pacific margin along the U.S. west coast is considered to be a conservative margin because of the way the two colliding plates interact along their shared boundary. In the Study Area, a narrow continental shelf (averaging only 25 km in width) moves to the northwest as part of the Pacific plate, and the continent east of the San Andreas Fault moves southeast as part of the North American plate (Kennett 1982; Dailey et al. 1993). Unlike more passive margins (e.g., along the U.S. Atlantic coast), the continent and the adjacent ocean floor reside on two different plates that move parallel to each other and in opposite directions, creating a geologic boundary referred to as a transform fault (Kennett 1982).

This conservative or translation margin is characterized by horizontal shear between the two plates which typically generate shallow focus earthquakes (focal depths less than 50 km) (Kennett 1982). The SOCAL and Pt. Mugu OPAREAs are unique along the Pacific coast in that the Pacific plate overrides the North American plate; this has produced the San Andreas Fault system (Dailey et al. 1993). The resulting Pacific margin is wide (up to 300 km in some areas) and is composed of a series of laterally shifted blocks that produce a checkerboard pattern of deep basins that are oriented from the northwest to the southeast and converge in the south (**Figure 2-2**) (Howell et al. 1980; Dailey et al. 1993).

The SCB stretches 575 km across the continental borderland from Point Conception in the north to Cabo Colnett in the southeast. The region is bounded by the California Current to the west and the California shoreline to the east. The SCB encompasses over 95,830 km^2 of ocean habitat and 22,530 km^2 of adjacent coastal areas (NRC 1990). It has many unique features including an accentuated bottom relief and varied bottom topography (NRC 1990; DoN 1999). First and foremost, there is a series of 600 to 3,000-m deep basins and surfacing mountains that have formed nine offshore islands and several large submerged banks and seamounts (NRC 1990; Dailey et al. 1993). In addition, there are 33 submarine canyons on the continental slope including 20 canyons that reach the mainland shelf (Emery 1960; NRC 1990). The Patton escarpment marks the outer edge of the continental borderland and is the true continental slope leading to the abyssal plain (**Figure 2-3**) (Uchupi and Emery 1963; Dailey et al. 1993).

The continental shelf off of the southern California coast has an average width of 6.4 km with the narrowest sections spanning less than 1.6 km and the widest reaching 24 km (Emery 1960). The widest sections of the shelf occur off of the U.S.-Mexico border, in San Pedro and Santa Monica bays, and southeast of Santa Barbara; the shelf in all four locations is at least 12 km wide. Around the islands of the continental borderland, shelf widths range from 0.16 km to 35 km, with the easternmost islands having narrower shelves and the westernmost islands having the widest shelves (Emery 1960). The seaward

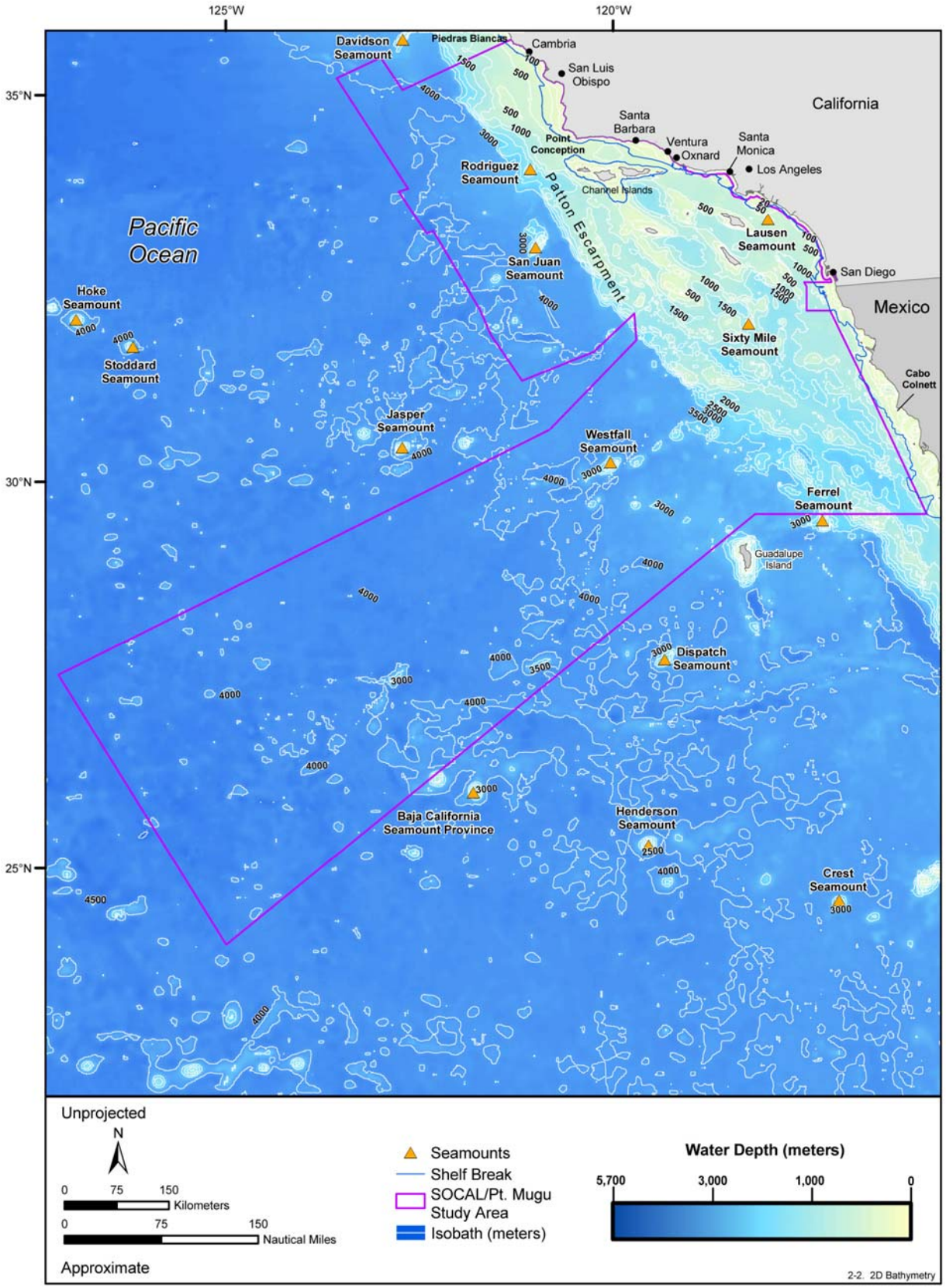

Figure 2-2. Two-dimensional (2D) bathymetry of the SOCAL and Pt. Mugu OPAREAs and vicinity. Source data: Smith and Sandwell (1997) and NOAA (2002). Source information: NGA (2007).

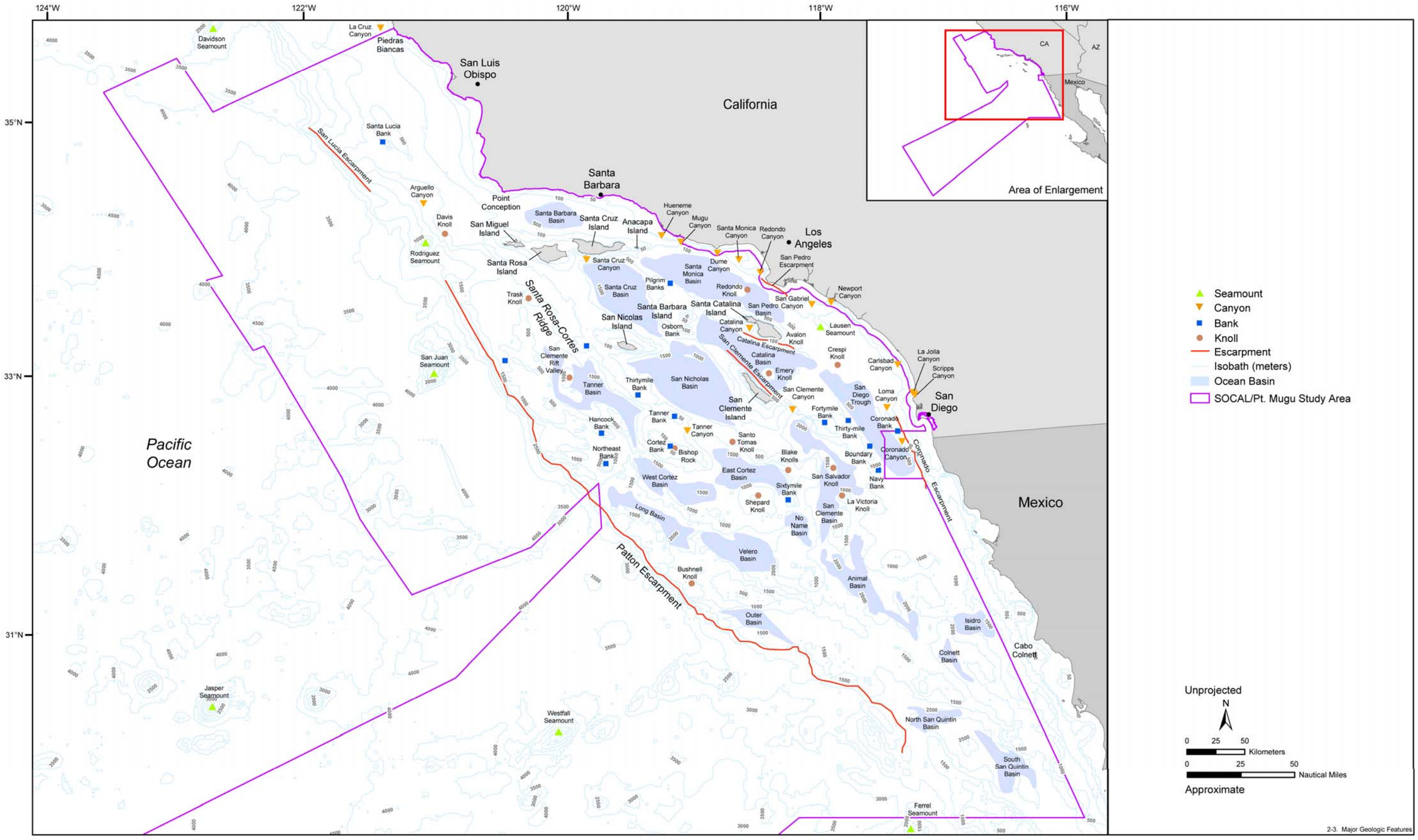

Figure 2-3. Major geologic features of the SOCAL/Pt. Mugu OPAREAs and vicinity. Source data: NRC (1990), NOAA (2002), and NGA (2007). Map adapted from: Shepard and Emery (1941) and Emery (1960).

gradient of the shelves both bordering the mainland and surrounding the islands is characteristically flat averaging less than 1°. The shelf break marking the outer extent of the continental shelf and the adjacent slope ranges in depth from 76 m off of Los Angeles to about 146 m both to the south and north. Beyond the shelf break, the basins and troughs of the continental borderland have average slopes of 8°, which is substantially less than the true continental slope located seaward of the borderland, which averages about 13° (Emery 1960).

North of Point Conception within the northern half of the Pt. Mugu OPAREA, the physiography becomes less complex as the continental borderland narrows considerably, terminating at the Santa Lucia Escarpment approximately 100 km offshore (Shepard and Emery 1941). No islands are present between Point Conception and Point Piedras Blancas near the northern extent of the OPAREA, and the most prominent bathymetric feature is the expansive Santa Lucia Bank which rises above the seafloor to a depth of 390 m. Arguello Canyon is the only major canyon found north of the SCB and in the Pt. Mugu OPAREA (Shepard and Emery 1941; NGA 2007).

2.3.2.2 Channel Islands

The Channel Islands are an archipelago of eight islands that lie off the northern region of the SCB (**Figure 2-3**). This ecologically rich area is among the most productive and diverse in the world and is home to over 500 species of fish and 1,500 species of marine invertebrates (DoN 2002b; MCBI 2003). Its diversity is partly due to unique water circulation patterns that incorporate warm equatorial waters from the south and subarctic waters from the north. These mixing water masses form a large semi-permanent eddy composed of warm nearshore waters and cool offshore waters (see **Section 2.5.1.2**). The Channel Islands originated three million years ago from volcanic activity at the seafloor and can be divided into two groups based upon their geographic location. The northern group includes San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands while the southern group includes Santa Barbara, San Nicolas, Santa Catalina, and San Clemente Islands. The islands vary in size and distance from each other and the mainland; these sizes and distances have changed with fluctuating sea levels over the geologic history of the region (Dailey et al. 1993).

2.3.2.3 Seamounts

Seamounts are undersea mountains that rise steeply from the ocean floor to more than 1,000 m above the surrounding ocean basin (Thurman 1997). They tend to be conical in shape with slopes ranging from 5° to 15° and volcanic in origin (Kennett 1982; Rogers 1994). Seamount topography is strikingly different from the surrounding ocean basin, and the effects seamounts can impart on local ocean circulation are complex and poorly understood (Rogers 1994; Open University 2001). However, seamount habitats have been linked to increased levels of phytoplankton biomass, primary production, and pelagic and demersal fishes (Zaika and Kovalev 1984; Fedorov and Chistikov 1985; Greze and Kovalev 1985; Parin et al. 1985; Rogers 1994). These conditions have been attributed to current patterns and the formation of Taylor columns (circulation vortices) above the seamounts (Darnitsky 1980; Boehlert and Genin 1987; Rogers 1994).

Five seamounts are known to be located within the SOCAL and Pt. Mugu OPAREAs and another nine are found in the vicinity of the OPAREAs (**Table 2-1**; **Figure 2-2**) (NGA 2007). The Westfall, Sixty Mile, and Lausen seamounts are located within the SOCAL OPAREA and the Rodriguez and San Juan seamounts are located within the Pt. Mugu OPAREA (**Figure 2-3**) (NGA 2007). Three seamounts are located just south of the SOCAL OPAREA; these are the Ferrel Seamount, which is found near the seaward extend of the continental borderland, the Dispatch Seamount, and the Baja California Seamount Province, both of which are found along the offshore portion of the SOCAL OPAREA (**Figure 2-2**) (NGA 2007). The Jasper Seamount is located just to the north of the offshore portion of the SOCAL OPAREA and the Davidson Seamount is located near the northern border of the Pt. Mugu OPAREA. The Henderson, Crest, Hoke, and Stoddard seamounts are located well beyond the OPAREAs (**Figure 2-2**). Additional information concerning the habitat aspects of seamounts is discussed in further detail in **Section 2.7.5.1.1** of this chapter.

Table 2-1. Seamounts located in the SOCAL and Pt. Mugu OPAREAs and vicinity (Shepard and Emery 1941; NGA 2007). [m = meter(s)]

Seamount	Latitude (decimal degrees)	Longitude (decimal degrees)	Depth (m)	OPAREA
Davidson	35.72	-122.72	1,333	N/A
Rodriguez	34.05	-121.07	655	Pt. Mugu
Lausen	33.4	-118	106	SOCAL
San Juan	33.03	-121	552	Pt. Mugu
Hoke	32.1	-126.93	1,616	N/A
Sixty Mile	32.05	-118.25	97	SOCAL
Stoddard	31.75	-126.2	2,425	N/A
Jasper	30.53	-122.7	1,312	N/A
Westfall	30.25	-120.03	2,006	SOCAL
Ferrel	29.5	-117.3	977	N/A
Dispatch	27.7	-119.33	1,553	N/A
Baja California Seamount Province	26	-124	3,000	N/A
Henderson	25.57	-119.55	2,500	N/A
Crest	24.58	-117.08	2,027	N/A

2.3.2.4 Submarine Canyons

Submarine canyons are among the most well studied features of the continental slope. Most are characterized by steep walls, winding valleys, narrow “V-shaped” cross-sections, steps, and considerable irregularity along the seafloor; 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 regions of the sea floor. Turbidity currents erode canyon walls and transport loose sediments accumulating on the shelf down the continental slope where they are ultimately deposited in a sediment cone or fan (Kennett 1982).

Thirty-three submarine canyons have been documented and named in the SCB and in the region north of Point Conception in the vicinity of the Pt. Mugu OPAREA (**Table 2-2; Figure 2-3**); however, it is likely that more exist along the continental slope in the SCB and farther south offshore of Mexico (Emery 1960; NGA 2007). Physiographic features similar to canyons, such as rift valleys, submerged valleys, gorges, and troughs are present throughout the SCB and may intersect with a canyon as it meanders from the continental shelf, down the slope, and terminates at the continental rise (Shepard and Emery 1941; NGA 2007). Of the 33 canyons in the region, 20 are adjacent to the mainland, 10 border islands, and 3 are located off of submarine banks (Emery 1960; Dailey et al. 1993). Nine submarine canyons span almost the entire width of the mainland shelf and five canyons span at least the outer third region of the shelf.

The remaining canyons are small indentations along the edge of the continental shelf (Shepard and Emery 1941; Emery 1960). Many submarine tributaries feed canyons that are located close to the shoreline; these tributaries transport water, sediment, and debris into the canyon systems. For example, Scripps Canyon contains three main tributaries, La Jolla Canyon contains seven, Hueneme Canyon has four, and Santa Monica Canyon possesses at least three (Emery 1960; Brueggeman 2006).

Table 2-2. Documented submarine canyons located offshore of southern California organized by latitude from south to north. Canyons located within the Pt. Mugu OPAREA or SOCAL OPAREA are identified (Shepard and Emery 1941; NGA 2007).

Submarine Canyon	Latitude (decimal degrees)	Longitude (decimal degrees)	OPAREA
Coronado	32.5	-117.37	SOCAL
Tanner	32.58	-119.03	SOCAL
San Clemente	32.75	-118.22	SOCAL
Loma	32.77	-117.48	SOCAL
Scripps	32.87	-117.27	SOCAL
La Jolla	32.88	-117.28	SOCAL
Carlsbad	33.1	-117.4	SOCAL
Oceanside	33.1	-117.4	SOCAL
Catalina	33.38	-118.55	SOCAL
San Gabriel	33.57	-118.07	SOCAL
Newport	33.58	-117.92	SOCAL
Redondo	33.81	-118.47	SOCAL
Santa Cruz	33.92	-119.82	Pt. Mugu
Santa Monica	33.92	-118.63	SOCAL
Dume	33.97	-118.8	SOCAL
Mugu	34.05	-119.08	Pt. Mugu
Hueneme	34.1	-119.23	Pt. Mugu
Arguello	34.35	-121.083	Pt. Mugu
La Cruz	35.71	-121.42	Pt. Mugu
Villa	35.8	-121.5	N/A
Lucia	35.97	-122	N/A
Mill Creek	35.97	-121.58	N/A
Sur	36.1	-122.07	N/A
Partington	36.13	-121.75	N/A
Carmel	36.53	-121.97	N/A
Chalmers	36.53	-121.97	N/A
Monterey	36.67	-122.08	N/A
Sekvoyya	36.8	-122	N/A
Soquel	36.8	-122	N/A
Cabrillo	36.81	-122.3	N/A
Ano Nuevo	36.85	-122.4	N/A
Ascension	36.92	-122.47	N/A
Pioneer	37.28	-123.25	N/A

In addition, many of the canyons in the OPAREA follow major submarine fault lines, including La Jolla, Catalina, and Tanner canyons as well as the San Pedro Sea Valley (SPSV). Numerous canyons lie in close proximity to the SOCAL and Pt. Mugu OPAREAs (**Figure 2-3**); however, only the major ones located within the SOCAL and Pt. Mugu OPAREAs will be discussed.

- Coronado Canyon—Coronado Canyon is the only conspicuous gash along the continental shelf within the 80.5 km stretch of the Coronado Escarpment (Shepard and Emery 1941). The canyon is approximately located off the Tijuana River, one of the largest rivers in the region. It has a V-shaped cross-section, an average gradient of 4.7%, and follows a meandering path to the seafloor (Shepard and Emery 1941; Shepard and Marshall 1975). The head of Coronado Canyon is located at a depth of 73 m approximately 13 km from shore (Shepard and Emery 1941; Shepard and Dill 1966). The canyon is 24 km long and terminates at a depth of 1,200 m where there is a large bend in the canyon convex to the north.

- Tanner Canyon—Tanner Canyon is located approximately 148 km offshore at the intersection between Tanner Bank and Cortez Bank (Shepard and Emery 1941). The path of the canyon axis follows a major fault line; it starts at a depth of 183 m, extends 21 km to the east, and empties into East Cortez Basin at a depth of approximately 1,097 m (Emery 1960).

- La Jolla and Scripps Canyons—La Jolla Canyon is located off La Jolla and initially trends seaward with its axis angled to the northwest. Scripps Canyon, a tributary of La Jolla Canyon, intersects La Jolla Canyon at an angle of nearly 90° a short distance beyond the canyon head (Shepard and Emery 1941). These two canyons were declared by Shepard and Emery (1941) to be the most heavily studied submarine canyons in the world, and that claim probably still holds true today, due at least in part, to the canyons' close proximity to shore and the Scripps Institute of Oceanography (SIO) (Covault et al. 2007; Magne et al. 2007; Thompson et al. 2007). Scripps canyon is a narrow gorge, approximately 1.6 km long trending northeast to southwest, with steep walls that have extensive kelp and surfgrass detrital habitat (Vetter and Dayton 1998). The canyon head is located within 60 m of the low-tide shoreline and has three main branches: North, Sumner, and South (Kennett 1982; Brueggeman 2006). The canyon descends rapidly (average gradient of 9.6%) and joins La Jolla Canyon at 274 m (Shepard and Emery 1941).

  La Jolla Canyon is wider (350 m at the 120-m isobath) than Scripps Canyon with gently sloping walls and a gradient that gradually decreases from about 15% at the canyon head to less than 2% at the San Diego Trough where the canyon terminates (Shepard and Emery 1941; Brueggeman 2006; Magne et al. 2007). La Jolla Canyon stretches for 35 km and has an average gradient of 4% (Shepard and Emery 1941). Along its course, the canyon bends, beginning in a northwest orientation at its head (depth ~25 m) and ending in a southwest orientation at is mouth (depth ~900 m), ultimately forming an arc that is convex to the north (Shepard and Emery 1941; Kennett 1982; Brueggeman 2006). Thousands of years of sediment deposition at the mouth of the canyon have created a large (521 km^2) sediment fan that extends 30 km from the mouth of the canyon to the San Diego Trough; deposition continues to be active today (Covault et al. 2007). Sediment from along the coastal shelf north of the La Jolla Canyon is transported south by alongshore processes, bypassing the Oceanside and Carlsbad canyons which begin farther offshore, and is then swept down through the canyon by turbidity currents at a variable rate of approximately 18 centimeters per second (cm/s) (Normark and Carlson 2003; Shanmugam 2003; Covault et al. 2007). These depositional processes have created a sediment layer at the mouth of La Jolla Canyon that is 72 m thick (Covault et al. 2007).

- Catalina Canyon—Catalina Canyon is one of only two canyons located off of an island within the SOCAL and Pt. Mugu OPAREAs (**Figure 2-3**). It is located off Little Harbor along the southwestern side of Catalina Island, and it marks the northwest termination point of Catalina Escarpment (Shepard and Emery 1941). The indentation that forms Little Harbor is also the confluence of the main watershed system on Catalina Island. Catalina canyon begins 1.6 km from the coastline at a depth of 90 m, extends 15.3 km to the southwest, and terminates at a depth of 1,030 m (Shepard and Emery 1941).

- Newport Canyon—Newport Canyon is located to the south of San Pedro Bay off of Newport Beach where the continental shelf is narrow (Felix and Gorsline 1971). The canyon head is located approximately 150 m from shore at the sand beach and forms a portion of the Newport spit (Maurer et al. 1994). The canyon follows a winding course to the south for 12 km although only the initial 5 km is considered a true canyon (Shepard and Emery 1941; Maurer et al. 1994). The remaining 7 km is a shallow and winding valley (average gradient of 4%) that terminates at a depth of 475 m near the edge of the San Diego Trough (Shepard and Emery 1941; Felix and Gorsline 1971). Sediment transport is limited to fine-grained particles (primarily silt and clay) rather than sand, designating Newport canyon as an inactive canyon (Maurer et al. 1994).

- Redondo Canyon—Redondo Canyon is located approximately 100 m offshore of Redondo Beach (Beer and Gorsline 1971). It extends 48 km out to sea and terminates at a depth of 671 m (Shepard and Emery 1941). Redondo Canyon is similar to Catalina Canyon in that it is located to the northwest of the termination point of a steep escarpment (San Pedro Escarpment, in this case) and to the southeast of a broad indentation of land (Santa Monica Bay) (Shepard and Emery 1941). The profile of Redondo Canyon is bowl-shaped near its head and V-shaped farther down its axis (Shepard and Dill 1966). The canyon descends along a straight path to the west at an average gradient of 4.1% and curves to the south near the canyon mouth at a depth of about 590 m (Shepard and Dill 1966). Sand and silts are transported down the canyon by periodic submarine slides and turbidity currents and are deposited in a submarine fan at its terminus (Emery 1960; Beer and Gorsline 1971). Although, accumulation rates of ^{210}Pb measured from the middle and lower portions of the canyon are similar to adjacent areas of the slope, suggesting that the lower reaches of Redondo Canyon may not be active (Alexander and Venherm 2003).

- Santa Monica Canyon—Santa Monica Canyon is an inactive canyon that starts at a depth of 60 m, 24 km off the coast of Venice (Shepard and Emery 1941; Normark et al. 2006). The canyon extends for 25 km to the west-south west forming and arc convex to the north and terminates in a sediment fan at the edge of the Santa Monica Basin at a depth of 700 m (Shepard and Emery 1941; Haner and Gorsline 1978). The canyon was active during periods of lower sea level, but deposition from the littoral zone is now interrupted by the shelf (Normark et al. 2006).

- Dume Canyon—Dume Canyon is a short steep canyon located on the northern shore of Santa Monica Bay off of Point Dume. It starts 550 m from the shore and is fed by Dume Creek (Shepard and Emery 1941; Shepard and Dill 1966). Dume Canyon extends 9 km to a depth of 570 m; it initially projects to the south and then bends sharply to the northwest forming an arc that is convex to the southeast. The canyon floor slopes sharply at a gradient of 9.4% (Shepard and Emery 1941; Shepard and Dill 1966; Haner and Gorsline 1978). In addition to accumulating sediment from Dume Creek, Dume Canyon captures sediment drifting south along the shoreline with the prevailing longshore current, resulting in a small (5 km wide) sediment fan at the mouth of the canyon (Normark et al. 2006).

- Mugu Canyon—Mugu Canyon differs from all of the canyons in that it follows a meandering course at the head of the canyon (Shepard and Emery 1941). The sand spit located at Point Mugu is considered to be the head of the canyon and it is located off the east side of the Santa Clara River delta (Shepard and Dill 1966). The canyon axis is V-shaped and can be traced outwards from the shelf for 14 km; it descends gradually (4.9% gradient) terminating at a depth of 732 m (Shepard and Emery 1941; Shepard and Dill 1966). The walls lining the canyon axis are steep and in some areas approach vertical drop-offs (Shepard and Dill 1966). Although Mugu Canyon is within the Santa Clara River delta, most of the sediment deposited by the river enters Hueneme Canyon, while Mugu Canyon is fed primarily by southward flowing longshore drift (Normark et al. 2006). A small sediment fan of nearly uniform thickness is located at the mouth of the canyon adjacent to and just northeast of the much larger Hueneme fan (Normark et al. 2006).

- Hueneme Canyon—Hueneme Canyon extends south off of Point Hueneme and cuts across the shelf and slope, terminating at the northwestern border of the Santa Monica Basin (**Figure 2-3**). The canyon head descends seaward about 250 m from shore (Shepard and Emery 1941). The canyon

gradually descends to the south with an average gradient of 3.2% over a distance of 21 km; although the gradient at the head of the canyon reaches 20%. The canyon walls are sloped gently and the canyon axis follows a twisting course to a depth of 686 m (Shepard and Emery 1941). A large depositional fan stretches from the mouth of the canyon for 40 km southeast across the Santa Monica Basin (Normark and Carlson 2003; Normark et al. 2006). The Hueneme fan is one of the largest depositional fans in the Continental Borderland because the outflow of the Santa Clara and Ventura rivers, which supply the majority of sediment to the Santa Monica Basin, feed directly into the Hueneme Canyon (Normark et al. 2006).

- Arguello Canyon—Arguello Canyon is located offshore between Point Conception and Point Arguello, and incises the continental slope and outer shelf. The canyon heads are found farther from shore (~16 km) than most of the other canyons in the Continental Borderland (**Figure 2-3**). Arguello Canyon actually has four heads that descend parallel to each other across the outer shelf and slope and eventually combine into a single axis below 1,000 m.[8] The canyon heads cuts across the outer shelf for only about 3.2 km and the rifts are a relatively shallow 150 m below their surroundings, a likely result of frequent slumping of the canyon walls (Shepard and Emery 1941).[8] Arguello Canyon is one of the longest canyons in the region, extending about 145 km, and its average gradient is the lowest in the region at 2.4%, with the outer reaches of the canyon sloping at a nearly level 0.6%. The canyon terminates on the abyssal plain at a depth of 3,600 m between the Santa Lucia and Patten escarpments (Shepard and Emery 1941).

- San Pedro Sea Valley—The SPSV is not a true submarine canyon because it lacks many of the defining characteristics of true canyons. It is an indentation of the slope that consists of a large, open depression formed by the intersection of two converging tectonic slopes. The SPSV extends to the south, intersects the San Pedro Escarpment, and terminates at a depth of 460 m (Shepard and Emery 1941).

2.3.2.5 Submerged Basins

A basin is a completely enclosed depression deeper than the surrounding seafloor. The sill is the deepest point along the basin rim. The topography off the southern California and Mexico coast includes numerous major offshore basins. There are 20 major basins within the SOCAL and Pt. Mugu OPAREAs and vicinity including (from north to south) Santa Maria, Santa Barbara, Santa Cruz, Santa Monica, San Pedro, Tanner, San Nicolas, Catalina, West Cortez, East Cortez, San Clemente, Long, Valero, No Name, Outer, Animal, Isidro, Coinett, North San Quintin, and South San Quintin basins (NRC 1990; Hyland et al. 1991; Hickey 1993; **Table 2-3**; **Figure 2-3**). Also included in this section is the San Diego Trough, which is not considered a true basin because it is not completely enclosed (Thompson et al. 1993) and the Santa Maria Basin which comprises the majority of the continental margin between Point Conception and Monterey Bay (Hyland et al. 1991). All true basins are completely enclosed at some depth (for example the Santa Monica Basin is completely enclosed at a depth of 740 m) and only semi-enclosed at shallower depths (Hickey 1993).

2.3.2.6 Banks and Ridges

Submerged banks are raised offshore plateaus that are similar to continental shelves except they lack a bordering land area (Emery 1960). In the SOCAL and Pt. Mugu OPAREAs, they range from very narrow in nearshore regions to 13 km in width farther offshore; several banks rise from the seafloor and extend to within several hundred meters of the surface (**Figure 2-3**). Bank tops contain a series of step-like terraces composed primarily of rocky bottom substrates (Emery 1960). Banks are capable of altering local circulation patterns and attracting a variety of marine life. Like the mainland and island shelves, the tops of banks in the continental borderland are flat, with an average gradient of less than 1° (Emery 1960).

Table 2-3. Geological characteristics of fourteen major basins within the Continental Borderland off of the southern California coast (adapted from Emery 1960). [m = meter(s); km^2 = square kilometer(s); km^3 = cubic kilometer(s)]

Basin	Sill Depth (m)	Area at Basin Floor (km^2)	Volume of Basin Below Sill Depth (km^3)
Santa Barbara	475	1,088	46
Santa Cruz	1,084	725	875
Santa Monica	737	2,020	208
San Pedro	734	699	79
Tanner	1,165	518	183
San Nicolas	1,106	958	963
Catalina	982	1,787	429
West Cortez	1,362	648	158
East Cortez	1,415	622	217
San Clemente	1,816	1,243	121
Long	1,697	544	63
Valero	1,902	570	421
No Name	1,553	78	42
San Diego Trough	1,372	1,761	N/A

There are 18 named submarine banks located within the SCB. Two of the most prominent banks are Cortes and Tanner which are located at the southeastern end of the Santa-Rosa Cortes Ridge. Cortes Bank and one of its prominent peaks, Bishops Rock, rise to within a few meters from the surface, creating a well-known hazard to navigation. Under the right conditions, the shallow water over Cortes Bank can generate mammoth waves (potentially more than 30 m high) which have recently become popular with “big wave” surfers who strive to surf the world’s largest waves (O'Hanlon 2001).

Submarine mountain ranges run parallel to many southern California basins forming ridges that separate the deep basins. The East Pacific Rise (a “mid-ocean” ridge) (EPR) marks the division between the Pacific Plate and the North American Plate and enters the region in the Gulf of California, which separates the Baja Peninsula from the mainland (Shepard 1973). The EPR appears to extend beneath the North American continent along the coast of California and then reappears north of California off the coast of Oregon (Kennett 1982). The seafloor spreading at the ERP to the north and south of the Study Area have resulted in activity along the San Andreas fault system (Kennett 1982; Open University 1998).The Santa Rosa-Cortes Ridge is neither a true island shelf nor a bank (Emery 1960). It extends approximately parallel to the mainland shoreline; Tanner and Cortes banks mark the southern end of the Santa Rosa-Cortez Ridge and the Channel Islands mark the northern end (**Figure 2-3**). Water depth along the entire ridge is less than 200 m, which inhibits entrainment of deeper waters east of the ridge by the California Current, resulting in localized upwelling along the shoreward side of the ridge (Emery 1960).

2.3.2.7 Escarpments

An escarpment is a steeply sloping drop in the seafloor usually marking the edge of a marginal plateau (e.g., a shelf) with seaward gradients of at least 1:10 (5.7°) and often approaching vertical drop-offs (Neumann and Pierson 1966). Escarpments often mark the boundary between two relatively level or gently sloping surfaces. Within the SCB, a series of escarpments run parallel to the mainland coast, and include, with increasing distance from shore, San Pedro, Coronado, Catalina, San Clemente, and Patton

(**Figure 2-3**). The escarpments are broad welts that contain long, straight troughs and ridges; the straightness of these troughs and ridges suggests that they were formed by horizontal displacement of submarine faults (Uchupi and Emery 1963). The San Pedro and Coronado escarpments are found close to the continental shelf break. Farther offshore and at greater depths (~1,500 to 3,000 m), the Catalina and San Clemente escarpments are located off the coastlines of Santa Catalina Island and San Clemente Island, respectively (**Figure 2-3**). Marking the edge of the SCB, the Patton Escarpment defines the location of the true continental slope where the ocean floor descends precipitously to the abyssal plain (Dailey et al. 1993). North of the SCB, the Santa Lucia Escarpment is located west of Santa Lucia Bank and begins at a depth of approximatlye 1,300 m and descends to about 3,600 m, at times exhibiting a gradient of 18° (Shepard and Emery 1941).

2.3.2.8 San Diego Bay

San Diego Bay is a naturally formed, crescent-shaped embayment located along the southwestern coastline of California, just north of the U.S.-Mexico border (**Figure 2-3**). The mouth of the bay is protected from the sea by Point Loma, which has an elevation of about 107 m (Emery 1960). Axial length of the bay is approximately 24.5 km; the outer half of the bay is narrow (1 to 2 km) and the inner bay widens to 2 to 4 km (Largier 1995). The mouth of the bay is deep, averaging 12 m; the southern end of the bay is shallow, ranging from 1 to 4 m deep, with the deeper areas maintained by dredging (Largier 1995; DoN 2000). Shoals at 2 to 4 m deep are located immediately beyond the mouth of the bay on either side of the dredged approach channel (Largier 1995).

2.3.3 Bottom Substrate

In the SCB, bottom substrate is heavily influenced by local submarine topography and oceanographic circulation patterns (DoN 1999). Soft, unconsolidated substrates (e.g., sands, silts, and mud) are distributed over much of the seafloor beneath the SOCAL and Pt. Mugu OPAREAs (**Figure 2-4**) (Cross and Allen 1993). Sandy substrates are found predominantly on the continental shelf while the smaller diameter silts (<62 microns [µm] in diameter) and mud dominate the bottom composition in the basins and on basin slopes of the continental borderland (DoN 1999; DoN 2000).

River systems dominate sediment deposition over the SCB, with runoff from offshore islands and erosion from submarine banks also contributing (Lund et al. 1992). Sedimentation rates decrease significantly with distance from shore; rates in Santa Monica, Santa Barbara, and San Pedro basins are highest averaging 0.8 to 1.5 mm/yr, whereas at the outer extent of the SCB (e.g., in Tanner Basin) rates average 0.1 to 0.2 mm/yr (Lund et al. 1992). Beyond 30 km there is an increasing percentage of organic carbon and carbonate in bottom sediments (Lund et al. 1992). Rocky outcrops dominate the bottom substrate at the continental shelf break, on the tops of offshore banks, along the shelf around offshore islands (e.g. Santa Catalina and San Clemente Islands), and within parts of submarine canyons (Allen et al. 1992). Santa Barbara, Santa Catalina, and San Clemente Islands are typically characterized by high relief, rocky habitat surrounded by soft sandy bottoms. Numerous submarine canyons incise the continental shelf and slope of the borderland, terminating in sediment deposition fans (see **Section 2.3.2.4** above). Thick layers of unconsolidated, course-grained, clastic sediment that has been transported down through the canyons makes up a significant amount of the bottom substrate in the SCB (Covault et al. 2007). For example, the sediment fans deposited at the mouths of the Oceanside, Carlsbad, and La Jolla canyons are 46, 59, and 72 m thick, respectively, and are distributed over a combined area of 1,260 km^2 (Covault et al. 2007).

Sediments within San Diego Bay are mostly soft (i.e., sand, silt, clay, and mud) with sands more common along the western margin of the bay (DoN 2000) and mud in the eastern and southern extremities of the bay (Largier 1995; DoN 2000). Seaward of the mouth of San Diego Bay, two shoals border the channel entrance; a rocky kelp-covered ridge to the west and a smooth, sandy depositional feature to the east (Largier 1995). Southeast of the bay mouth and enclosed within the crescent-shaped spit of land that defines the bay, bottom sediments are dominated by fine-grained sand with isolated patches of cobble and boulder (Shepard 1973). Seaward of the 37-m isobath, a mix of silt and sand with large sections of

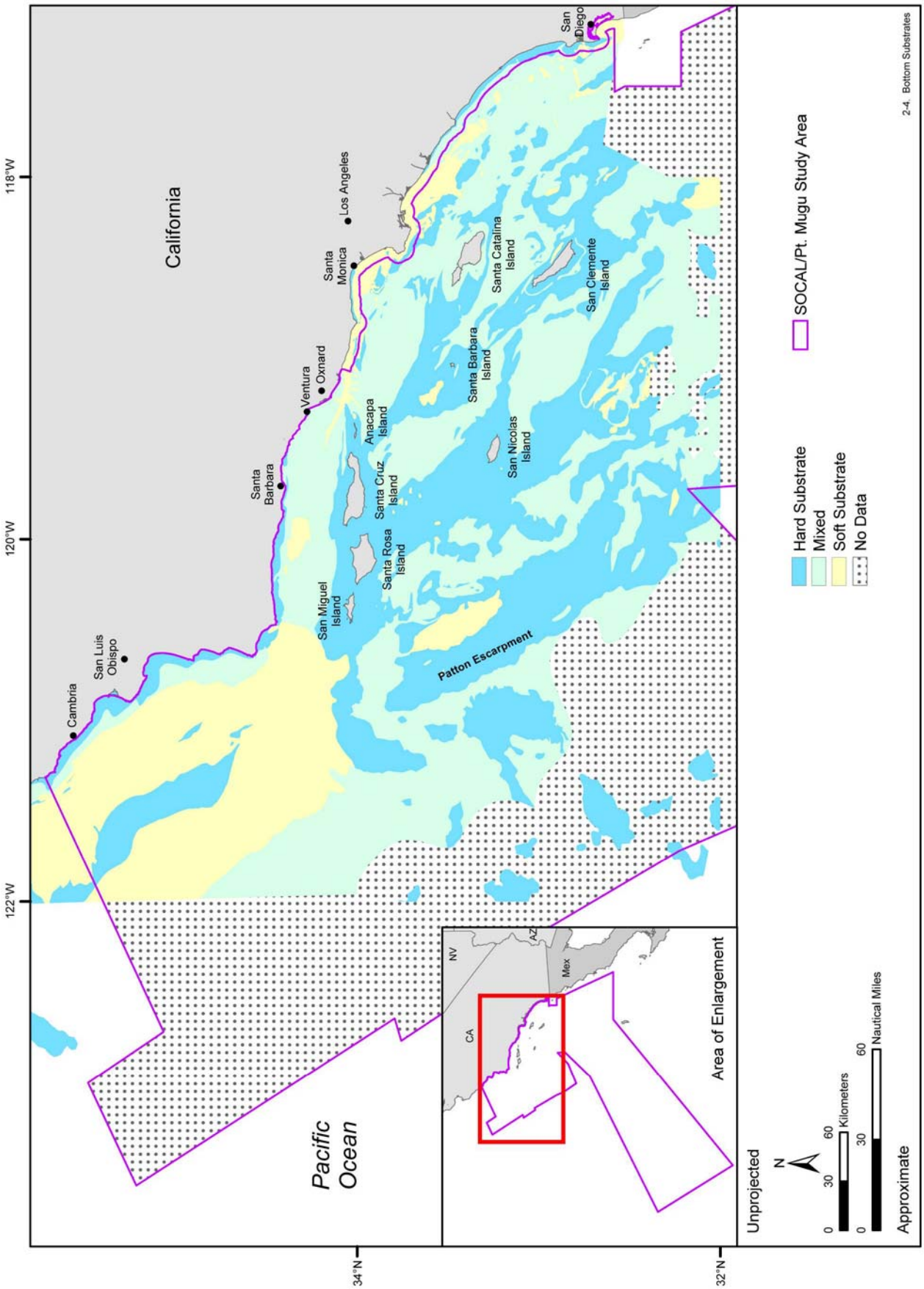

Figure 2-4. Composition of bottom substrate in the SOCAL and Pt. Mugu OPAREAs and vicinity. Source data: CSU (2001).

mainly fine grain-silt comprises the bottom substrate, with the exception of a large area of course sand west of the U.S.-Mexico border and sandy sediment on top of Coronado Bank (Shepard 1973).

The seafloor in Santa Monica Bay, located seaward of Los Angeles, is mainly composed of sandy and muddy unconsolidated sediments with grain size decreasing seaward (Dojiri et al. 2003; Edwards et al. 2003). Mud dominates sediment composition from a depth of about 20 m to the Santa Monica Basin (780 m), and sandy sediments (63 to 250 µm) predominate in nearshore areas mainly off the coast of Playa del Rey and El Segundo and on Short Bank (Edwards et al. 2003). Several isolated, rocky outcrops are interspersed throughout the bay, including along the Malibu coast east of Point Dume, along the coast off of the Palos Verdes Peninsula, on Short Bank between the Santa Monica and Redondo canyons, and within the two canyons as well. Erosion and subsequent deposition by nearshore streams and rivers have resulted in gravel and cobble beds forming along the Malibu and Palos Verdes coasts (Dojiri et al. 2003). Similar bottom substrate composition (i.e., sands and cobble) occurs along the shelf break (~100 m) as well as surrounding the other areas of hard bottom (Dojiri et al. 2003; Noble and Xu 2003). In addition to the erosional deposition from Malibu Creek, the Hyperion sewage outfall, which releases treated sewage sludge from Los Angeles to a point 8 km offshore near the middle of Santa Monica Bay, is the other primary source of sedimentation in the bay (Alexander and Venherm 2003). Sediment deposition in waters greater than 200 m in depth is dominated by hemipelagic sediments, indicating that terrestrial derived sediments mostly remain in the bay rather than being transported to the deep sea environment (Alexander and Venherm 2003).

2.3.4 Seismic Activity

The coastal areas of southern California have a dynamic history of seismic activity that continues through to the present day (Kennett 1982; Zedler 1982; Fisher et al. 2003; Fialko 2006; Catchings et al. 2008). The adjacent offshore continental borderland is also tectonically active and contains several faults and fault systems that run parallel to those on shore (**Figure 2-5**) (Astiz and Shearer 2000; Legg and Kamerling 2003). The numerous faults that run through the onshore and offshore continental crust of the region are a result of translation or shear motion between the Pacific and North American tectonic plates. The faults that result are classified as transform faults, the most famous of which is the San Andreas Fault, and are characteristic of a conservative plate margin (Kennett 1982). Named faults or fault systems occurring in the SCB include the Santa Catalina, Santa Cruz Island, Santa Rosa Island, and San Clemente faults, as well as the San Diego Trough (**Figure 2-5**).

The northwest-southeast running faults can be divided into four distinct fault zones. The easternmost zone includes the Newport—Inglewood and Rose Canyon faults (Legg and Kennedy 1979; Astiz and Shearer 2000); this zone passes onshore near San Diego and may connect with faults in Baja California (Brune et al. 1979; Astiz and Shearer 2000). The second zone includes the Palos Verdes Hills—Coronado Bank—Agua Blanca faults that passes onshore near Ensenada, Mexico. The third zone to the west includes the Santa Cruz—Santa Catalina—San Pedro—San Diego Trough—Bahia Soledad faults which pass onshore south of Punta Banda. The fourth zone includes the Santa Cruz—San Clemente—San Isidro faults (Astiz and Shearer 2000). Shallow earthquakes, those occurring at a depth of less than 30 km, are characteristic of a region with active transform faulting (Kennett 1982).

Twenty major earthquakes (magnitude 5.0 or greater on the Richter scale) have been recorded in the Study Area since 1932, and a total of 221 major earthquakes have been recorded in the southern California region over the same time period (**Figure 2-5**) (Astiz and Shearer 2000; USGS 2008). Nearly 500,000 lower magnitude (<5.0) earthquakes have been recorded by the USGS since 1932, indicating that seismic activity in the region (both on and offshore) is a constantly occurring phenomenon (**Table 2-4**) (USGS 2008). Major earthquakes (as defined above) make up only 0.04% of the total number of earthquakes recorded since 1932, whereas earthquakes measuring less than 2.0 on the Richter Scale comprise over 72% of all earthquakes.

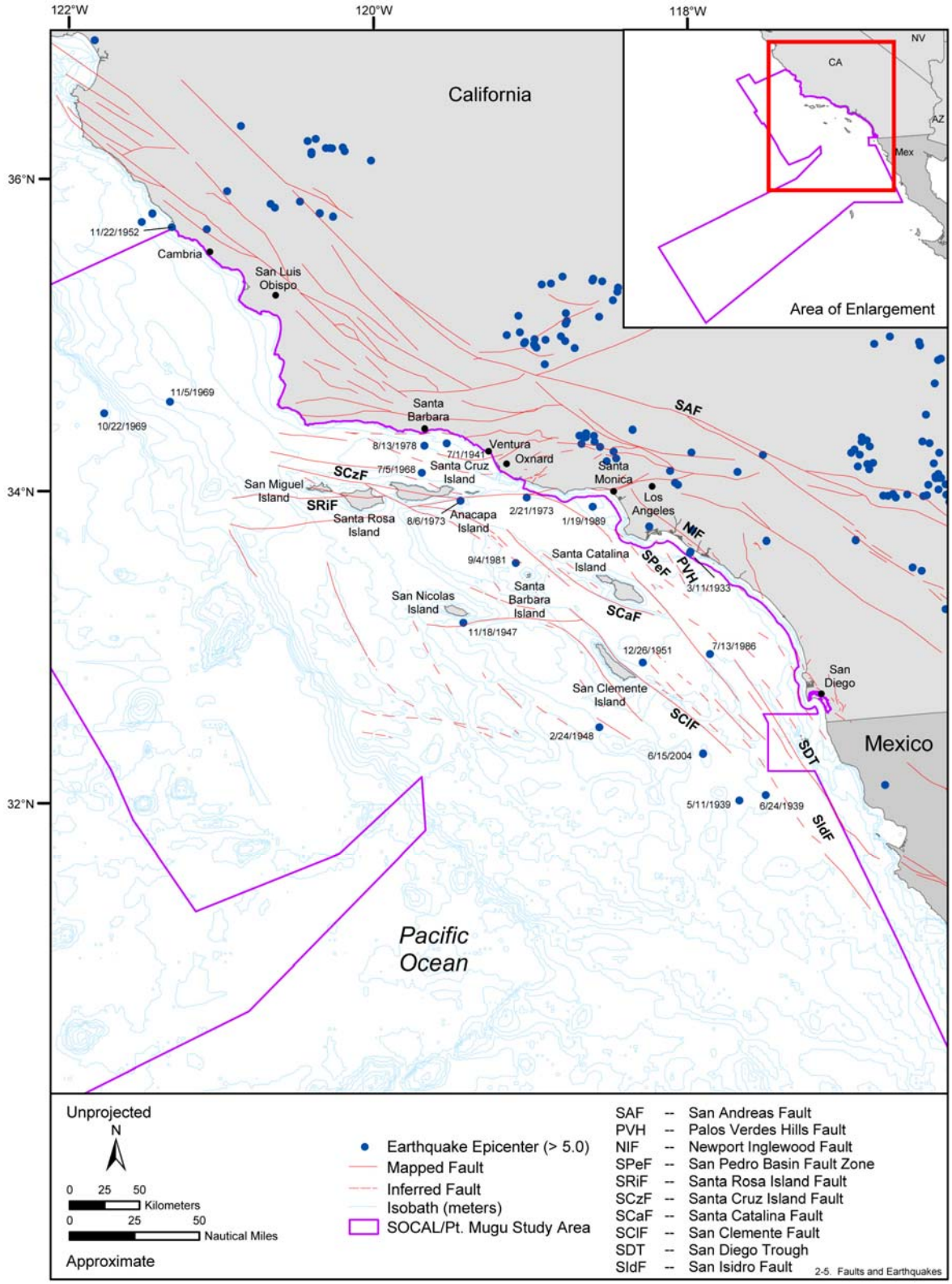

Figure 2-5. Major fault lines and the epicenters of major earthquakes (>5.0 on the Richter Scale) located in the SOCAL and Pt. Mugu OPAREAs and vicinity. Source data: USGS (2008). Map adapted from: Wilkinson (1976), Astiz and Shearer (2000), Grant and Shearer (2004), and Legg et al. (2004).

Table 2-4. Earthquakes recorded in the southern California region from 1932 through early 2008. Earthquake magnitude is based on the Richter Scale (USGS 2008).

Earthquake Magnitude	Number of Earthquakes
0.1 to 0.9	79,080
1.0 to 1.9	282,339
2.0 to 2.9	116,497
3.0 to 3.9	17,117
4.0 to 4.9	1,987
5.0 to 5.9	195
6.0 to 6.9	23
7.0 to 7.9	3
Total	**497,241**

Tsunamis are long wavelength ocean waves that travel rapidly (~200 m/s) across ocean basins, and can cause considerable damage to coastal areas once they reach shallow water near shore (Pond and Pickard 1983). Tsunamis are typically generated by seismic activity (i.e., earthquakes) or rapid slope failures that displace large amounts of sediment (Legg and Kamerling 2003; Legg et al. 2004). The continental borderland with its numerous banks, basins, and canyons is particularly susceptible to slope failures, in addition to being a seismically active region. An underwater landslide triggered by an earthquake just offshore could generate a tsunami whose tallest waves would arrive approximately one minute after the landslide.[9] Tsunamis have been recorded in the SCB at the Santa Barbara Channel (1812), off of San Diego (1862), west of Point Conception (1927), and questionably, in Santa Monica Bay (1930) (Legg and Kamerling 2003; Borrero et al. 2004). In December of 1812, a 7.2 magnitude earthquake generated a moderate sized tsunami (wave run-up exceeding 4 m in some areas) that affected over 60 km of coastline near Santa Barbara (Borrero et al. 2001). In 1927, a 7.0 magnitude earthquake northwest of Point Conception generated a tsunami that affected the entire west coast causing wave heights in some regions to exceed 2 m (Borrero et al. 2001). Since then, a series of minor tsunamis have affected the California coast, including a recent one in 1989 (Legg et al. 2004).

2.4 CHEMICAL OCEANOGRAPHY

2.4.1 Hydrography

Hydrography is the study of the physical characteristics of the waters on the earth's surface and includes the measurement of parameters that describe those waters. For marine waters those parameters include temperature, salinity, nutrient concentration, dissolved oxygen, density, and any other parameters that may describe the physical characteristics of ocean waters (Pickard and Emery 1990). The physical and even chemical properties of marine waters vary with distance from shore and with depth. Shallow coastal, or insular waters, such as those over the continental shelf and immediately surrounding the Channel Islands, vary more dramatically over seasonal timescales than the deeper (>200 m) waters found in the basins of the SCB, which remain far more stable throughout the year with only minor fluctuations (Emery 1960). Coastal waters are heavily influenced by terrestrial input, which moderates salinity, nutrient concentration, and even temperature (Warrick et al. 2007). Water temperatures in the deep basins and submarine canyons of the continental borderland can vary by an average of 15°C from surface waters (Berelson 1991; NDBC 2003b; NDBC 2003a; Nezlin et al. 2004). Two descriptive parameters that provide basic information about marine waters are temperature and salinity, which both affect water density and how sound propagates through the water column. Water masses and surface and deepwater currents can be distinguished from adjacent waters by their temperature and salinity (Pickard and Emery 1990).

The following sections describe SST and salinity profiles in the SOCAL and Pt. Mugu OPAREAs and vicinity.

2.4.1.1 Sea Surface Temperature

SST can be measured very accurately and over long periods of time by temperature sensors fixed to moored buoys; however, these data only represent temperatures at a specific location (i.e., point data) and require a certain amount of interpolation between buoys to gain a more comprehensive perspective of the temperature profile of a region. Satellite based measurements of SST can provide a comprehensive picture of SST on large spatial scales, but often lack the spatial resolution needed for precise temperature measurements, particularly near the coastline (Schalles 2006). Presenting measurements from both sources can provide the most accurate assessment of SST in a given region.

In the SCB, seasonal SST fluctuations occur in association with upwelling, seasonal and interannual changes in climate, and latitude. On average, there is approximately an 11°C annual flux in SST throughout the year along the California coast (**Figure 2-6**). Over the course of the year, there is an increase in SST along a north-south gradient ranging from 11°C in the north during winter to 22°C in the south during summer (Bearzi 2003). Maximum temperature variations within the Study Area range from 10° to 23°C.

A long-term record of oceanographic conditions at several sites within the Study Area is available from oceanographic buoys maintained by the NOAA's NDBC.[1] SST measured over a 22-yr period (1980 through 2001) in the northern part of the Pt. Mugu OPAREA, 21 nm northwest of Point Arguello averaged 14.0°C, with the warmest temperatures occurring in September (15.8°C) and the coolest in May (12.3°C). A maximum temperature of 29.2°C—nearly twice the annual average—was recorded in August of 1994 (NDBC 2003a). Farther south, near the border separating the SOCAL and Pt. Mugu OPAREAs, a buoy located 121 nm west of San Diego recorded an annual mean SST of 16.1°C over an 11-yr period from 1991 through 2001 (NDBC 2003b). The warmest month on average was September (18.6°C), and the coolest month was April (14.3°C). Even though the latitudinal distance between the two data buoys represents only about half of the north-south span of the Study Area, a distinct difference in SST is observed. The average annual temperature at the southern buoy is 2.1°C warmer, and the warmest month (September in both locations) is nearly 3.0°C warmer. The coolest month is 2.0°C warmer at the southern buoy (NDBC 2003b). The northern buoy is located in the waters of the cold, southward flowing California Current and the southern buoy is located in the warm, northward flowing waters of the California Countercurrent, which accounts for much of the difference in the SST at the two locations. Latitudinal difference is also a factor as is the influence of upwelling, which occurs to a greater degree in association with the California Current (PFMC 2003). Differences between the air temperature and the SST in the region are small, averaging just 0.5°C annually at the location of the northern buoy and 1.0°C at the southern buoy (NDBC 2003b; NDBC 2003a).

ENSO events can dramatically alter the SST regimes in the SCB. During El Niño conditions, a weakening of the California Current allows warmer subtropical waters from the coastal countercurrent to flow northward; this creates anomalously warm water off of the California coast (**Figure 2-7**) (Dailey et al. 1993; Hayward 2000). During El Niño conditions, warm-water fish migrate into the region and cold-water fish migrate out of the Study Area (Allen et al. 2002). During La Niña events, the southward flow of the California Current strengthens; this transports cold, subarctic waters farther south within the SCB, enhances coastal upwelling, and creates anomalously cold SST off of the California coast (3° to 4°C below normal; **Figure 2-7**) (Hayward et al. 1999; Schwing et al. 2000; Burtenshaw et al. 2004).

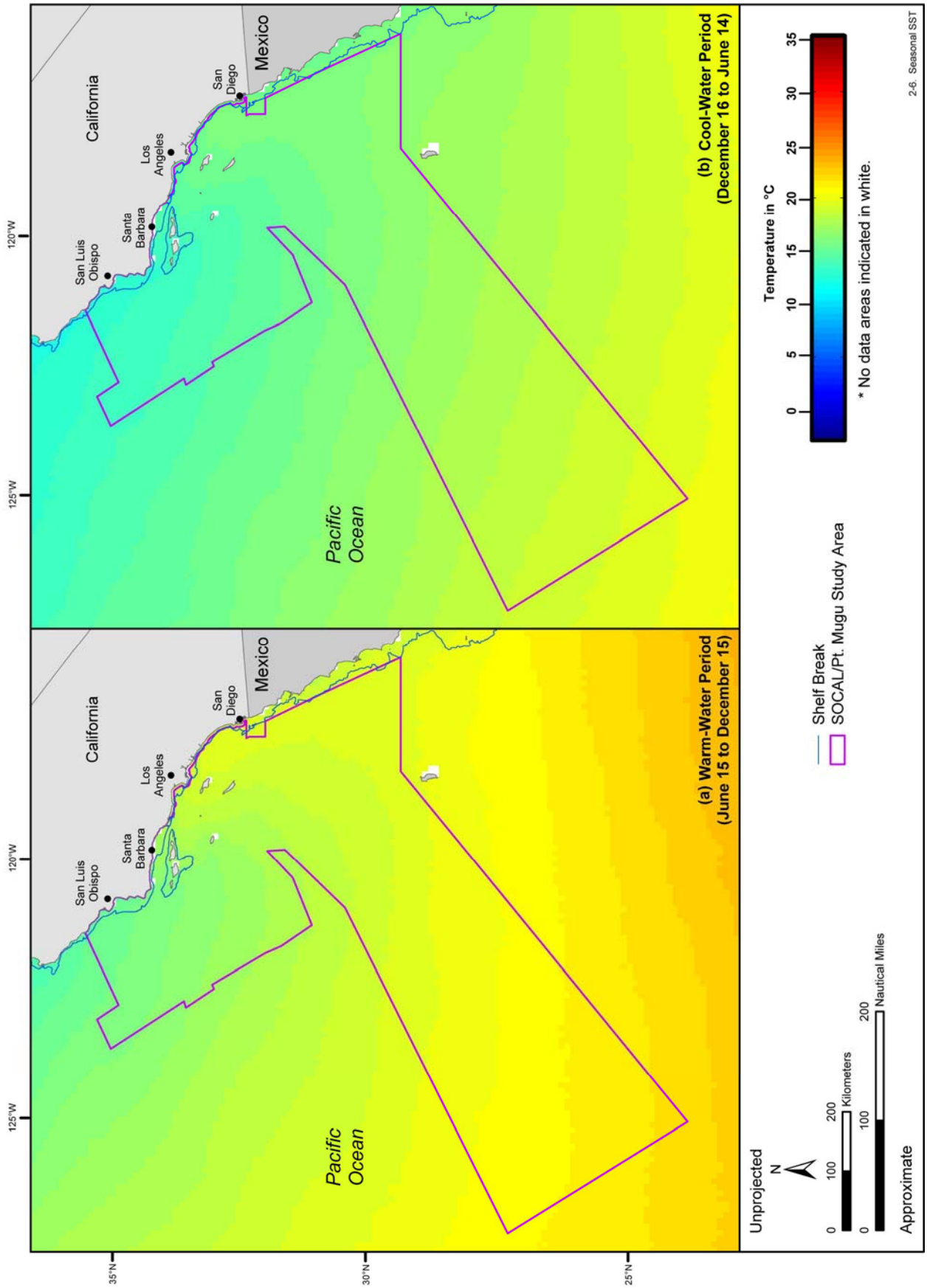

Figure 2-6. SST in the SOCAL and Pt. Mugu OPAREAs and vicinity during the a) warm-water period (15 June through 15 December) and b) the cool-water period (16 December through 14 June). Source data: PODAAC (2004).

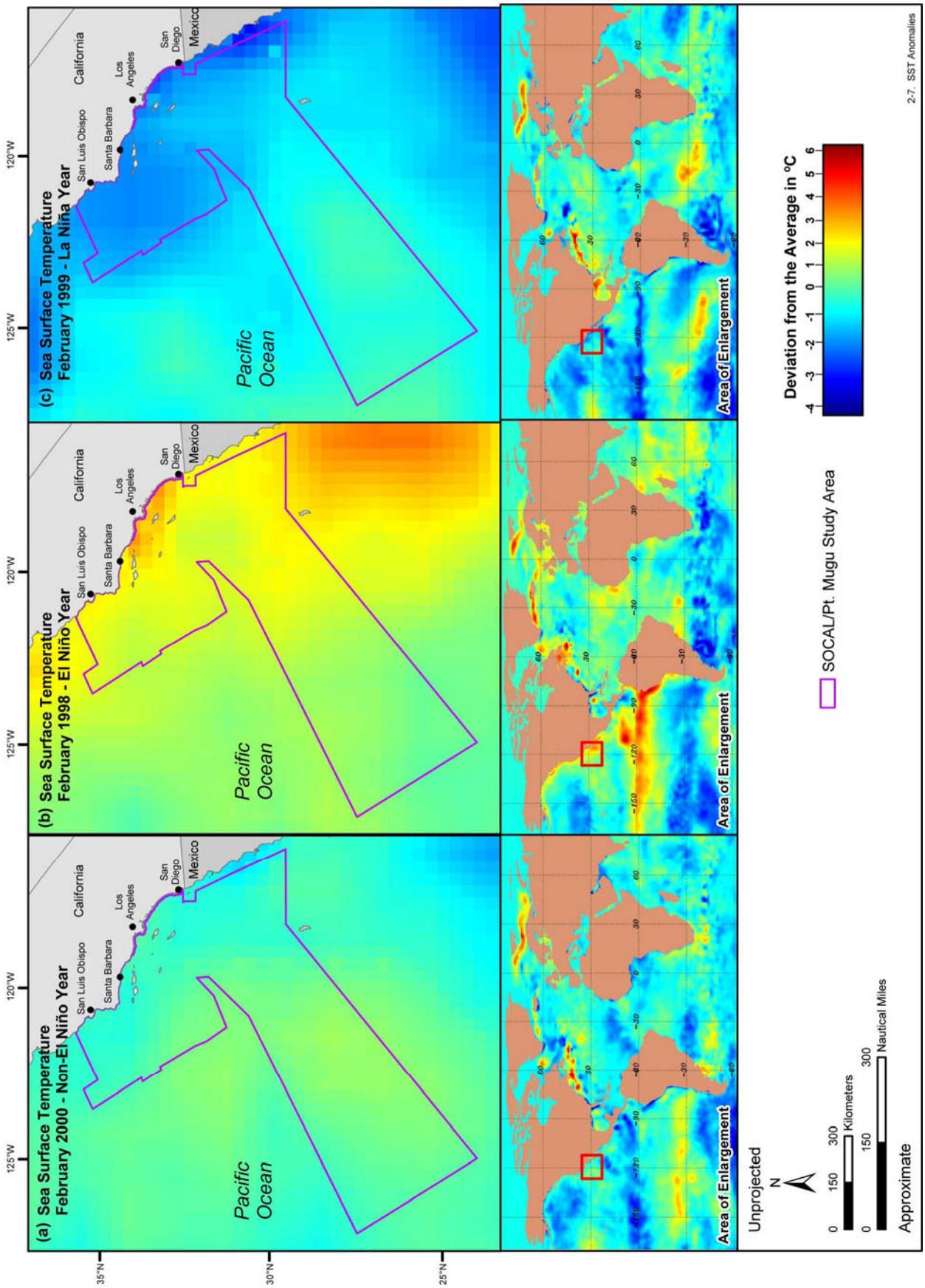

Figure 2-7. SST anomaly (i.e., deviation from an average of multiple years) during the month of February for a) Non-El Niño b) El Niño, and c) La Niña years. Insets depict the global SST anomaly for the same time period. Source map (scanned): DoD (2002).

2.4.1.2 Salinity

The surface salinity within the SOCAL and Pt. Mugu OPAREAs is typical of an oceanic environment, ranging from 32.9 to 34.5 practical salinity units (psu) (DoN 1999). Salinities are generally stable but have slight seasonal variation; maximum salinities occur in summer (May) during periods of low rainfall and low freshwater runoff while minimum salinities occur in winter (December) during periods of high rainfall and high freshwater runoff (DoN 1999). The lowest salinities are found in the north due to the influx of less saline Pacific Subarctic Water. Salinities increase in the southern portion of the Study Area due to the influx of saline Pacific Equatorial Water from the south (Hickey 1993; Hayward et al. 1999; Bograd et al. 2000; Schwing et al. 2000; Schwing et al. 2002). Coastal lagoons and embayments, including the southern regions of San Diego Bay, may become brackish (<30 psu) during periods of high rainfall or heavy freshwater runoff events or may become hypersaline (>40 psu) during periods of low rainfall when freshwater runoff decreases or ceases altogether (Zedler 1982; DoN 2000). Surface salinity in the region shows the greatest variability near the mouths of coastal rivers, including at the mouth of Ballona Creek in Santa Monica Bay; the Ventura/Santa Clara River System in the Santa Barbara Channel; the Los Angeles, San Gabriel, and Santa Ana rivers in San Pedro Bay; and the San Diego River just north of San Diego (MMS 2001; Nezlin et al. 2004; Warrick et al. 2007).

2.5 PHYSICAL OCEANOGRAPHY

2.5.1 Water Masses, Currents, and Circulation

The water column can be divided into three separate water masses: a surface layer, an intermediate layer defined by a rapid change in temperature (referred to as the thermocline), and a deepwater layer (Pickard and Emery 1990). Two main processes drive the circulation of water masses in the ocean: forcing by the wind (referred to as wind-driven circulation) and differences in water density (referred to as thermohaline circulation). Surface currents are primarily wind-driven and dominate circulation in the upper 100 m of the water column. Gradients in salinity and temperature cause changes in water density; these differences in density drive thermohaline circulation, which dominates the circulation below 100 m; however, density driven currents are capable of moving water masses throughout the water column (Pickard and Emery 1990). The following is a discussion of circulation patterns affecting the waters of the SOCAL/Pt. Mugu Study Area including surface circulation, deepwater circulation, oceanic fronts, and the North Pacific Subtropical Gyre (NPSG).

2.5.1.1 North Pacific Subtropical Gyre

Approximately half of all global primary production is supported by oceanic phytoplankton, yet phytoplankton biomass makes up only about 1 to 2% of the total amount of carbon in plants (Falkowski 1994; Lalli and Parsons 1997). Oceanic subtropical gyres occurring in both hemispheres of the Atlantic and Pacific oceans as well as in the Indian Ocean make up over 40% of the earth's surface and account for the majority of the global primary production (Karl 1999). The offshore areas of the SOCAL/Pt. Mugu Study Area are affected by the easternmost region of the NPSG, the most expansive gyre on Earth.

Despite being the largest ecosystem on the planet, the NPSG is remote, poorly sampled, and not well understood (Karl 1999). The NPSG encompasses 2 X 10^7 km^2 of ocean and is bounded by the North Pacific Current to the north, the Northern Equatorial Current to the south, the California Current to the east, and the Kuroshio Current to the west creating the planet's largest circulation pattern (**Figure 2-8**). The NPSG is a very old ecosystem in which the present boundaries have existed since the Pliocene (10^7 yr ago) (McGowan and Walker 1985) and is considered a "climax" community, that is, an ecosystem that has reached a final and permanent stage of succession, and one which is inexorably linked to the climate. Such a community can be studied to determine the effects of climate change on the seascape, community structure, and community dynamics of the ecosystem (Karl 1999).

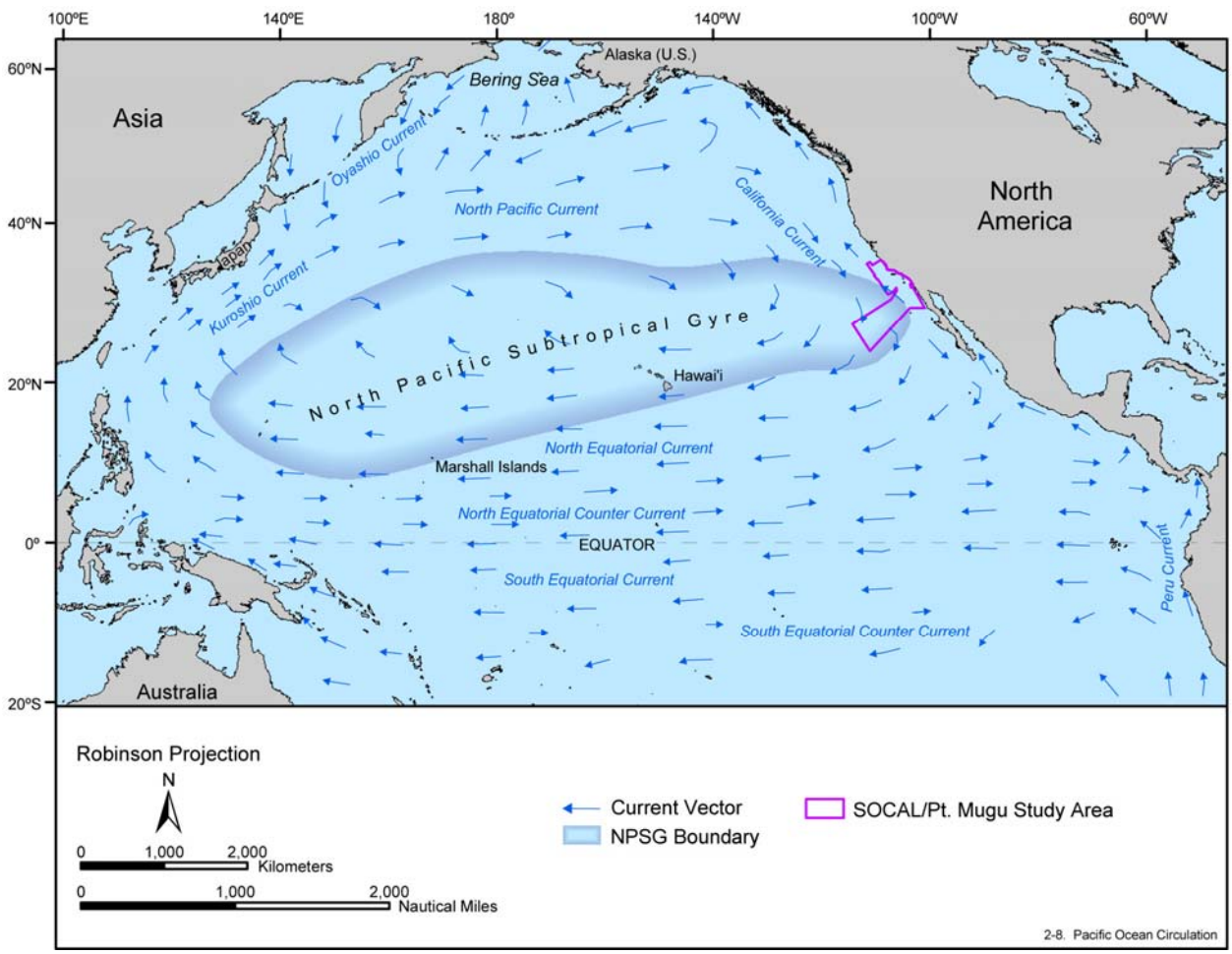

Figure 2-8. Surface circulation of the North Pacific Ocean highlighting the extent of the NPSG. Source map (scanned): Pickard and Emery (1990). Source information: Karl (1999).

The NPSG is thought to be a semi-enclosed, stable, and relatively homogenous habitat; however, increasing evidence suggests that the NPSG exhibits substantial physical, chemical, and biological variability in both time and space (Karl 1999). For example, regions of the NPSG show extensive mesoscale variability demonstrated by the formation of discreet eddies, near-inertial motions, and internal tides (Venrick 1990). In addition, during winter months, tropical cyclones pass through the NPSG deepening the mixed layer and injecting nutrient rich water into the typically oligotrophic surface waters, which can fuel ephemeral phytoplankton blooms (Karl 1999). Over longer time scales, the NPSG is affected by the ENSO cycle. During an El Niño event, shifts occur in the circulation patterns creating weaker flow, enhanced primary production, and intense water column stratification (Karl et al. 1995).

These conditions enable community shifts in the phytoplankton towards nitrogen fixing cyanobacteria (e.g., *Trichodesmium* spp.), altering the ecosystem in the NPSG from a nitrogen-limited to a phosphorus-limited ecosystem (Karl et al. 1995; Karl 1999).

2.5.1.2 Surface Currents

Coastal headlands, promontories, submarine canyons, basins, and ridges of the SCB introduce small-scale variations to large-scale circulation patterns, primarily in the formation of sub-mesoscale or small scale eddies (NRC 1990).[5] This complex morphology combined with dramatic changes in coastline topography result in circulation patterns and forcing mechanisms that differ significantly from other

locations on the U.S. Pacific coast (Hickey 1993). Although these small-scale circulation patterns are difficult to analyze, they have important implications for the coastal marine ecosystem of the SCB.[5]

Surface waters in the SOCAL/Pt. Mugu Study Area are dominated by three distinct water masses: the Pacific Subarctic Water, the North Pacific Central Water, and the Pacific Equatorial Water (**Figure 2-9**). Pacific Subarctic Water enters the Study Area from the north and is characterized by low temperatures, low salinity, high dissolved oxygen, and high nutrients (Reid et al. 1958; MMS 2001). North Pacific Central Water enters the region from the west and is composed of relatively warm water with low dissolved oxygen and low nutrient concentrations (Reid et al. 1958; MMS 2001). Pacific Equatorial Water enters the SCB from the south and has high temperatures, high salinity, low oxygen, and high nutrient content. Although three distinct water masses enter the region, the water in the Study Area is mainly a mixture of Pacific Subarctic Water from the north and Pacific Equatorial Water from the south (Tibby 1941; Dailey et al. 1993; Hickey 1993); these two water masses generate three major surface currents: the California Current, the California Countercurrent, and an inshore coastal current. The confluence of the California Current and the California Countercurrent form a large, semi-permanent cyclonic gyre, the southern California Eddy, which occupies much of the SCB (Dorman 1982).

Surface circulation in the SCB is greatly affected by regional climatic changes. The California Current weakens during periods of El Niño (Dawson and Pieper 1993) and during warm phases of the PDO; however, the California Countercurrent intensifies during warm phases of the PDO (Lluch-Belda et al. 2001; Lluch-Belda et al. 2003). Conversely, during La Niña and cool periods of the PDO, the California Current intensifies and the California Countercurrent slackens (Schwing et al. 2000; Lluch-Belda et al. 2003).

- California Current—The California Current is the eastern boundary current in the North Pacific basin, and exhibits features, such as broad, slow, equatorward flow that are typical of eastern boundary currents worldwide (Pickard and Emery 1990). The current originates as the eastward flowing North Pacific Current reaches North America and splits into the Alaska Current (which moves north) and the southward flowing California Current (**Figure 2-8**). The latitude of the divergence varies from about 45°N in winter to 50°N in summer (Pickard and Emery 1990). The California Current extends as far as 1,000 km from shore, includes waters to a depth of about 300 m, and averages about 300 km in width in the Study Area (Dailey et al. 1993; Hickey 1993; Neander 2001). It flows along the coasts of Washington, Oregon, and California as far south as the Baja Peninsula before feeding into the westward flowing North Equatorial Current (Pickard and Emery 1990). Although maximum current speeds only reach 15 cm/s, the dimensions of the California Current allow it to transport an average of 10^7 cubic meters of water per second (m^3/s) as it follows parallel to the edge of the continental borderland along the Patton Escarpment (Dailey et al. 1993; Hickey 1993; Karl 1999).

  The California Current dominates the flow and circulation patterns in the SCB (Hickey 1979; Dailey et al. 1993; DoN 1999)[5] by transporting cold, low salinity, high dissolved oxygen, and nutrient rich waters into the region (**Figure 2-10**) (DoN 1999; Burtenshaw et al. 2004). Surface waters from the California Current mix with warmer, more saline waters from the central Pacific and the California Countercurrent, contributing to the formation of numerous mesoscale and sub-mesoscale cyclonic eddies in the waters of the SCB (NRC 1990; Miller 1996; DoN 1999; Di Lorenzo 2003).[5] The southward flow of the current coupled with upwelling-favorable winds often result in strong upwelling along the coast, predominantly in winter and spring, as surface waters are transported seaward (Huyer 1983; Hickey 1992).

  The volume of water transported by the California Current is variable throughout the year and the current is rich in eddies (Owen 1980; DoN 1999; Di Lorenzo 2003). During spring, portions of the current move inshore and become jet-like with maximum transport occurring in the late summer and fall (Hickey 1993; DoN 1999; Strub and James 2000).[5] The California Current is weakest in winter and early spring and becomes displaced westward by the combined flow of the California Undercurrent (which may surface at times) and the California Countercurrent (DoN 1999). Eddies formed along the California Current range in size from small (10 to 50 km in diameter) to large (100 to 1,000 km in diameter) and can persist in the vicinity from months to years (Owen 1980). During an

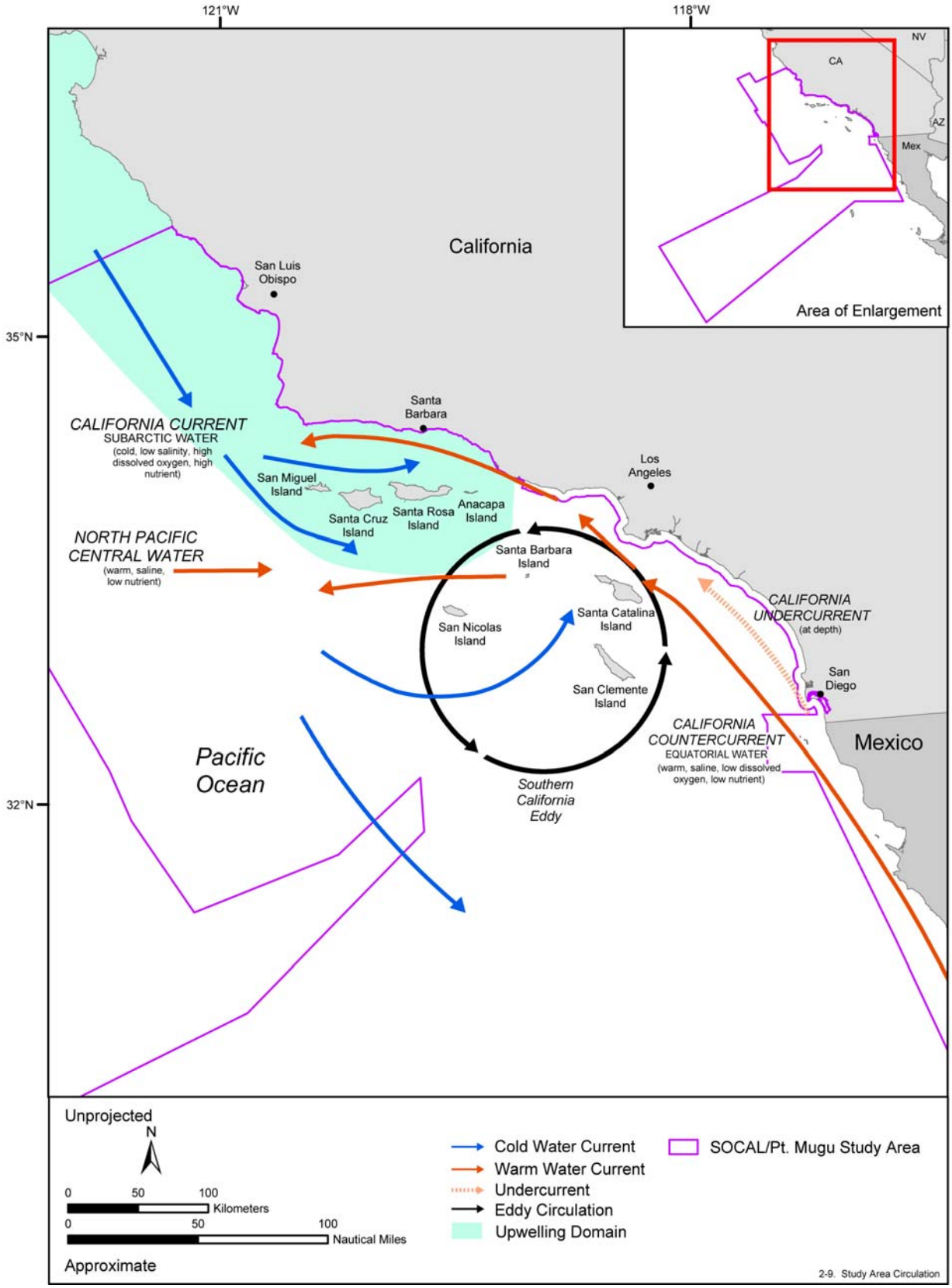

Figure 2-9. Major ocean currents affecting the circulation in the SOCAL and Pt. Mugu OPAREAs. Source Information: Hickey (1992) and PFMC (2003). Map adapted from MMS (2001).

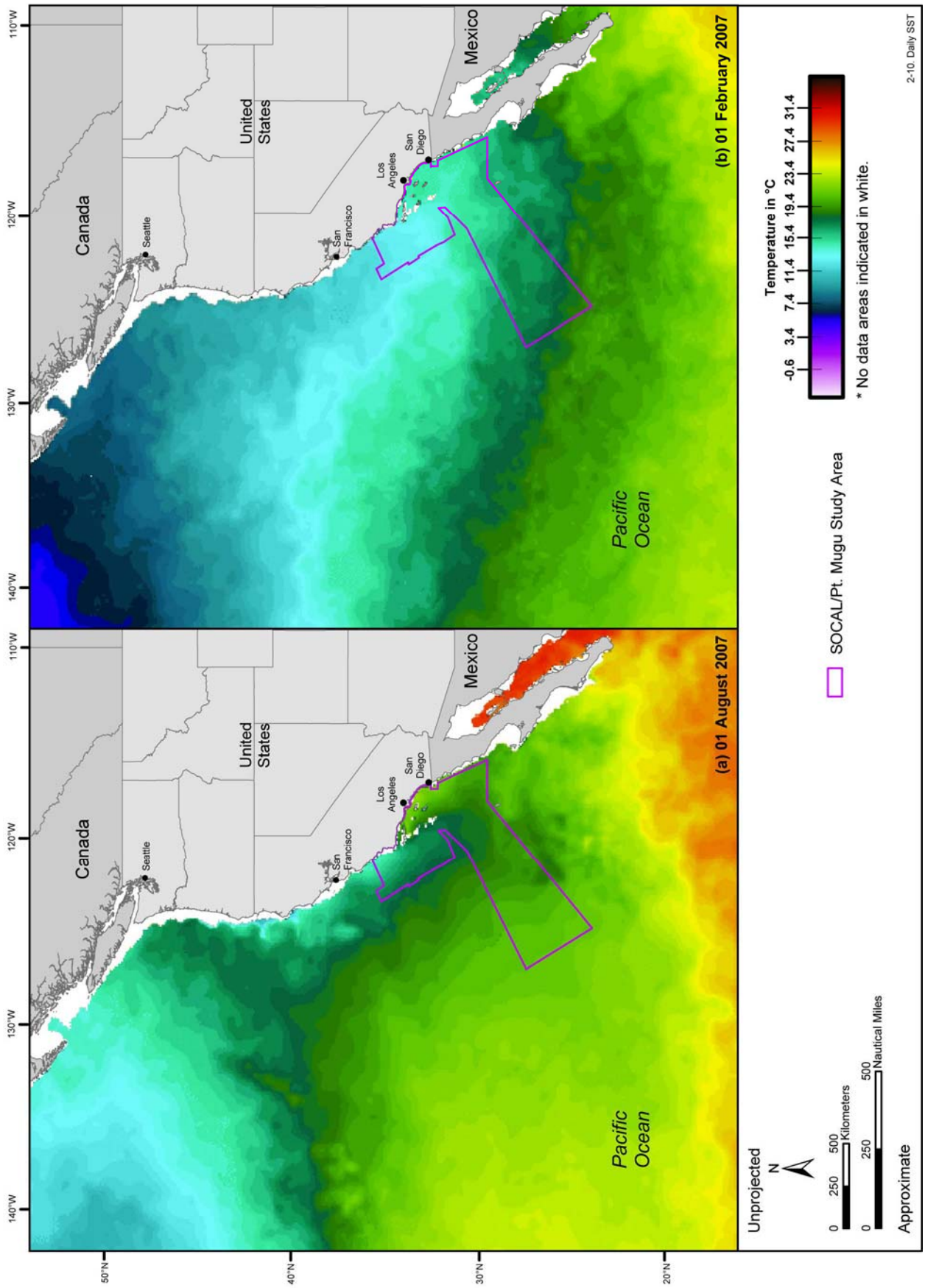

Figure 2-10. Daily surface circulation in the SOCAL and Pt. Mugu OPAREAs and vicinity revealed by satellite images of SST on 01 August 2007 and 01 February 2007. Cold water transported south by the California Current is clearly visible and dominates the circulation in the OPAREAs. The warmer waters of the northward flowing California Countercurrent are seen along the coastline. Map adapted from: NRL (2007).

average year, approximately 20 eddies are formed in the SCB, with twice as many eddies formed during the cool-water period than during the warm-water period (Owen 1980; Miller 1996).[5] Recent attempts at modeling the observed, long term increase in SST of California Current waters, predict that upwelling in the SCB may be reduced in the coming years resulting in a freshening of the surface waters in the SCB (Di Lorenzo et al. 2005). Reduced upwelling has biological implications as well, because without the influx of nutrients from deeper waters, primary and secondary production are likely to be impacted. These predictions are correlated with observed trends in SST and salinity and offer an explanation for recent declines in zooplankton abundance (Di Lorenzo et al. 2005).

Between San Diego and Punta Colnett (210 km south of San Diego in Baja California) the California Current branches shoreward and then to the north forming the southern California Countercurrent (Dailey et al. 1993).[5]

- California Countercurrent—In the central portion of the SCB, the southern California Countercurrent flows northward along the coast, inshore of the California Current (Dailey et al. 1993; Valdez-Holguín et al. 1998). This poleward flowing countercurrent is strongest in summer or early fall when upwelling favorable winds are weak and weakest or nonexistent in spring when upwelling along the coast peaks (Hickey 1992; Di Lorenzo 2003). During winter, the northward flowing California Undercurrent, which is usually observed at depths of 100 to 500 m, may surface and become entrained with the California Countercurrent (Hickey 1992; Neander 2001). Both currents are weakened by the onset of strong northerly winds in spring, which intensify the offshore flow of surface waters and the onshore and subsequent upwelling of deeper waters (Estrada and Blasco 1979; Hickey 1992, 1993; Di Lorenzo 2003). When present, the California Countercurrent is narrow (10 to 40 km wide) and more jet-like (peak speed of 30 to 50 cm/s) than the California Current (Hickey 1992; Neander 2001). As the countercurrent flows along the shoreline to the north it is blocked by the Channel Islands (Dailey et al. 1993). The bulk of the flow of the California Countercurrent becomes diverted westward where it combines with the California Current to form a semi-permanent, cyclonic gyre known as the Southern California Eddy (Dailey et al. 1993; Di Lorenzo 2003). The remainder of the current passes through the Channel Islands, enters the Santa Barbara Channel to the north, and at times proceeds past Pont Conception to continue northward as the Davidson Current (Dailey et al. 1993; Neander 2001).

- Southern California Eddy—The Southern California Eddy is the most resolved eddy of the California Current system due to its large scale (~200 km in diameter) and degree of persistence (Owen 1980). It is formed when the poleward California Countercurrent combines with the equatorward California Current to form a counterclockwise (cyclonic) rotation within the SCB (Hickey 1979; Dailey et al. 1993; Haury et al. 1993; Di Lorenzo 2003). Maximum strength of the eddy occurs in summer and early fall when northerly winds are weakest and the strength of the California Countercurrent is greatest (Owen 1980; Di Lorenzo 2003). In spring, when upwelling dynamics dominate the circulation in the SCB, the eddy may not be discernable at all; in fact, the Southern California Eddy is rarely observed as a closed gyre, rather it is better described as a rotation that links the opposing flows of the California Current and the California Countercurrent (Di Lorenzo et al. 2005). The core of the Southern California Eddy is often well developed, particularly as summer progresses into fall and the eddy moves westward over the continental shelf and slope before becoming unstable and decaying (Di Lorenzo 2003). Persistent upwelling of nutrient rich waters in the core supports a high concentration of chlorophyll (Owen 1980). Current speeds measured at about 50 km from the center of the eddy reach 20 cm/s (Owen 1980).

- Alongshore Current—Northwesterly, onshore winds periodically force a net current to the south along the coastline with average speeds from 1.0 to 3.3 cm/s; this disrupts the northward flow of the Southern California Eddy along the coastline (Lentz and Winant 1979; NRC 1990). A significant impact of this alongshore current is that it can transport large quantities of sand along the southern California coast, causing the entrances of bays and lagoons to migrate or shift, which has the potential to temporarily close off these regions from oceanic waters (Zedler 1982).

- San Diego Bay—The mean tidal range in the bay is 0.85 m, and typical tidal current speeds range between 30 and 50 cm/s (maximum up to 1.0 m/s) near the inlet of the bay and 10 and 20 cm/s in the southern regions of the bay (Largier 1995; Wang et al. 1998). Winds can reach upwards of 5 m/s; however, the overall fetch of the bay limits the significance of wind-driven currents (Wang et al. 1998). Circulation in San Diego Bay varies and can be described by dividing the bay into four distinct hydrodynamic sections extending from the mouth of the bay to the estuary at the southern end of the bay: 1) marine, 2) thermal, 3) seasonally hypersaline, and 4) estuarine (DoN 1995; DoN 2000).

  - Marine—Circulation in the marine section is dominated by tidal exchange with the ocean. Tides in the bay are mixed diurnal and semi-diurnal, with the semi-diurnal component dominating. The result of the mixed tidal components is that the highest high tide (MHHW) always precedes the lowest low tide (MLLW) so that the ebb tide between MHHW and MLLW creates the strongest tidal currents. The tidal range between MHHW and MLLW is about 1.7 m, but can be as large as 3 m (Largier 1995). In San Diego Bay, this area of efficient flushing is within 5 to 6 km of the entrance. Residence time of water in the marine section is just a few days; the net result of circulation in San Diego Bay is the presence of cold, clean ocean water at depth.

  - Thermal—In the thermal region, still located in the northern region of the bay (to Glorietta Bay, 32.7°N), currents are driven primarily by surface heating from solar radiation. The vertical exchange of water results from the entry of a cold, oceanic water mass at depth with the flood tide followed by the receding of warm surface water with the ebb tide. Vertical mixing occurs at the boundary layer separating the cooler, denser water and the warmer, less dense water.

  - Seasonally Hypersaline—Between Glorietta Bay and Sweetwater Marsh National Wildlife Refuge (NWR) (32.7 to 32.6°N) is a seasonally hypersaline region (>35 psu). Water is stratified by salinity gradients induced by increased rates of evaporation, particularly in summer, and because freshwater input is primarily limited to runoff and discharge from creeks and rivers following storms. For approximately 9 mo of the year there is no appreciably freshwater input to the bay (DoN 2000).

  - Estuarine—South of the Sweetwater Marsh NWR, the estuarine section of the bay is characterized by occasional freshwater input from the Otay and Sweetwater rivers. Residence time of water in this section of the bay can exceed 1 mo and may approach much longer times (~300 d).

2.5.1.3 Oceanic Fronts

Hydrographic fronts, defined as sharp gradients in temperature or density (or some similar physical feature), mark the boundaries between two dissimilar water masses. Often, these fronts can be detected via satellite imagery derived from the passive remote sensing of infrared radiation (Etnoyer et al. 2004). The density difference between two distinct water masses acts to aggregate phytoplankton and zooplankton and to generate a vertical advection of plankton and nutrients (Etnoyer et al. 2004). High concentrations of fish and invertebrate larvae along with high rates of primary productivity are often associated with fronts occurring near the shelf break and with offshore frontal features, such as eddies or meanders (Roughgarden et al. 1988; Munk et al. 1995). Many of these frontal features tend to be ephemeral in space and time, shifting with the currents up to 1,000 km and forming and decaying in days to months. The spatial distribution of fronts is also affected by the season and interannual influences such as the state of the ENSO (Etnoyer et al. 2004).

Although most frontal systems are ephemeral, some larger scale fronts are essentially permanent oceanographic features. The Ensenada Front, located between Point Conception and Punta Vizcaino, Mexico is persistent and detectable throughout most of the year, and it is one of the dominant features of the California Current System (Peláez and McGowan 1986; Haury et al. 1993; Santamaria-Del-Angel et al. 2002). The location of the front is easily recognizable via satellite imagery of ocean color by following the position of the 0.25 and 0.5 millgrams per cubic meter (mg/m^3) chlorophyll *a* (chl *a*) concentration isolines, which form an “M-shape” in the images (**Figure 2-11**) (Santamaria-Del-Angel et al. 2002). The

front is strongest in the spring and summer (late March to early July) and marks the boundary between the oligotrophic waters to the south and the more eutrophic waters to the north (Haury et al. 1993; Santamaria-Del-Angel et al. 2002). The Ensenada Front has been well studied using satellite imagery (Peláez and McGowan 1986; Kahru and Mitchell 2000, 2001), *in situ* chlorophyll measurements (Gaxiola-Castro and Alvarez-Borrego 1991; Haury et al. 1993; Kahru and Mitchell 2001), and temperature (Haury et al. 1993). The southern region of the front is characterized by low pigment concentrations and relatively homogenous conditions while the northern region is highly structured and graded (**Figure 2-11**) (Santamaria-Del-Angel et al. 2002).

During La Niña years, more frontal systems tend to form off the southern California coast and tend to persist longer than during El Niño years; however, frontal systems occurring farther offshore in the central Pacific tend to have the opposite trend (Etnoyer et al. 2004). During El Niño years, the abundance of frontal systems shifts northward and the typical "M-shape" of the Ensenada Front off the southern California coast becomes less distinct due to a weaker California Current and the northward penetration of subtropical waters into the region (**Figure 2-11**) (Santamaria-Del-Angel et al. 2002). Due to the shift in the current regime, the Ensenada Front can only be detected off of southern California for short periods of time during El Niño years (Haury et al. 1993).

2.5.1.4 Tidal Circulation and Internal Tides

Tidal circulation is important to the marshes in southern California; tides provide most of the moisture to intertidal wetlands and drive the circulation in San Diego Bay (Zedler 1982; Wang et al. 1998). The tides in the Study Area are mixed semi-diurnal and diurnal resulting in variable amplitude high and low tides over a full tidal cycle (Emery 1960; Zedler 1982; Largier 1995). The mean tidal amplitude of spring tides is less than 1.6 m (2 m in San Diego Bay) (Wang et al. 1998), with the highest spring tides occurring in January and June (near the solstice) and the lowest occurring in March and September (near the equinox) (Emery 1960; Zedler 1982).

A tidal bore is a phenomenon in which the leading edge of the flood tide is focused by coastal topography or bathymetry into a wall or surge of water that travels up a river against the direction of the current or into a bay. Tidal bores can occur both at the surface and internally (i.e., in the water column), vary seasonally, and are highly predictable with cycles similar to (but usually out of phase with) the familiar tidal cycle (Pineda 1994; Cacchione and Pratson 2004). Internal tidal bores (or internal waves) are similar to surface waves except that they occur along the interface of stratified layers within the water column (e.g., along isopycnals) and are often recognized by strong temperature signatures. Internal waves play a significant role in cross-shelf transport of nutrients and plankton, sediment resuspension, and contribute to coastal upwelling events (Pineda 1994; Cacchione and Pratson 2004). Internal bores and waves can have amplitudes greatly exceeding those of surface waves (up to 120 m) (Pineda 1994).

Internal tidal bores occur on time scales of hours to days (Pineda 1994; Noble and Xu 2003; Tapia et al. 2004). Pineda (1994) describes the occurrences of internal bores in the SCB in three phases: 1) the shoreward movement of cold, dense water followed by 2) its down slope return, and 3) the subsequent advection of warmer, less dense surface water towards shore. During the first phase, a cold-water bore is advected shoreward at depth (usually below the mixed layer); this displaces warm surface water offshore and creates an imbalance between the denser inshore water and less dense offshore water. A front forms between these two water masses. During the second phase (a few hours after the onset of the internal bore), the cold water recedes offshore, moving down slope and is forced by gravity to relieve the density imbalance. During the third phase, warm surface waters move shoreward to replace the departing colder waters, pushing the thermal front towards shore (Pineda 1994, 1999; Souza and Pineda 2001; Helfrich and Pineda 2003).

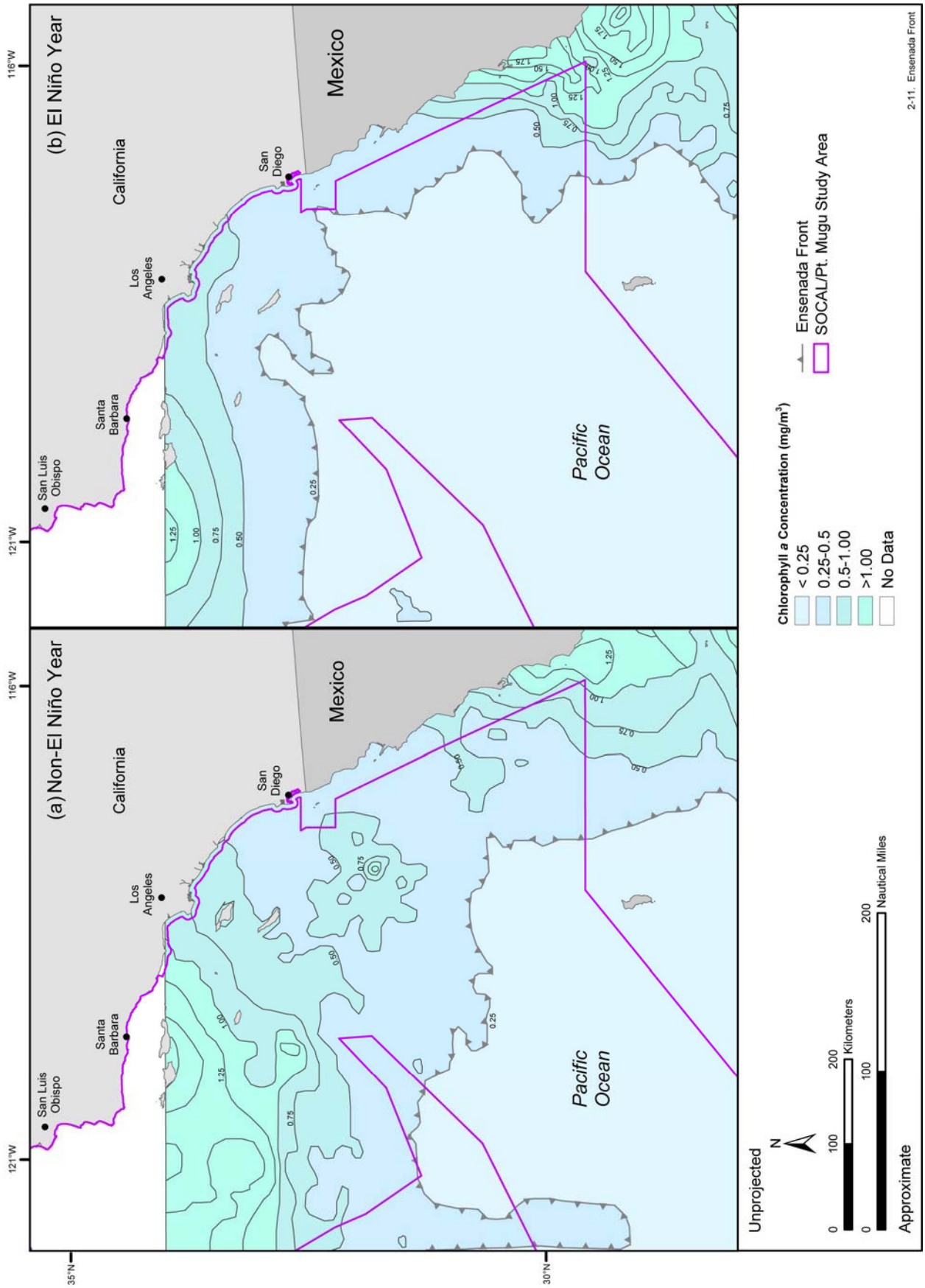

Figure 2-11. Distribution of chlorophyll and the location of the Ensenada Front in the SOCAL and Pt. Mugu OPAREAs and vicinity during a) non-El Niño and b) El Niño years. Source map (scanned): Santamaria-del-Angel et al. (2002).

In the SCB, internal bores are seasonal; they occur 7 to 12 or 19 to 24 d following a new moon and are more frequent during the spring and summer when the water column is well stratified (Pineda 1994). Internal bores are identified by a diurnal or semidiurnal modulation in SST (Pineda 1994, 1999; Souza and Pineda 2001; Pineda and López 2002). In the SCB, onshore propagation occurs as a single, semi-discrete temperature front; although, some events contain several fronts. The bores propagate at speeds of 10.6 to 19.6 cm/s (Pineda 1999). Tidal bores play a major role in the aggregation, recruitment, and settlement of larvae and other planktonic organisms in the nearshore regions (e.g., along the coast of San Miguel Island) as well as with sediment resuspension and cross shelf transport (Pineda 1991, 1999; Helfrich and Pineda 2003; Cacchione and Pratson 2004).

2.5.1.5 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. The average depth of the thermocline in the SCB is about 76 m or approximately at the 12°C isotherm (Kim and Miller 2007). Maximum surface temperatures in the SCB occur from July to September with a sharp decline in temperature over the first 20 m of the water column (Dailey et al. 1993; NDBC 2003a; NDBC 2003b). From November to April, the water column becomes less stratified as upwelling mixes deeper waters up to the surface and wind-driven mixing increases (Dailey et al. 1993). Interannual variations in the depth of the thermocline appear to be correlated with long-term climatic changes, including the ENSO and the PDO (Miller 1996; Kim and Miller 2007).

2.5.1.6 Deepwater Currents/Water Masses

Below the thermocline (pycnocline), the California Undercurrent flows northward along the coast with speeds ranging from 3 to 25 cm/s; the maximum water velocity occurs at a depth of 60 to 100 m in the SCB (**Figure 2-9**) (Jackson 1986; NRC 1990; Hickey 1992). In the Santa Monica and San Pedro basins, for example, the maximum current velocity occurs at a depth of 100 m near the shelf break and at about 40 m over the outer shelf, where the reduction is likely due to bottom frictional effects; the velocity at 100 m is about twice the velocity at 40 m (Hickey 1992). This northward flow opposes the equatorward subtropical California Current at depth and spans the entire mid-latitude eastern boundary of the North Pacific (Pierce et al. 2000). The California Undercurrent is typically found inshore of the California Current and is composed of water originating in the Equatorial Pacific (NRC 1990). This water mass can be distinguished from deep water contained farther offshore in the California Current by its higher salinity and lower dissolved oxygen (Estrada and Blasco 1979; Hickey 1992). The California Undercurrent is typically observed at depths of 100 to 500 m, but during winter it may surface and become entrained with the California Countercurrent (Hickey 1992; Neander 2001). Because of its periodic continuity with the California Countercurrent, many oceanographers have regarded the two currents as a single current (Hickey 1979, 1992; DoN 1999; Neander 2001).

The flow of the California Undercurrent is relatively weak; its maximum strength occurs during summer and early fall, and a secondary maximum occurs in winter (Hickey 1992, 1993).[5] Deepwater circulation can be divided into three seasonal patterns (NRC 1990; DoN 1999). From December to February, poleward flow is strengthened and partially displaces the California Current to the west (Neander 2001). From March to June, along-shore winds strengthen driving surface waters offshore and creating strong upwelling circulation patterns which can dominate surface and subsurface flow over the shelf and slope. During these times the California Undercurrent is weakest and subsurface flow may actually reverse direction and become equatorward (Hickey 1992). The California Current may intensify in localized areas due to interaction with bottom topography. From July to November the California Current dominates, weakening the California Undercurrent (DoN 1999). In general, the water contained in the California Undercurrent does not reach the surface. However, during periods of weak California Current flow (winter months or during an El Niño event), the California Undercurrent may reach the surface offshore of Los Angeles, join the California Countercurrent (known as the Davidson Current north of Point Conception), and flow as far north as Vancouver Island, Canada (Hickey 1979; NRC 1990, 1992).

Deepwater circulation patterns and subsurface currents in the SCB are also affected by localized and often dynamic tidal bottom and turbidity currents that flow through the many submarine canyons in the region. These currents can commonly reach velocities of 20 to 50 cm/s both up and down slope and fluctuate with a frequency similar to that of the local tidal cycle; although, not always in phase with the surface tides (Shanmugam 2003; Cacchione and Pratson 2004). These currents transport large amounts of sediment from the shelf to marginal basins or the abyssal plain (Shepard 1973; Normark and Carlson 2003). Similarly, internal waves (and bores) can dominate subsurface circulation over short time scales (hours to days) (See **Section 2.5.1.4**)

2.5.1.7 Upwelling

Upwelling is an advective process that occurs when surface waters are forced offshore (in the case of coastal upwelling) and deeper, colder, nutrient-rich waters from below the mixed layer flow vertically to replace the departing surface water (Mann and Lazier 1996; Burtenshaw et al. 2004). Upwelling can either be wind-driven or induced by the interaction of subsurface currents with density layers or physiographic features (e.g., seamounts or submarine ridges). In the SCB and along the Pacific coast, wind-driven upwelling occurs when persistent northerly winds result in the net offshore transport of surface waters. Along the coast in the northern hemisphere, upwelling favorable winds are those that force surface waters perpendicular and to the right of the wind direction, which for the U.S. Pacific coast are northerly winds (i.e., out of the north) (see Ekman spiral Pickard and Emery 1990). Denser and colder deepwater then moves vertically or up slope to the surface to replace the surface water, replenishing the nutrients in the euphotic zone and fueling primary production in the SCB.

There are coastal areas of the world where persistent upwelling-favorable winds cause upwelling to occur nearly year-round. Major upwelling areas of the world are found off the coasts of Peru, California, and southwestern Africa. Upwelling usually leads to increased surface primary productivity as higher concentrations of dissolved nutrients in the upwelled water fuel growth and reproduction of phytoplankton (Mann and Lazier 1996; Open University 2001).

Winds that promote upwelling are generally strong (10 cm/s or greater) along the California coastline; upwelling in this region is variable in strength and occurs throughout the year with the strongest upwelling occurring in the spring and summer months (Reid et al. 1958; Walsh et al. 1974; Walsh et al. 1977; Estrada and Blasco 1979; Schwing et al. 2000; Leet et al. 2001; MMS 2001).[5] In the SCB, however, upwelling tends to be limited to late winter and early spring due to a large reduction in wind stress.[5] Coastal upwelling is arguably the dominant process affecting the physical and ecological structure of eastern boundary current systems, including the California Current System (Schwing et al. 2000). Coastal upwelling substantially affects regional and local oceanic circulation, thermohaline structure and stability, and water mass exchange between the coastal and deep ocean (Schwing et al. 2000).[5] Intense upwelling has been correlated to recruitment success for commercially important fish stocks in coastal California waters.

Additionally, upwelling associated with both large scale and mesoscale eddies occurring in the waters of the SCB has been documented (Owen 1980; Di Lorenzo 2003; Di Lorenzo et al. 2005). The rotation of cyclonic (counterclockwise) eddies results in the advection of surface waters away from the center or core of the eddy, and the subsequent upwelling of colder, nutrient-rich deepwater from below the pycnocline. The influx of nutrients often fuels a phytoplankton bloom at the core of the eddy (Owen 1980). The largest and most persistent eddy-like feature in the SCB is the cyclonic Southern California Eddy, which is strongest in summer and weakest in spring (see **Section 2.5.1.2**) (Di Lorenzo 2003). The vast majority of mesoscale and sub-mesoscale eddies occurring in the SCB are cyclonic.[5] Anticyclonic eddies can also generate upwelling; instead of occurring at the core of the eddy upwelling occurs in narrow bands along the perimeter of the eddy where surface waters are drawn in towards the core.

2.6 BIOLOGICAL OCEANOGRAPHY

Detailed descriptions of macrofauna found in the Study Area, such as marine mammals, sea turtles, fishes, and corals and other invertebrates, may be found later in this MRA (i.e., **Section 2.7** and

Chapters 3 and **4**). This section describes the plankton, which are particularly influenced by the physical environment and constitute a vital link in the global food web. Particular reference is given here to the physical mechanisms that affect the occurrence of plankton.

Plankton are organisms that float or drift in the water column and are unable to maintain their position against the force of the currents (Parsons et al. 1984). Planktonic assemblages include phytoplankton (plant-like organisms), zooplankton (animals) including ichthyoplankton (larval fish), and bacterioplankton (bacteria). In general, plankton are very small or microscopic although there are exceptions. For example, jellyfish and pelagic *Sargassum* are unable to move against the surrounding currents and therefore are considered plankton despite the fact that these organisms are macroscopic, with some jellyfish reaching 3 m in diameter (Lalli and Parsons 2000).

2.6.1 Primary Production

Primary production refers to the amount of inorganic material (e.g., nitrate and phosphate) that is converted into organic compounds (e.g., proteins and lipids) primarily through the process of photosynthesis (Lalli and Parsons 2000). Phytoplankton are often referred to as primary producers, because, like terrestrial plants, they are able to use solar radiation and the pigment chlorophyll (mainly chl *a*) to fix carbon and create their own energy. Furthermore, phytoplankton form the base of the marine food chain making them essential to the overall productivity of the ocean (Mann and Lazier 1996).

Chlorophyll *a* is the principal pigment that enables phytoplankton to photosynthesize (Mann and Lazier 1996; Lalli and Parsons 2000; Schalles 2006). Measuring chl *a* concentrations over large spatial scales is often accomplished using satellite-based detectors of ocean color (e.g., **Figure 2-12**). Translating the measurements of ocean color into estimates of primary production is a complex process involving multiple steps, each of which can introduce inaccuracies into the estimate. Sophisticated algorithms are developed to address these complexities, which include: uncertainty in the contribution of other pigmented compounds to the measured chl *a* reflectance, particularly in turbid coastal regions; filtering atmospheric scatter from the water column response; and applying a single algorithm that must account for chl *a* concentrations ranging over five orders of magnitude from low levels in the world's open oceans to much higher levels in coastal waters and estuaries (Schalles 2006). Nevertheless, satellite-based measurements of ocean color provide an excellent, global-scale assessment of primary production in the world's oceans (Schalles 2006).

Analysis of global primary production reveals that 55.8% of the world's oceans (between 50° South [S] and 50°N) contain mean concentrations of less than 0.1 mg/m^3 chl *a*, whereas 41.8% average between 0.1 mg/m^3 and 1.0 mg/m^3 chl *a*, and only 2.4% exceed 1.0 mg/m^3 chl *a*. These ranges have been used to define the terms oligotrophic, mesotrophic, and eutrophic, respectively, which are used to classify the productivity of aquatic regions (Schalles 2006). In the SOCAL/Pt. Mugu Study Area primary production, as measured by chl *a* concentrations, varies on both seasonal and interannual time scales (Chen-Tung et al. 2004; Legaard and Thomas 2006); although, concentrations are consistently greatest along the coastline and decrease with distance from shore (**Figure 2-12**). Estimates close to shore, including around the coastline of the Channel Islands, approach 10 mg/m^3 during the cool-water period (December 16 to June 14), which includes the spring upwelling season. Concentrations are not as high during the warm-water period (June 15 to December 15) when the California Countercurrent peaks in intensity, bringing warm, nutrient-poor waters into the SCB that inhibit primary production (Hickey 1992; Di Lorenzo 2003). From the Channel Islands northward, persistent upwelling fuels primary production throughout the year; however south of the Channel Islands upwelling favorable winds slacken in summer and fall diminishing the influx of nutrients from below the pycnocline and reducing phytoplankton production. Farther offshore beyond the Patten Escarpment, concentrations of chl *a* are greatly reduced and conditions are generally oligotrophic, averaging less than 0.1 mg/m^3 throughout the year (**Figure 2-12**) (Rodier and Le Borgne 1997; Karl 1999).

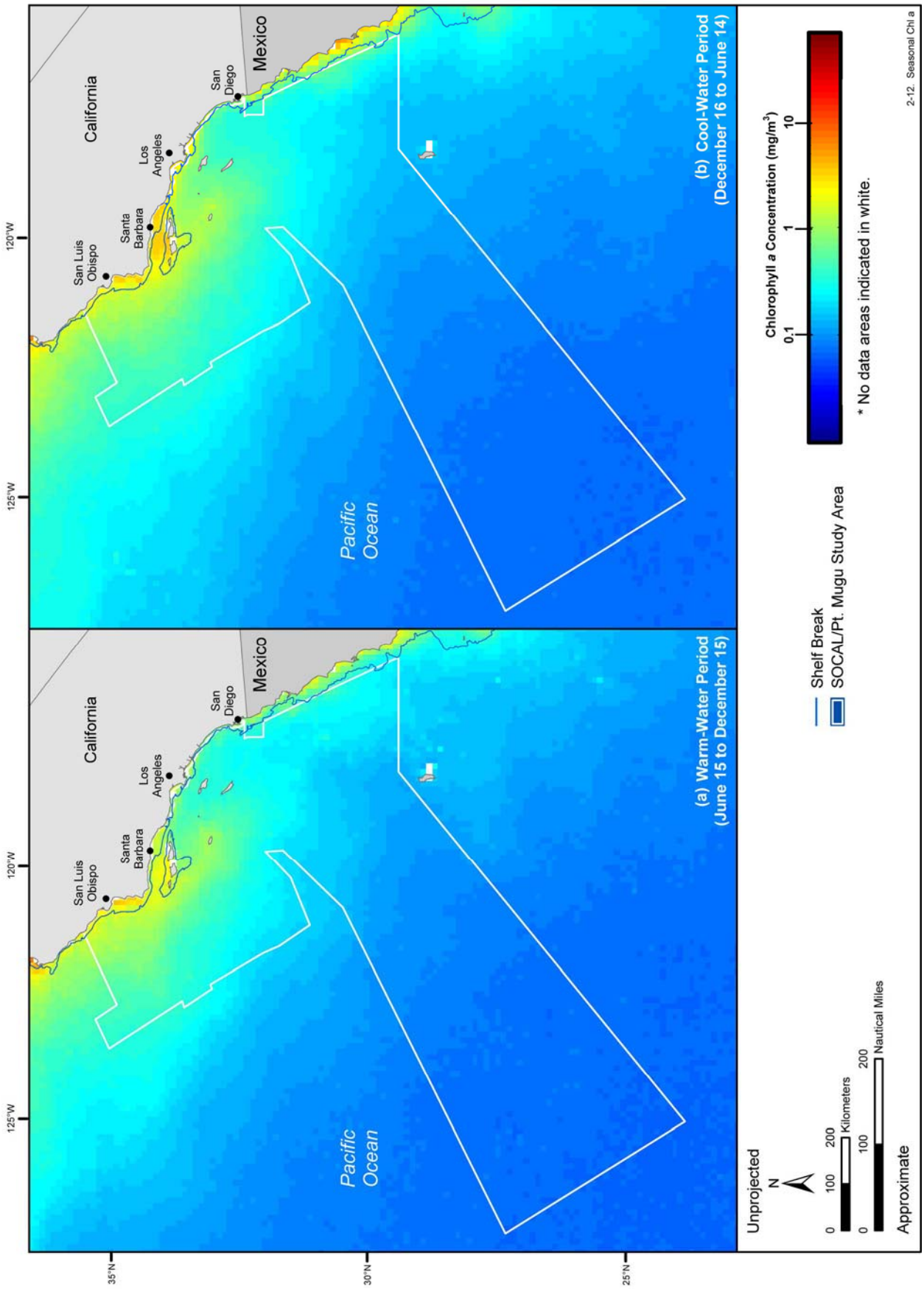

Figure 2-12. Seasonal distribution of chl a in the SOCAL and Pt. Mugu OPAREAs and vicinity during the a) warm-water period (15 June through 15 December) and b) the cool-water period (16 December through 14 June). Source data: NASA (2005).

2.6.2 Phytoplankton

Phytoplankton are single-celled organisms that are similar to plants because they photosynthesize using sunlight and chlorophyll to generate energy. Photosynthesis is a chemical reaction that converts energy from the sun into chemical energy stored within organic molecules by combining water, carbon dioxide, and light energy to form sugar and oxygen (Lalli and Parsons 2000). In the oceanic ecosystem, 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; Lalli and Parsons 2000). Rates of photosynthetic production can vary between <0.1 mg of carbon per square meter per day (mgC/m^2/d) in oligotrophic regions to >10 mgC/m^2/d in highly productive (eutrophic) areas (Thurman 1997).

Growth and distribution of phytoplankton are influenced by temperature (Eppley 1972), light (Yentsch and Lee 1966), nutrient concentrations (Goldman et al. 1979), and to a lesser degree pH, iron concentration, and salinity (Parsons et al. 1984). When one of these essential factors is in short supply, growth is said to be limited by that factor. In general, the distribution of phytoplankton is patchy, occurring in regions with the optimal conditions for growth.The concentration of chlorophyll measured in the water column or at the sea surface can be used as a proxy for phytoplankton abundance; regions of enhanced chlorophyll concentrations are indicative of high phytoplankton abundance (**Figure 2-12**). In general, the concentration of phytoplankton (chl *a*) decreases with increased distance from the shore and with water depth. Peak chl *a* concentration (phytoplankton biomass) is often found below the sea surface and appears to be a permanent feature, referred to as the deep chlorophyll maximum (DCM), in oceanic waters from 45°N to the tropics (Parsons et al. 1984).

Over 280 species of phytoplankton have been reported in the SOCAL/Pt. Mugu Study Area and vicinity (Abbott and Hollenberg 1976). In the SCB, waters from both the north and the south mix and promote increased phytoplankton abundance and diversity (DoN 1999). The phytoplankton community (ranging in size from a few microns to hundreds of microns) is comprised of diatoms and dinoflagellates typically found in both colder northern waters and warmer southern waters (Walsh et al. 1977; Estrada and Blasco 1979; Hardy 1993). The diversity of phytoplankton species in the region reflects the transition from subarctic waters in the north to more subtropical waters to the south (Hardy 1993).

In the SOCAL/Pt. Mugu Study Area, phytoplankton production is moderately high (150 to 300 grams of carbon per square meter per year [gC/m^2/yr]) (Hardy 1993; Burtenshaw et al. 2004; Kudela et al. 2005); however, there is heterogeneity in the distribution of chlorophyll both spatially and temporally (Hardy 1993; Legaard and Thomas 2006). Highest levels of productivity occur in spring and summer, and the lowest levels of production occur during winter (Burtenshaw et al. 2004). Phytoplankton biomass is typically highest near the shorelines of the mainland and Channel Islands (Hardy 1993; Burtenshaw et al. 2004) where small-scale eddies, upwelling, and turbulence provide the necessary nutrients for increased levels of production.[5]

In offshore regions where the overall nutrient concentrations are low, the phytoplankton communities are dominated by small nanoplankton and picoplankton that contribute substantially to the overall productivity in the region (Hardy 1993; Karl 1999; Higgins and Mackey 2000). Phytoplankton concentrations in offshore regions peak in late winter when intense winter winds increase the depth of the mixed layer (Legaard and Thomas 2006).

The effects of El Niño on chlorophyll and phytoplankton communities are more difficult to quantify than trends in physical parameters, because the long-term data set is limited (Hayward 2000); however, several trends have emerged. Along the California coast, there is a decrease in phytoplankton production in the surface waters due in part to a decrease of upwelling strength (**Figure 2-12**) (Kahru and Mitchell 2000; Santamaria-Del-Angel et al. 2002; Hernández de la Torre et al. 2004). This causes the chlorophyll maximum to occur deeper in the water column in conjunction with deeper nutrient concentrations (Fiedler 1984; McGowan 1984; Hayward 2000). In addition, El Niño conditions weaken the California Current and tend to favor an increase in subtropical species (Leet et al. 2001; Santamaria-Del-Angel et al. 2002; Legaard and Thomas 2006). Offshore of Baja California and in the NPSG, the onset of El Niño results in

an increase in primary production due to a community shift towards nitrogen-fixing cyanobacteria such as *Trichodesmium* spp. (Karl et al. 1995; Kahru and Mitchell 2000; Santamaria-Del-Angel et al. 2002). Following an El Niño, coastal phytoplankton abundance (and chl *a* concentration) increases to long-term average levels (Lavaniegos et al. 2003; Hernández de la Torre et al. 2004). Conversely, La Niña conditions cause a shift towards more subarctic phytoplankton species and an increase in coastal phytoplankton abundance (Goes et al. 2001; Chen-Tung et al. 2004).

2.6.2.1 Harmful Algal Blooms

Like other coastal regions, southern California can experience large blooms (i.e., rapid exponential growth) of phytoplankton. Blooms of harmful algal species, referred to as HABs, can pose serious public health threats, and the economic impact of HABs can total hundreds of millions of dollars annually. In the SCB, HABs are associated with the widespread mortality of wildlife including birds, fish, and marine mammals (Scholin et al. 2000; Trainer et al. 2000; Kudela et al. 2005). Major HABs of the diatom *Psuedo-nitchia* spp. and the dinoflagellates *Lingulodinium polyedrum, Gymondimium polyedra, G. splendis,* and *Prorocentrum micans* have been reported in the SOCAL and Pt. Mugu OPAREAs and vicinity (Hardy 1993; Kudela et al. 2003; Kudela et al. 2005). In many cases, these blooms form in the south and propagate to the north; however, it is difficult to monitor, predict, and understand the origins and fate of HABs (Kudela et al. 2003). In 1995, a large red tide of the non-toxic dinoflagellate, *L. polyedrum*, extended from the upper Baja peninsula in the south to Monterey Bay in the north and constituted the largest and most widespread red tide off the California coast since 1902 (Kudela et al. 2003). In the spring of 1998, the California coast harbored the toxic dinoflagellate *Pseudo-nitchia* spp. in relatively low abundances. Following 1998, a series of *Pseudo-nitchia* blooms occurred in 2000 and 2002 that extended along much of the California coastline (Kudela et al. 2003). Subsequently, in the spring and summer of 2003 and 2004, blooms of *Pseudo-nitchia* spp. accompanied by some of the highest concentrations of particulate domoic acid (DA) ever recorded in U.S. waters occurred off the coasts of Los Angeles and Orange counties (Schnetzer et al. 2007). Concentrations of DA in Los Angels Harbor reached 12.7 micrograms per liter (µg/L), and the HAB was linked to over 1,400 marine mammal strandings that occurred in the SCB during 2003 and 2004 (Schnetzer et al. 2007). Runoff events (Kudela and Cochlan 2000) and decreases in upwelling strength (Trainer et al. 2000; Kudela et al. 2003) are believed to be the main causes of these harmful phytoplankton blooms in the SOCAL/Pt. Mugu Study Area.

2.6.3 Secondary Production

Secondary production refers to the increase in biomass of heterotrophic organisms through the consumption of primary producers. Zooplankton and bacteria within the water column feed on phytoplankton (as well as each other) and comprise the second link in the marine food web (Lalli and Parsons 2000).

2.6.4 Zooplankton

Marine zooplankton are aquatic animals ranging in size from 20 µm to >2,000 µm (e.g., large shrimp) (Parsons et al. 1984); they can be separated into two distinct categories based upon their coastal proximity. Oceanic zooplankton (e.g., salps and copepods) are typically found offshore and in many depths. Neritic zooplankton (e.g., fish larvae and benthic invertebrate larvae) are typically found inshore in waters overlying the mainland and island shelves (Uchida 1983).

Zooplankton in the SCB have been well studied with an emphasis on neritic zooplankton occurring in bays, harbors, and the nearshore environment (Dawson and Pieper 1993). The CalCOFI has monitored zooplankton abundance off of southern California since 1949 (Bernal 1979); the nearshore zooplankton populations are a large and diverse assemblage that ranges from small protozoans to large shrimp and jellyfish (Dawson and Pieper 1993).

Along the California coast, zooplankton biomass has been shown to be unrelated to upwelling strength (Bernal and McGowan 1981). Rather, the abundance of zooplankton is related to the strength of the

California Current such that high levels of transport result in high zooplankton biomass (Bernal and McGowan 1981; Dawson and Pieper 1993; Leet et al. 2001). Within the SOCAL/Pt. Mugu Study Area, two distinct zones of zooplankton diversity exist. In the northern region (located north of latitude 33°N), the zooplankton community is dominated by subarctic zooplankton species while the southern region (south of latitude 33°N) contains a higher diversity of organisms and is dominated by more subtropical species (Bernal and McGowan 1981). Off the California coast, zooplankton biomass tends to reach its maximum in summer; this coincides with peak krill (*Euphausia pacifica*, i.e., euphausiid) biomass. The high abundance of euphasiids attracts whales to congregate and feed off the California and Mexico coastlines (Burtenshaw et al. 2004). Since 1951, there has been a significant decrease (~80%) in macrozooplankton biomass off of the southern California coastline associated with warming SST, but the mechanisms responsible for this decline are not currently well understood (Roemmich and McGowan 1995a, 1995b; Hayward 2000).

High densities of zooplankton are found in the nearshore regions (inside the 200-m shelf break) of the Study Area, coinciding with higher concentrations of phytoplankton (Bernal and McGowan 1981). Protozoans (abundance) and micrometazoans (biomass) dominate the microzooplankton community, whereas crustaceans dominate the macrozooplankton community (Beers and Stewart 1967, 1969a, 1969b; Dawson and Pieper 1993). Bays and harbors tend to be dominated by copepods. Offshore, zooplankton biomass is variable with depth but tends to collect at or near the DCM. Equatorial radiolarians dominate the offshore microzooplankton in summer; however, in winter there is a shift towards subarctic species coinciding with the influx of colder water from the north (Dawson and Pieper 1993). The offshore macrozooplankton are comprised of many of the same species that are found nearshore (Dawson and Pieper 1993).

In the SCB, ENSO conditions affect the distribution of zooplankton (Hayward 2000; Zamon and Welch 2005). During strong El Niño events, macrozooplankton biomass declines substantially (Roemmich and McGowan 1995a, 1995b; McGowan et al. 1998; Hayward 2000); during the strong 1998 El Niño event, the macrozooplankton biomass was lower than ever documented in the 1951 to 1998 record (Hayward et al. 1999). In addition, southern, warm-water species became more abundant and northern, cool-water species declined (Hayward 2000; Leet et al. 2001). During La Niña conditions, macrozooplankton biomass is anomalously high and subarctic species are more abundant (Schwing et al. 2000). Schwing et al. (2000) hypothesized that increased upwelling during a La Niña event can negatively impact the recruitment of benthic nearshore organisms (e.g., urchins, barnacles, and crabs); these organisms are dependant on relaxed upwelling conditions to transport planktonic larvae onshore for settlement (Schwing et al. 2000).

2.7 HABITATS

The majority of the habitats discussed for the SOCAL/Pt. Mugu Study Area are located nearshore. There are three major nearshore areas that are analyzed in this assessment up to the high, high tide line: (1) San Diego Bay; (2) the mainland coastline of the Pt. Mugu Study Area; and (3) the Channel Islands coastline located within the Pt. Mugu Study Area. The remainder of the habitats that are analyzed in this assessment are located at least 3 nm offshore. Marine ecosystems in the waters of the SOCAL/Pt. Mugu Study Area 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. 1980a).

Habitats in this assessment 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. The marine area associated with the SOCAL/Pt.Mugu Study Area includes three biogeographic regions: (1) the colder Oregon province; (2) the warmer California province; and (3) the transition zone between the two. Point Conception is often identified as marking the general boundary between the Oregon and California provinces (NOAA 2007). The majority of species in the Pt. Mugu Study Area occur in the Oregon province in suitable habitats from the Cape Blanco to Point Conception,

California. The species located in the southern reaches of the Pt. Mugu Study Area and in the SOCAL Study Area occur in the California province in suitable habitats from Point Conception, California to northern Baja California (Airamé et al. 2003; NCCOS 2005; Blanchette et al. 2006; Blanchette and Gaines 2007; Blanchette et al. 2007).

Habitat and species composition is strongly influenced by the dominant forms of vegetation, tidal influence, depth, and type of substrate (Proctor et al. 1980a). 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 SOCAL/Pt. Mugu Study Area, several habitat types (i.e., kelp, seagrass, etc.) and habitat areas (i.e., rocky intertidal, beaches, 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 on rocky reef locations. 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 SOCAL/Pt. Mugu Study Area (**Figure 2-13**).

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 (the Pacific lamprey, anadromous fish such as steelhead trout, and estuarine-dependent fish such as halibut), birds, mammals, and invertebrates (Ferren Jr. et al. 1995). They provide vital food and habitat for many invertebrates including clams and crabs as well as offering shelter and nesting sites for many species of migratory waterfowl along the Pacific flyway.

Coastal wetland ecosystems in southern California are naturally scarce (Baird 1993); however, they are also heavily disturbed environments. California has lost 91% of its historical wetland area (Leet et al. 2001). Wetlands provide habitat for several endangered species including the salt marsh bird's beak (*Cordylanthus maritimus*), California clapper rail (*Rallus longirostris obsoletus*), California least tern (*Sterna antillarum browni*), California brown pelican (*Pelecanus occidentalis californicus*), and the threatened western snowy plover (*Charadrius alexandrinus nivosis)* (Leet et al. 2001). California has

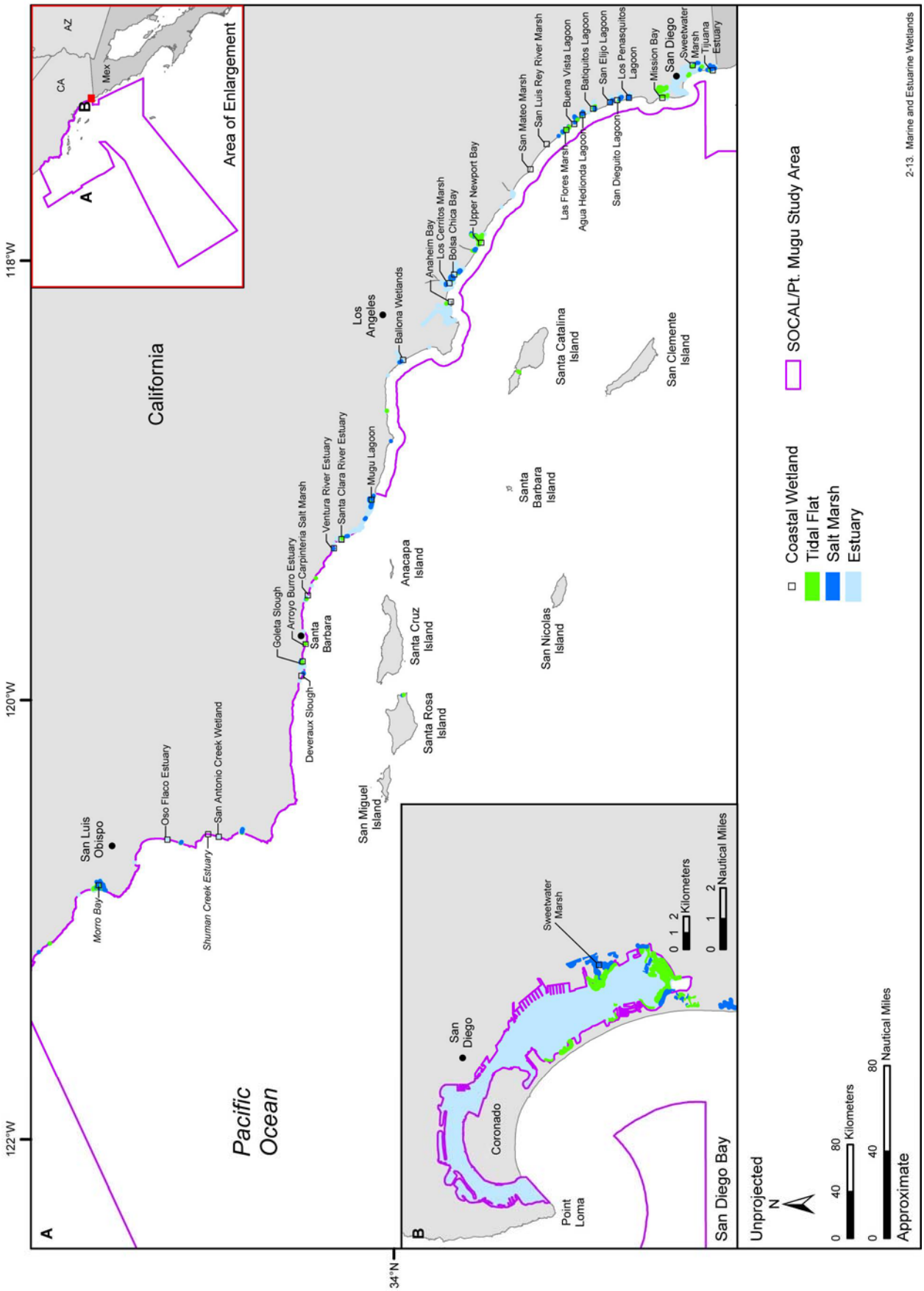

Figure 2-13. Marine and estuarine wetland habitat in the SOCAL/Pt. Mugu Study Area. Source data: Zedler (1982), DoN (2000), NOS (2001), TerraLogic GIS and Copps (2004), and NOS (2006).

enacted laws to protect many of its wetland habitats. Restoration has become an important tool to remediate the damage to ecosystem functions resulting from coastal wetland loss (Armitage et al. 2007). The creation of functional habitat and restoration efforts that are in force include Mission Bay, San Diego Bay, Bataquitos Lagoon, and Mugu Lagoon; however, diligence is needed to assure that protective measures are actively enforced (Kennish 2001).

There are at least seven major types of estuaries in the Study Area: river mouth, canyon mouth, lagoonal, coastal dune-creek, bay, structural basin, and artificial drain estuaries (Ferren Jr. et al. 1995).

- River mouth estuaries are located at the mouths of large rivers that have some perennial flow which produces almost permanently brackish water in the estuary. Examples of river mouth estuaries include the Ventura River Estuary in Ventura County and the Santa Clara River Estuary at McGrath State Beach in Ventura County. The Tijuana Estuary at the mouth of the Tijuana River is also considered a river mouth estuary; however, because of its large size and extensive low marsh habitats, it also has attributes of a bay estuary (**Figure 2-13**) (Ferren Jr. et al. 1995).

  Canyon mouth estuaries are formed as a result of the California coastline landscape of canyons, arroyos, and valleys that drain watersheds into the ocean through small estuaries that are variable in size, frequency of tidal flooding, salinity regimes, and biota. Examples of canyon mouth estuaries include the Arroyo Burro Estuary in Santa Barbara County (with habitats that supports the endangered fish, the tidewater goby [*Eucyclogobius newberryi*]) and Devereux Slough, which is located at Coal Oil Point Reserve at the University of California, Santa Barbara. In contrast to river mouth estuaries where runoff generally exceeds evaporation throughout the year, many canyon mouth estuaries such as Devereux Slough receive virtually no runoff during the dry season, and subsequently, evaporation results in a loss of almost all water in the estuary (**Figure 2-13**) (Ferren Jr. et al. 1995).

- Lagoonal estuaries are primarily found in San Diego County. They have mouths closed by sand bars most of the year, and are generally characterized by brackish fringe-marshes, salinities that approach those of fresh water, and support fauna typical of brackish to fresh water conditions. Buena Vista Lagoon is an example of a lagoonal estuary in the SOCAL/Pt. Mugu Study Area (**Figure 2-13**) (Ferren Jr. et al. 1995).

- Coastal Dune-Creek estuaries are characterized by having a perennial source of freshwater from adjacent dunes, and are generally brackish most of the year. Coastal dunes contain significant amounts of fresh water that continually replaces water lost from evaporation in addition to perennial runoff from some streams. Some of these estuaries may have historically been the mouths of rivers or streams before a change in flow resulted in the abandonment of the mouths for new sites. Examples of coastal dune-creek estuaries in the SOCAL/Pt. Mugu Study Area include Oso Flaco Estuary at the Guadalupe Dunes in San Luis Obispo County and San Antonio Creek Estuary and Shuman Creek Estuary at San Antonio Dunes Terrace on Vandenberg Air Force Base in Santa Barbara County (**Figure 2-13**) (Ferren Jr. et al. 1995).

- Bay estuaries have large areas of subtidal habitat (bays) and low elevation salt marsh on the bay margins. There is a strong marine influence in bay estuaries because there is (1) a consistently open and generally wide mouth; (2) a large body of marine water that floods wetland habitats; and (3) the low elevation of adjacent marshes that results in diurnal (twice daily) tidal flooding of these marshes. They are characterized by distinctive habitat such as extensive low elevation intertidal mud flats and biotic communities such as cordgrass and eelgrass beds. Examples of bay estuaries in the SOCAL/Pt. Mugu Study Area include Morro Bay, Bolsa Chica Bay, Anaheim Bay, Upper Newport Bay, Mission Bay and Kendall-Frost Reserve, and San Diego Bay (**Figure 2-13**) (Ferren Jr. et al. 1995).

- Structural basin estuaries are formed in areas of considerable tectonic activity with coastal down-faulted and down-folded geologic structures. Structural basin estuaries have supporting watersheds that are steep and short, and that are characterized by occasional catastrophic flooding and

sedimentation, particularly from large storms following chaparral fires in adjacent foothills and mountains. Examples of structural basin estuaries in the SOCAL/Pt. Mugu Study Area include down-faulted basins, such as the one containing Goleta Slough in the Goleta Valley and down-folded basins such as the one containing Carpinteria Salt Marsh in the Carpinteria Valley (**Figure 2-13**) (Ferren Jr. et al. 1995).

- Artificial drain estuaries are small, narrow estuaries that form where both agricultural and urban drains reach the coast. Some are small wetlands on sandy beaches at the mouths of culverts and storm drains while others reach the coast as canals and have tidal channels with fringe marshes along the margins. Depending on the type of runoff, these small estuaries may vary in water quality between being extremely polluted to average water quality. An example of an artificial drain estuary in the SOCAL/Pt. Mugu Study Area is the Oxnard Drain in Ventura County which carries both agricultural and urban runoff. Tidewater gobies have been found at this site suggesting that estuarine conditions are adequate to sustain a population of this endangered fish (Ferren Jr. et al. 1995).

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 (Carlisle et al. 2002). 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). Low, middle, and high salt marsh characteristic vegetation is listed in **Table 2-5.** The middle salt marsh, generally has low plant diversity (usually less than 25 species) and the high salt marsh is generally characterized by a high diversity of herbs, shrubs, and trees (Nixon 1982).

Many species of concern require coastal salt marsh habitats, including species of endangered plants (e.g., salt marsh bird's beak), mammals (southern California salt marsh shrew), birds (Belding's savannah sparrow), fish (tidewater goby), and insects (mudflat tiger beetle). Coastal salt marshes also provide habitat for non-listed declining species such as the Olympia oyster in the Carpinteria salt marsh (Ferren Jr. et al. 1995). The salt marsh bird's beak (*C. maritimus*), a federally and state protected endangered species, can be found in the high salt marsh of two refuge locations within the SOCAL/Pt. Mugu Study Area, in the Tijuana slough NWR and the Sweetwater Marsh NWR (Zedler et al. 1992). Also, in the high marsh of Tijuana estuary, six federally endangered birds can be found (Kennish 2001).

Along the California coastline, coastal salt marshes form discontinuous marshes that can develop in sheltered regions along the inland margins of bays, lagoons, and estuaries (**Figure 2-13**) (DoN 2002a). They may also develop along the unexposed boundaries of sand spits, which have enclosed embayments along the rocky coast. Adjacent ecosystems at lower elevations such as tidal flats and seagrass beds 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.

Coastal salt marshes are continuously impacted by development in the SOCAL/Pt. Mugu Study Area. Agricultural development (e.g., pesticide pollution), urbanization (e.g., filling), agency activities (e.g., ditching and chemical treatment for mosquito abatement), resource extraction (e.g., fisheries), access (e.g., soil removal), and introduction of invasive exotic species (e.g., European sea lavender [*Limonium ramosissimum*]) has significantly reduced the quantity and quality of salt marshes (Ferren Jr. et al. 1995). Restoration efforts are currently underway for several salt marsh habitats in the SOCAL/Pt. Mugu Study Area. For example, the U.S. Navy has to date established six salt marsh restoration projects within Mugu lagoon since 1988. Mugu lagoon, a 2,500-ac coastal salt marsh, provides habitat for seven federal and state listed species (Tetra Tech EM 2007). It is the largest remaining coastal salt marsh in southern

California and since the marsh is located on a military base (Naval Base Ventura County) it has been free from many of the human activities that impact other coastal salt marshes in southern California (Ambrose et al. 2006).

Table 2-5. Characteristic flora indicative of salt marsh zonation in the SOCAL/Pt. Mugu Study Area (Nixon 1982; Zedler 1982; Ferren Jr. et al. 1995).

Common Name	Scientific Name
Low salt marsh	
Cordgrass	*Spartina foliosa*
Saltwort	*Batis maritima*
Annual pickleweed	*Salcornia bigelovii*
Perennial pickleweed	*Spartina virginica*
Middle salt marsh	
Perennial pickleweed	*Spartina virginica*
Saltgrass	*Distichlis spicata*
Alkali heath	*Frankenia salina*
Jaumea	*Jaumea carnosa*
Sea-lavender	*Limonium californicum*
Estero sea-blite	*Suaeda esteroa*
Arrow-grass	*Triglochin concinna*
High salt marsh	
Salt grass	*Distichlis spicata*
Parish's glasswort	*Arthrocnemum suberminale*
Shoregrass	*Monanthochloe littoralis*
Perennial pickleweed	*Spartina virginica*

2.7.1.2 Tidal Flats

Tidal flats are relatively broad, flat intertidal habitat submerged during high tide and located along protected coastal intertidal areas (DoN 2000). In the SOCAL/Pt. Mugu Study Area, 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 use the nutrient-rich detritus found in tidal flats (DoN 2000). The flora and fauna supported by tidal flats are typical of that found in the bays and estuaries along the California coastline 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.[10] Some of the tidal flats in the SOCAL/Pt. Mugu Study Area are depicted in **Figure 2-13**.

- Mudflats—Mudflats form in protected coastal intertidal 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.[10] 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 all tide-levels having a substantial amount of crustaceans, pelecypods, and

gastropods (Proctor et al. 1980b; Allen et al. 2002); however, the California horn snail (*Cerithidea californica*) is the dominant animal found in the intertidal mud flat where populations commonly reach hundreds of animals per square meter (Thompson et al. 1993). Ghost shrimp (*Callianassa californiensis*) and California jackknife clams (*Tagelus californianus*) characterize the mid-tide level and polychaetes and oligochaetes dominate the sub-tide level. Migratory water birds use the extensive algal cover and resident invertebrate meiofauna present in mudflats (DoN 2000). One of the largest mudflat habitats in the SOCAL/Pt. Mugu Study Area is located in the Mugu lagoon (Onuf 1987).

- Sand Flats—Sand flats are comprised of sand particles with low organic matter content (1% to 2%).[10] 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. 1980b).

2.7.1.3 Tidal Creeks

Tidal creeks allow estuarine waters to circulate in and out of wetlands (Seliskar and Gallagher 1983; Onuf 1987). 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 Mugu lagoon, the tidal creeks can be as much as 1 m deeper and have currents that are faster than in the adjacent marsh. Most of the tidal creeks are short (<0.5 km) and the only long tidal creek extends approximately 4 km because Mugu lagoon is narrow (Onuf 1987).

2.7.1.4 Channels

Channels are a deep subtidal habitat that can be a naturally occurring or artificially dredged portion of an estuary; 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. 1980b). 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. 1980b).

2.7.2 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). Sandy beaches have a steep gradient, topographically, because they are exposed to significant wave action; therefore, the sediments are coarse in size, aerobic, experience rapid and differential drying, and are more strongly zoned than mudflats (Dugan et al. 2000). 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 (hr/d). 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. 1980b; Airamé et al. 2003).

In the SOCAL/Pt. Mugu Study Area, beaches are a major habitat (**Figure 2-14**). Dugan et al. (2000) recorded that exposed sandy beaches make up over 75% of the mainland shoreline and approximately 23% of the Channel Islands coastlines (Dugan et al. 2000). Allen and Pondella (2006) document that sandy beaches make up approximately 57% of the coastline north of Point Conception and almost 82% of the mainland coastline from Point Conception south to the Mexican border. NOAA (2007) determined that the CINMS has approximately 76 km of sandy beach habitat.

There are two main types of beaches, those that are (1) protected and exist in low energy environments; and (2) unprotected in exposed, constant, high-energy wave action environments. Beach sand tends to be coarser in unprotected, wave-exposed regions and finer within protected estuaries and bays (Proctor et al. 1980b).

- 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 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. 1980b). 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. 1980b). 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).

These habitats support extensive invertebrate communities that are an important food resource for shorebirds. A number of plants and animals have become adapted to this stressful habitat; the most common invertebrates found are the common sand crab (*Emerita analoga*), isopods (e.g., *Excirolana chiltoni*), talitrid amphipods (e.g., *Megalorchestia* spp.), polychaetes (e.g., *Euzonus mucronata*), the Pismo clam (*Tivela stultorum*), the bean clam (*Donax gouldii*), and the purple olive snail (*Olivella bipiicata*) (Dugan et al. 2000). Typical plants along coastal shoreline areas in the SOCAL/Pt. Mugu Study Area include beach sagewort (*Artemisia pycnocephala*), dunce buckwheat (*Eriogonum parviflorum*), beach ragweed (*Ambrosia chamissonis*), red sand verbena (*Abronia maritima*), and beach evening primrose (*Camissonia cheiranthifoia*) (Schoenherr 1989). Native plant cover is especially important because it serves as important habitat for nesting, roosting, and foraging bird species including the endangered California least tern (*S. antillarum browni*), the threatened western snowy plover (*C. alexandrinus nivosus*), and the Belding's savannah sparrow (*P. sandwichensis beldingi*) (Dugan et al. 2000). Additionally, these beaches provide resting areas for some marine mammals; many species of pinnipeds have large rookeries on the isolated and undisturbed beaches of the Channel Islands (Le Boeuf and Bonnell 1980). See **Chapter 3** for specific haulout, rookery, and nesting sites.

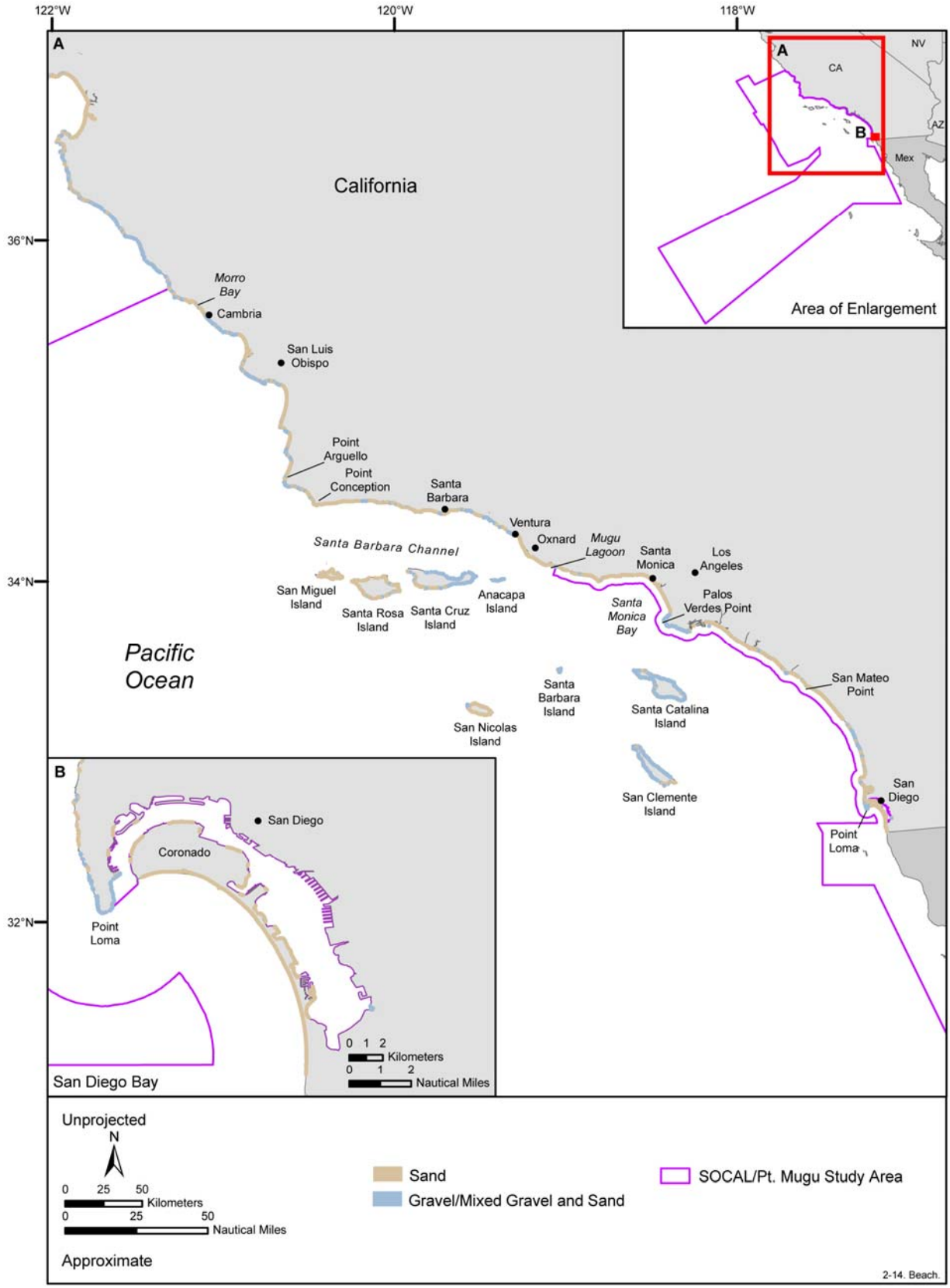

Figure 2-14. Beach habitat including sandy and gravel beaches in the SOCAL/Pt. Mugu Study Area. Source data: NOS (2001, 2006).

2.7.3 Rocky Intertidal

Rocky intertidal habitat forms along the shoreline between high and low tide and is present on all shorelines of California and the Channel Islands where sand is absent due to constant wave action, currents, steep submarine slopes, and a lack of offshore sand reservoirs (**Figure 2-15**) (NOS 2001; Airamé et al. 2003; NOS 2006). 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 (Thompson et al. 1993; Airamé et al. 2003). Four zones of biological assemblages are traditionally associated with different tidal heights, similar to the ecological zonation characteristics of beach habitats (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). The splash zone is the uppermost intertidal band; it is only occasionally wetted by waves. The high intertidal zone is located below the splash zone and is exposed to air regularly; therefore, the organisms common in this zone have adapted to temperature fluctuations and desiccation. The middle intertidal zone is covered with water at higher low tides; thus, the organisms in this zone are offered some protection from desiccation. The low intertidal zone is located at the lowest low tide level and is almost always submerged (Airamé et al. 2003).

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). Along the California coastline, 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 (*Egregia menziesii* [feather boa kelp], and other brown algae). In addition, various sea anemones, sea stars, and brittle stars are very prominent (Proctor et al. 1980b).

- 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. 1980b).

Throughout the SOCAL/Pt. Mugu Study Area there are frequently changing water temperatures, substrates, upwelling conditions, wave exposures, water transparencies, levels of natural and human-induced disturbances, and nutrient concentrations. In the SOCAL/Pt. Mugu Study Area, important biogeographical boundaries define the distribution, abundance, size, and recruitment of intertidal communities. For example, north of Point Conception (strong upwelling and high wave exposure), intertidal communities are dominated by macrophytes, while mussels and barnacles are relatively scarce. South of Point Conception (weak, seasonal upwelling and warmer water temperatures), intertidal communities are dominated by mussels and barnacles, while macrophytes had low abundance

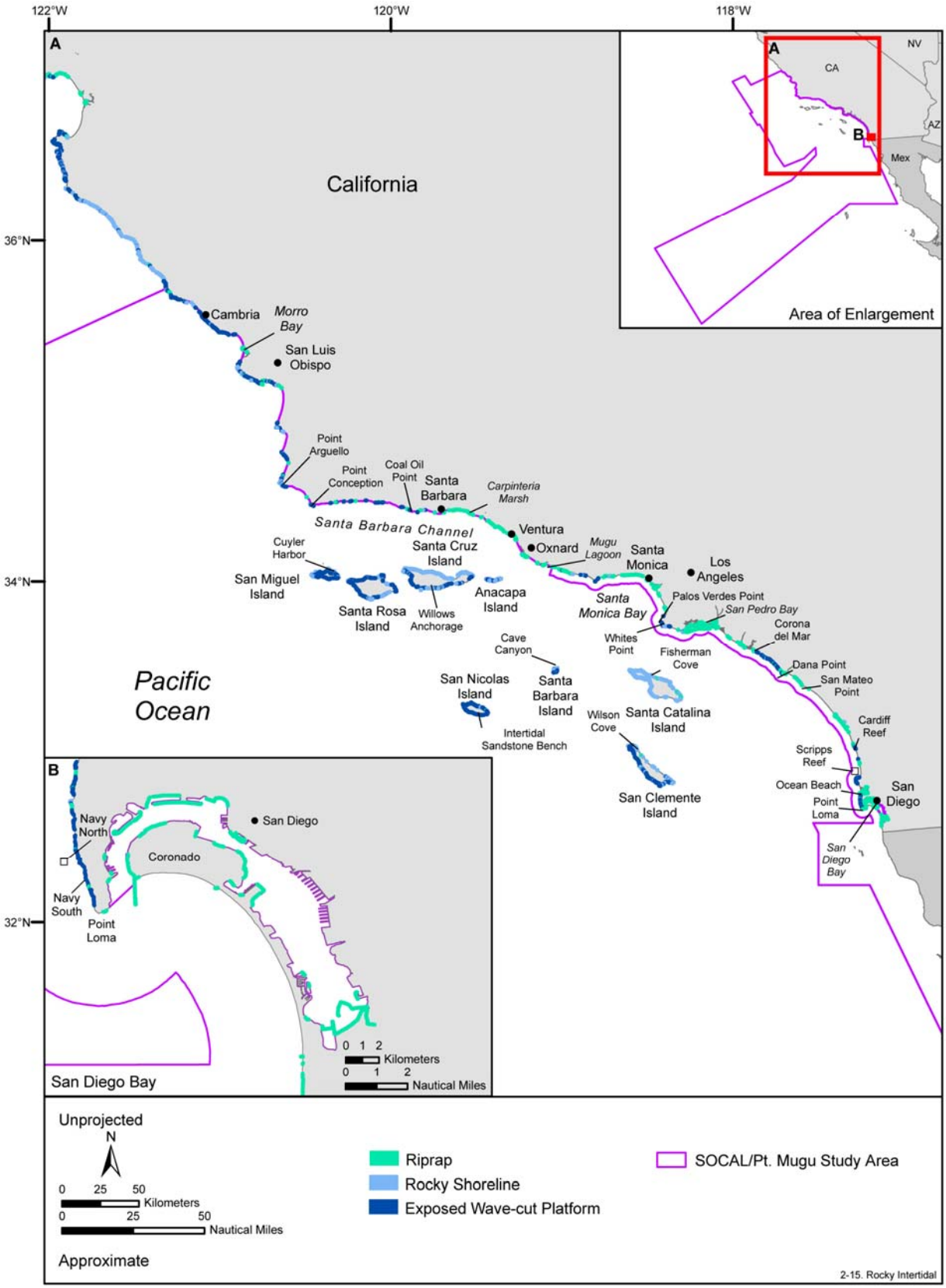

Figure 2-15. Rocky intertidal habitat including natural and manmade (riprap) rocky substrate in the SOCAL/Pt. Mugu Study Area. Source data: NOS (2001, 2006).

(Blanchette and Gaines 2007). Water temperature is the governing factor that determines the broad-scale, biogeographic patterns of the rocky intertidal habitats throughout the Study Area (Seapy and Littler 1980). On a finer scale, wave action and coastal upwelling usually leads to richer intertidal communities. At an even finer scale, substrate stability, sand inundation, substrate hardness and heterogeneity, desiccation stress, human-induced disturbances, and natural disturbances such as storm waves, floods, and sedimentation play a role in determining the characteristics of an intertidal community. It is within this framework that biological interactions (i.e., predation, competition, diseases) play an important role in determining local patchiness (Seapy and Littler 1980). In a rocky intertidal zone, local patchiness and percent cover is of the utmost importance because space and light are often the limiting resources.

The SOCAL/Pt. Mugu Study Area coastline possesses an exceptional diversity of valuable rocky intertidal resources (Miner et al. 2005). NOAA (2007) determined that the CINMS has approximately 152 km of rocky intertidal habitat. The MMS (2001) documented that less than 25% of the SOCAL/Pt. Mugu mainland coastline is considered rocky intertidal habitat. In San Diego county, bedrock intertidal reefs comprise 14% of the coastline and the remaining 86% consists of sand, gravel, or cobble beaches (Engle and Adams 2003). Most rocky intertidal shores in the San Diego county occur on the Point Loma and La Jolla peninsulas (Engle and Adams 2003). The Channel Island rocky intertidal habitats tend to have higher biodiversity, species richness, biomass, and percent cover than the mainland sites (Littler 1980; Seapy and Littler 1993a, 1993b). Also, the southeastern Channel Islands tend to have larger macroflora biomass than the northwestern Channel Islands, and even lower still, the mainland tends to have lower macroflora biomass than the Channel Islands (Littler 1980). The Channel Island rocky intertidal habitats are generally more rich (i.e., diversity, abundance, richness, and biomass) than the mainland because the nearshore environment is dominated by sandy areas that are infrequently separated rocky substrates; whereas, the Channel Islands nearshore environment is composed primarily of rocky substrate with relatively small expanses of sand (Allen and Pondella 2006).

The SOCAL/Pt. Mugu Study Area offers some of the richest and least disturbed (i.e., the Channel Islands) rocky intertidal habitats in California. Rocky intertidal habitats in the SOCAL/Pt. Mugu Study Area are characterized by a diversity of macroflora and macrofauna species (**Table 2-6**) (Richards 2000).

Table 2-6. Characteristic macroflora and macrofauna that commonly occur in rocky intertidal habitats of the SOCAL/Pt. Mugu Study Area (Richards 2000).

Common Name	Scientific Name
Barnacles	*Balanus glandula*
	Chthamalus sp.
	Tetraclita rubescens
Turfweed	*Endocladia muricata*
Feather boa kelp	*Egregia menziesii*
Rockweed	*Pelvetia compressa*
	Hesperophycus californicus
Mussels	*Mytilus californianus*
Other invertebrates	
Owl limpets	*Lottia gigantea*
Black abalone	*Haliotis cracherodii*
Sea stars	*Pisaster ochraceus*

There have been many monitoring studies set up to record this diversity and to document any changes to this important habitat. Some of the rocky intertidal monitoring studies that have been or are currently being conducted in the SOCAL/Pt. Mugu Study Area are listed and discussed below.

- One of the first studies of the rocky intertidal habitats in the Study Area was conducted in 1964 at San Nicolas Island by Caplan and Boolootian (1967). Since San Nicolas Island is a military base under the administration of the Navy, fishermen and other unauthorized personnel are not allowed to visit the island; therefore, the intertidal areas are undisturbed and well preserved (Caplan and Boolootian 1967).

- Between 1975 and 1979, as part of a broad investigation by the BLM (now MMS), 22 rocky intertidal habitats (7 mainland sites and 15 island sites) in the SOCAL/Pt. Mugu Study Area were monitored and 349 macrofauna species were recorded (Seapy and Littler 1993b).

- In 1982, the Channel Islands National Park began monitoring the rocky intertidal community. They documented the significant impact that storm waves had on mussel and rockweed communities. They also, recorded black abalone population declines by over 99% throughout the Channel Islands National Park due to withering syndrome (WS), a bacterial disease (Richards 2000).

- Littler (1980) monitored the diversity of macroflora and macrofauna at over 60 sites in the SOCAL/Pt. Mugu Study Area and vicinity (**Table 2-7**; **Figure 2-15**). Over 224 species of macroflora and 315 species of macrofauna were recorded, emphasizing the importance and diversity of rocky shore environments along the California coastline (Littler 1980).

Table 2-7. A selected listing of the rocky intertidal monitoring sites conducted by Littler (1980) located within the SOCAL/Pt. Mugu Study Area (see Figure 2-15) and the number of macroflora and macrofauna species recorded at each site .

Location	Site	Macroflora (# of species found)	Macrofauna (# of species found)	Total taxa (Total # of species found)
Channel Islands				
San Miguel Island	Cuyler Harbor	61	55	116
Santa Cruz Island	Willows Anchorage	77	100	177
San Nicolas Island	Intertidal sandstone bench	69	51	120
Santa Barbara Island	Cave Canyon	88	69	157
Santa Catalina Island	Fisherman Cove	73	96	169
San Clemente Island	Wilson Cove	64	65	129
Mainland				
	Coal Oil Point	71	56	127
	Whites Point	36	69	125
	Corona del Mar	66	71	137
	Ocean Beach	92	58	150

- A rocky intertidal study of San Diego County was conducted to identify the dynamics of species abundance among seasons, years, and sites throughout central and southern California. A total of 35 key species were monitored for a 6-yr period between 1997 and 2003 (Engle and Adams 2003).

- In 1997, the Navy partially funded (along with the University of California, Santa Barbara) the monitoring of 4 rocky intertidal sites (Cardiff Reef, Scripps Reef, Navy North, Navy South) on the San

Diego shoreline for a period of 5 yr, and for an additional 3 yr for 2 of the sites (Navy North and Navy South) (**Figure 2-15**) (Engle and Adams 2003).

- A regional intertidal monitoring network, MARINe (Multi-Agency Rocky Intertidal Network), conducted significant monitoring of rocky intertidal habitats in the SOCAL/Pt. Mugu Study Area. MARINe was funded by the MMS with additional funding and support from local and state governments, universities, and private organizations. They conducted 9 yr of monitoring for 6 sites in San Luis Obispo County, 12 yr for 9 sites in Santa Barbara County, 10 yr for 5 sites in Ventura and Los Angeles Counties, and 8 yr for 4 sites in Orange County (Miner et al. 2005).

Rocky intertidal habitats in the SOCAL/Pt. Mugu Study Area are subject to a variety of potential perturbations, including oil spills, vessel groundings, water pollution, harvest, alien species, and overuse (trampling) by people (Richards 1994, 2000). For example, the intertidal black abalone (*Haliotis cracherodii*) experienced huge population loses during the 1980s (Davis et al. 1994), by 1993, catastrophic mortality (caused by "withering syndrome") had been documented for all of the Channel Islands (Engle 1994).

2.7.4 Continental Shelf Habitats and Assemblages

The bottom environment of central and southern California is complex due to the variety of bottom substrates and the complicated system of water circulation and bathymetry (Chikuni 1985). Marine benthic assemblages (both flora and fauna) are extremely diverse and include representatives of nearly all phyla. 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; Murray and Bray 1993; Thompson et al. 1993) With increasing depth, light intensity declines and eventually algae and plants are unable to survive; therefore, benthic flora decrease in abundance and size.

In the SOCAL/Pt. Mugu Study Area, rocky, sandy, and muddy substrates occur within the continental shelf subtidal environment and support habitats such as seagrass, kelp, and live/hardbottom communities.

Benthic flora is nearly ubiquitous in the photic zone. It occurs 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 man-made structures. They can also form extensive populations in sheltered, shallow habitats on soft substrates or grow completely unattached.

Marine invertebrates may range in size from microscopic forms (microinvertebrates) to the larger organisms (macroinvertebrates), and may be benthic or pelagic. The SOCAL/Pt. Mugu Study Area supports a wide variety of invertebrates due to its transitional location between cold and warm biogeographic provinces and diversity of substrates. Not including microinvertebrates, the total number of species may be in excess of 5,000. Examples of some of the macroinvertebrates within the SOCAL/Pt. Mugu Study Area include multiple species of corals, prawns, spiny lobster, crabs, sea urchins, sea cucumbers, sea star, abalone, nudibranchs, scallops, mussels, squid, clams, barnacles, snails, salps, tunicates, jellyfish, sea slugs, and anemones (NOAA 2007).

2.7.4.1 Kelp

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 west coast region (**Figure 2-16**). They extend from sea floor 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).

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; Stephens et al. 2006). It persists on rocky reefs that are occasionally subject to severe wave action and tidal currents (Stephens et al. 2006). 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. 1980b). Kelp can grow up to 10 centimeters per day (cm/d) and is among the most productive of marine plants. Kelp forests exhibit extremely high rates of primary production, estimated at 350 to 2,800 grams of carbon per square meter (gC/m^2).

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).

Kelp forests provide refuge, forage, and nursery areas to support commercial and sport fish, invertebrates, marine mammals, and marine birds (NOAA-NMS 2006). For example, kelp forests in central and southern California provide support for nearly 800 animal and plant species including sea urchins, squid, abalone, spiny lobster, California halibut, Pacific mackerel, rockfish, and crab (Leet et al. 2001). The California sea otter, a threatened species, often use kelp forests along the central and southern coasts of California as a refuge from predation by white sharks and as nursery areas. In addition, 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. Harbor seals, sea lions, and elephant seals are common pinnipeds in southern California that use kelp forests to feed on shallow-dwelling kelp forest fishes and for refuge from storms and predation. Gray whales use kelp forests to escape predation by killer whales and as a feeding area (Cummings and Thompson 1971; Nerini 1984; Deysher et al. 2002). In addition, to the primary habitat that kelp forests provide, kelp also provides secondary habitats via drift kelp (detached kelp). More information on drift kelp as a habitat is discussed in **Section 2.7.4.2** of this chapter.

Dense forests of kelp grow in rocky nearshore habitats along the entire California coast (NCCOS 2005). Several species of kelp occur throughout the Study Area, primarily giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis leutkeana*). The most notable species for southern California is the giant kelp (Stephens et al. 2006). Giant kelp forms large beds or forests that can extend up to 1.6 km in width and several kilometers in length (Foster and Schiel 1985). Bull kelp is the more dominant species in kelp beds north of Point Conception; however, in central and southern California, bull kelp can be commonly found mixed in with giant kelp. Bull kelp is more commonly found in the kelp beds of central and northern California than those in southern California. Bull kelp and giant kelp the mixed beds characteristic of the extensive kelp forests in the SOCAL/Pt. Mugu Study Area.

Inshore of giant and bull kelp beds, *Macrocystis integrifolia* and *Egregia menziesii* (feather boa kelp) may occur in dense stands that also form canopies (Stephens et al. 2006). *Macrocystis integrifolia* occurs primarily north of Point Conception and feather boa kelp is the dominant kelp in the inshore waters south of Point Conception (Rodriguez et al. 2001). Offshore of giant kelp beds in southern California, *Pelagophycus porra* (elk kelp) extends into the water column, occasionally to the surface, and sometimes it can form extensive beds (Stephens et al. 2006). Bladder chain kelp (*Cystoseira osmundacea*) can occur with giant kelp to form dense masses. *Sargassum* sp. can form canopies in winter-spring in

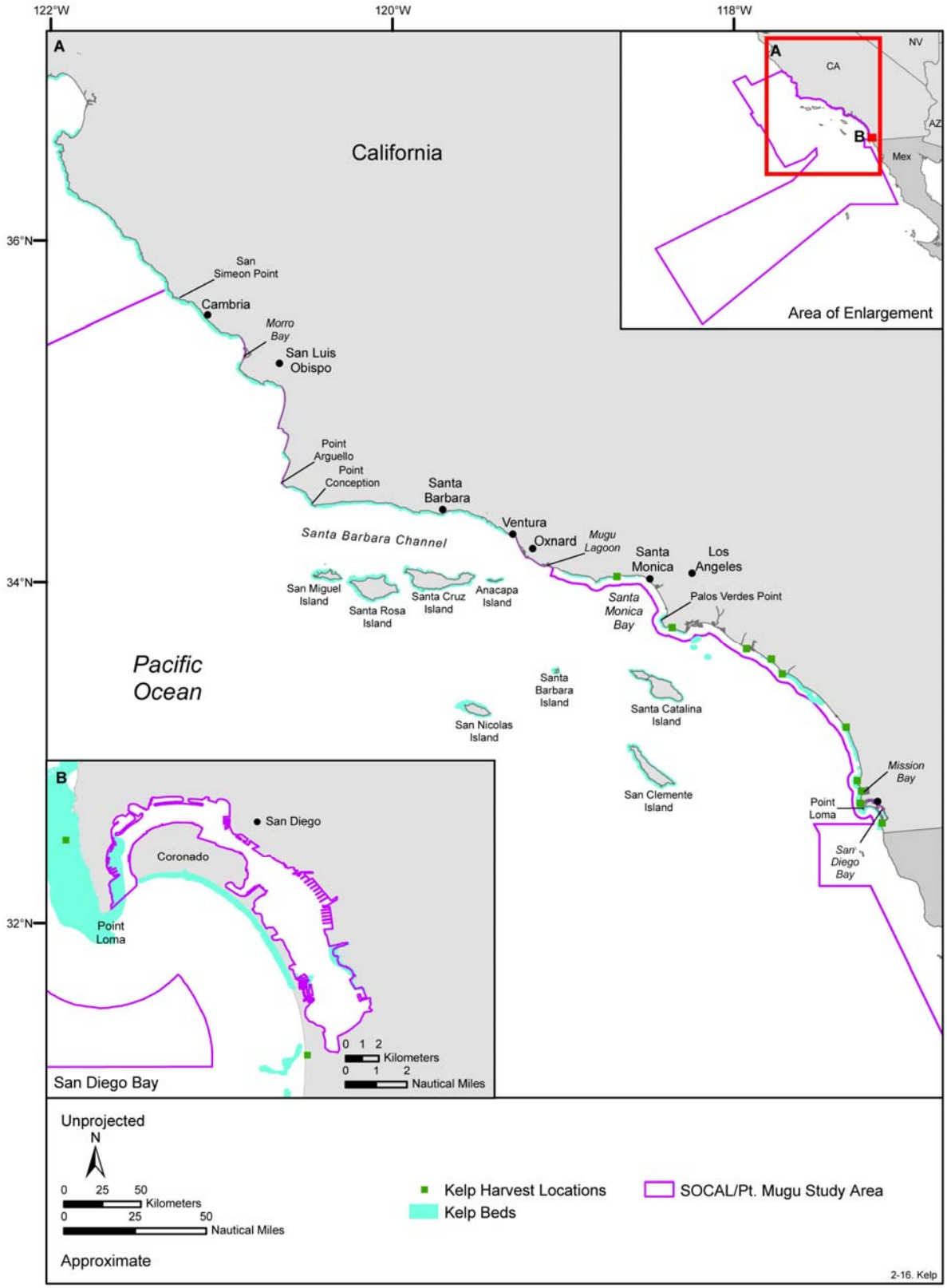

Figure 2-16. Kelp habitat and permitted kelp harvesting locations in the SOCAL/Pt. Mugu Study Area. Source data: NOS (2001), TerraLogic GIS and Copps (2004), and NOS (2006). Source maps (scanned): Waterproof Charts, Inc. (2003).

southern California, especially in shallow water. These *Sargassum* canopies can attract some fishes that are normally associated with giant kelp, such as the kelp perch, *Brachyistius frenatus*. Several species of brown algae (*Pterygophora californica*, *Laminaria farlowii*, *L. setchellii*, *Eisenia arborea*, and *Desmarestia ligulata*) can form understory canopies (Stephens et al. 2006). Other important kelp species include winged kelp (A*laria marginata*) and sea palm (*Postelsia palmaeformis* Ruprecht). Sea palm, is an endemic, intertidal kelp found only on very wave-exposed rocky shores of the Study Area (Nielsen et al. 2006). In general, south of Point Conception, feather boa kelp is the dominant kelp in the inshore waters; giant kelp dominates the intermediate waters; and south of Point La Jolla, elk kelp dominates the offshore waters. The kelp beds along the U.S. Pacific coast and Channel Islands are the most extensive and elaborate submarine forests in the world (Rodriguez et al. 2001).

- Giant Kelp—Giant kelp (*M. pyrifera*) provides much of the structure and biomass of central and southern California kelp forests (Foster and Schiel 1985). They flourish in wave-exposed areas of nutrient-rich cool water 6 to 40 m deep, 10° to 15°C, and bottom light intensities above 1% that of the surface (Leet et al. 2001). Giant kelp is a subtidal alga but they have also been found in some intertidal areas in California (North and Hubbs 1968). Giant kelp can reach lengths of up to 60 m and the fronds (leaves) can grow up to 60 (cm/d) (Leet et al. 2001).

  Giant kelp forests are especially well developed along the Pacific coast of North America from central California to Baja California. Giant kelp in the northern hemisphere ranges from Ano Nuevo Island in central California to Punta Asuncion-Punta San Hipolito in Baja California, Mexico (Foster and Schiel 1985). The bed off Point Loma is one of the largest along the California coast at 1 to 1.5 km wide and 7 km long (Deysher et al. 2002).

  Giant kelp can live up to 8 yr (Leet et al. 2001) but major causes of mortality are storm-displacement, sea urchin herbivory, and harvesting. Sea urchins that have very little drift kelp or other macroalgae to feed on will form frontal-attacks on the kelp holdfast and cause “urchin barrens” (Tegner et al. 1995). Following the removal of the southern sea otter from southern California, these decimated “urchin barrens” formed due to an imbalance in the predator/prey relationship between sea urchins, sea otters, abalone, and spiny lobster in the kelp ecosystem. In turn, a heavy toll was taken on the abalone and spiny lobster fisheries.

  Giant kelp is a perennial alga that undergoes natural seasonal change in abundance and distribution due to biological interactions (such as diseases or over-grazing by sea-urchins), pollution, catastrophic storms, and oceanographic conditions, such as El Niño and La Niña (Leet et al. 2001). Warmer, nutrient-stressed El Niño conditions can deter growth and development of a canopy. During these conditions, less canopy is on the sea surface and more sunlight can penetrate to the understory macrophytes which can grow in spite of lower nutrients. In contrast, during the cold, nutrient-rich La Niña conditions, giant kelp grow an extensive, shady canopy that can inhibit some of the understory. During warm water years, both kelp and urchins die off but the urchins fare better than the kelp. Because sea urchins can survive warm water periods, when cool water returns, kelp is unable to reestablish even though water temperature is optimal.

- Bull Kelp—Bull kelp (*Nereocystis luetkeana*) is found interspersed within the giant kelp beds. Bull kelp is morphologically different from giant kelp but have a similar, although smaller, holdfast to attach to rocky substrate. It flourishes in wave-exposed areas of nutrient-rich cool water 3 to 20 m deep and 4° to 15°C (Leet et al. 2001). Bull kelp is an annual alga and can reach maximum growth rates of up to 13 cm/d under optimal environmental conditions of high light, nutrient, and water clarity.

  Bull kelp is primarily found adjacent to exposed shores along the Pacific coast of North America, ranging from Alaska to California. From Monterey Bay northward to Alaska, bull kelp is the dominant canopy kelp species in coastal waters. Along the central California coast, bull kelp and giant kelp often form mixed beds to form the extensive kelp forests characteristic of the SOCAL/Pt. Mugu Study Area.

Very little information is available concerning the percentage of bull kelp within the giant kelp forests in central and southern California. It is known that in southern California, bull kelp is generally restricted to areas that are unsuitable for giant kelp; this includes the inshore area, the surge zone, and the outer edges of the giant kelp beds; however, in central California, bull kelp is much more common in the kelp beds than in southern California. Bull kelp is able to withstand higher wave action than giant kelp because it is able to stretch more than 38% of its length before breaking. Thus, following heavy winter storms, bull kelp can become more abundant and sometimes replace much of the giant kelp in southern California (Leet et al. 2001).

Distribution—The locations of kelp beds in the SOCAL/Pt. Mugu Study Area have generally been consistent through time; however, the extent of these beds has varied considerably. Kelp is broadly distributed throughout California, with large concentrations found between Point Conception and Point Mugu and considerable amounts located around the Channel Islands (**Figure 2-16**) (NCCOS 2005). More specifically, in central California, and some of the Channel Islands, such as San Clemente Island, the steep bottom profile restricts kelp beds to a narrow band that parallels the shoreline (DoN 2002b; NCCOS 2005). In southern California and some of the Channel Islands, such as Santa Catalina and Santa Barbara Islands, the kelp beds can extend far offshore along broad and shallow rocky extensions and well stabilized sand bottoms which have less extreme relief than northern regions (NCCOS 2005). Around the Channel Islands the physical settings for kelp beds are more variable than mainland locations. The structure of kelp forests between and around the islands can depend on their exposure to oceanic swells, with the more protected waters providing for larger and more stable forests.

Harvest—The commercial harvest of kelp and other marine vegetation near the coastline has been a well-established industry in central and southern California. Kelp is harvested for use as a binder, emulsifier, and molding material in a broad range of products and as a food source for abalone in aquaculture (DoN 2002a). It was originally harvested as a source of potash for making gunpowder during World War One (WWI).[11] Along the California coast, giant kelp was first harvested during the early 1900s; since 1917, kelp harvesting has been managed by the CDFG under regulations of the Fish and Game Commission (Leet et al. 2001). Currently, giant kelp is harvested from Imperial Beach (**Figure 2-16**), near the U.S./Mexico border, to Monterey Bay, California. At one time, giant kelp was one of California's most valuable living marine resources and in the mid-1980s supported an industry valued at more than $40 million a year (Leet et al. 2001). **Figure 2-16** depicts current locations where kelp harvesting activities occur.

Protection—The kelp habitat around Santa Catalina Island is protected by several reserves and the California SWRCB has also designated stretches of the island's coastline as an Area of Special Biological Significance (ASBS). The kelp habitat associated with San Clemente Island is subject to both recreational and commercial harvest and is managed by the CDFG. The kelp associated with San Miguel Island, Santa Rosa Island, Santa Cruz Island, Anacapa Island, and Santa Barbara Island is federally protected under the CINMS Act (McArdle 1997).

Loss—Starting in the late 1970s, significant declines of California kelp beds have occurred, likely due to both natural and human-induced causes (NOAA 2007). In the 1950s and 1960s, the kelp forests off Point Loma, La Jolla, and along the Palos Verdes Peninsula (Los Angeles County) (**Figure 2-16**) began to deteriorate (Foster and Schiel 1985). Since 1957, California kelp beds have undergone a two-thirds reduction in standing biomass (Steneck et al. 2002). El Niño events and increasing SST have been linked with this decline (Dayton et al. 1992; Tegner et al. 1996). Surveys conducted in 1967, 1989, and 1999 showed that kelp canopy in the SOCAL/Pt. Mugu Study Area declined from 13,960 to 4,532 to 2,953 hectares (ha), respectively (Leet et al. 2001); however, in the past several years, the oceanographic environment in California waters has been conducive for kelp growth resulting in strong recruitment and a general increase in canopy size (NOAA 2007).

Restoration—Between 1967 and 1980, kelp restoration was conducted along the Palos Verdes Peninsula (Leet et al. 2001); however, El Niño events severely decreased the size of those beds (Leet et al. 2001). Many restoration attempts have failed but there have been two major successful projects, one along the Palos Verdes Peninsula and the second at the entrance to Mission Bay (Leet et al. 2001).

Assemblages Associated with Kelp—In the CINMS, nearly 1,000 species are known to inhabit kelp forests (Davis et al. 1994). **Table 2-8** lists the most common fish, macrofauna, and macroflora species that can be found associated with kelp beds in the SOCAL/Pt. Mugu Study Area. Many species of young-of-the-year and juvenile fishes, such as senoria (*Oxyjulius californica*) and surfperch (*Brachyistius frenatus*), use kelp beds for refuge (NCCOS 2005). Also, kelp beds typically support abundant macrofaunal assemblages with strong vertical zonation that rivals that of rocky intertidal habitats (Rodriguez et al. 2001). Due to the transitional location between cold and warm biogeographic provinces and diversity of substrates, the SOCAL/Pt. Mugu Study Area supports a wide variety of macrofauna that may be in excess of 5,000 species (NOAA 2007). In 1997, Chess and Hobson (1997), identified over 260 species of sponges, hydroids, sea fans, mollusks, echinoderms, and ascidians in the kelp beds along the mainland coastline of California. Kelp beds typically support abundant algal assemblages that form the understory and work to increase habitat heterogeneity. Stipate kelps such as boa kelp, palm kelps, and bladder weeds can rise one or more meters off the bottom like bushes. Below these, smaller low-growing algae grow up to less than 1 m in height. Below these, a turf layer can form with an underlying crust layer dominated by pink coralline algae (NOAA-NMS 2006).

Table 2-8. Conspicuous and common fish, macrofauna, and macroflora species that are found associated with kelp beds and rocky reef habitats in the SOCAL/Pt. Mugu Study Area (Thompson et al. 1993; Chess and Hobson 1997; Hobday et al. 2001; Rodriguez et al. 2001; Nielsen et al. 2006; Stephens et al. 2006).

Common Name	Species	Common Name	Species
Fishes			
Blue rockfish	*Sebastes mystinus*	Olive rockfish	*Sebastes serranoides*
Black rockfish	*Sebastes melanops*	Kelp rockfish	*Sebastes atrovirens*
Striped seaperch	*Embiotoca lateralis*	Gopher rockfish	*Sebastes carnatus*
Black-and-yellow rockfish	*Sebastes chrysomelas*	Painted greenling	*Oxylebius pictus*
Kelp greenling	*Hexagrammos decagrammus*	Lingcod	*Ophiodon elongatus*
Blacksmith	*Chromis punctipinnis*	Señorita	*Oxyjulis californica*
Halfmoon	*Medialuna californiensis*	Opaleye	*Girella nigricans*
Garibaldi	*Hypsypops rubicundus*	Kelp bass	*Paralabrax clathratus*
Black perch	*Embiotoca jacksoni*	California sheephead	*Semicossyphus pulcher*
Treefish	*Sebastes serriceps*	Ocean whitefish	*Caulolatilus princeps*
Giant sea bass	*Stereolepis gigas*	Rock wrasse	*Halichoeres semicinctus*
Zebraperch	*Hermosilla azurea*	Barred sand bass	*Paralabrax nebulifer*
Blue rockfish	*Sebastes mystinus*	Olive rockfish	*Sebastes serranoides*
Macrofauna			
Rock oyster	*Chama pellucida*	Mussels	*Mytilus edulis* and *M. californianus*
Green abalone	*Haliotis fulgens*	Pink abalone	*Haliotis corrugata*
Purple urchin	*Strongylocentratus purpuratus*	Red abalone	*Haliotis rufescens*
White abalone	*Haliotis sorensoni*	Red urchin	*Strongylocentratus franciscanus*
Threaded abalone	*Haliotis assimilis*	Diadematid urchin	*Centrostephanus coronatus*
Macroflora			
Stalked kelp	*Pterygophora californica*	Southern sea palm	*Eisenia arborea*
Broadleaf kelp	*Laminaria farlowii* and *L. setchellii*	Type of giant kelp	*Macrocystis integrifolia*
Feather boa kelp	*Egregia menziesii*	Elk kelp	*Pelagophycus porra*
Bladder chain kelp	*Cystoseira osmundacea*	Winged kelp	*Alaria marginata*
Brown algae	*Pterygophora californica* and *Desmarestia ligulata*	Sea palm	*Postelsia palmaeformis* Ruprecht

E. arborea is a particularly important species found in low intertidal to subtidal depths (10 m) 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 *M. pyrifera* (Edwards and Hernández-Carmona 2005). It has been suggested that *E. arborea* stores sufficient nitrogen in its tissues to survive extended periods of nutrient limitation such as those conditions experienced during El Niños (Hernández-Carmona et al. 2001). As a consequence, *E. arborea* exhibits greater survival and recruitment during and following an El Niño and it is possible for it to gain a competitive advantage over and temporarily exclude *M. pyrifera* (Edwards and Hernández-Carmona 2005).

2.7.4.2 Drift Kelp

Tides, currents, and storm-generated waves may cause some kelp to dislodge from its substrate to form floating kelp masses known as drift kelp. Kelp beds can provide significant quantities of drift kelp to adjacent habitats. Drift can be transported to the shore, remain as a floating kelp mass, or sink through the water column to the deep benthos. 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; Rodríguez 2003). The drift kelp that has been carried into nearshore areas provides important nutrients to beach and rocky intertidal communities, the floating kelp masses provide a source of food and shelter for fishes, and the small portion of the drift kelp that sinks to the benthos provides nutrients to organisms in deep benthic nutrient limited habitats. This drift kelp that sinks to the bottom of the continental shelf and slope and to the meso- and bathypelagic zones contributes significantly to the production in the deep sea (Rodriguez et al. 2001).

Historically, drift kelp has been largely overlooked as an important habitat in California waters. It has been largely unstudied until the 1980s when it was recognized as an important nursery area for two commercially important species, the white seabass and California halibut. Drift algae was identified as the primary settlement areas for white seabass and juvenile kelp bass during the summer months and an important secondary settlement area for California halibut, which settle primarily in certain protected areas of bays and estuaries (e.g. Malaga Cove north of the Palos Verdes Peninsula) (Allen and Pondella 2006).

2.7.4.3 Seagrass

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 runoff (Phillips and Meñez 1988). Seagrasses form structurally complex habitats that promotes biodiversity and species richness (Hovel and Regan 2007).

Despite its value, seagrass habitats have experienced significant amounts of loss. Worldwide, between the mid 1980s and the mid 1990s, 1,200,000 ha of seagrass habitat have been lost (Short et al. 2000; Green and Short 2003). In southern California, as little as 10% of the historical distribution of eelgrass

remains (Leet et al. 2001). The major reason for seagrass habitat loss in the SOCAL/Pt. Mugu Study Area is coastal modification. Coastal modifications can cause shading, resuspension of sediment (via dredging, recreational watercraft, ferries, tankers, freighters), and deposition of upland soils and oil spills may reduce the transmission of light to and/or bury seagrasses. Also, seagrass habitat fragmentation caused by natural processes like scouring by waves and currents and anthropogenic processes like boating (i.e., propeller scarring and vessel groundings), fishing, and coastal development breaks seagrass beds into small, isolated patches making it difficult for recovery (Hovel and Regan 2007).

In addition, an invasive alga, *Caulerpa taxifolia*, poses a substantial threat to the extensive eelgrass meadows in southern California. This alga causes ecological and economic devastation by overgrowing and eliminating native seaweeds, seagrasses, reefs, and other communities. In June 2000, *C. taxifolia* was discovered to occur in Agua Hedionda Lagoon, in Carlsbad, California and in Huntington Harbor, California (Williams and Grosholz 2002). *C. taxifolia* covered 3,500 square meters (m^2) at Agua Hedionda and was dispersed over 20,000 m^2 at Huntington Harbor (Jousson et al. 2000). Both of the locations, Agua Hedionda and Huntington Harbor, which have been affected, are labeled in **Figure 2-17**; however, after an extensive eradication and surveillance effort by the southern California *Caulerpa* Action Team, there has been no *C. taxifolia* found in Agua Hedionda Lagoon since September 11, 2002, and similar results were found for Huntington Harbor (Woodfield and Merkel 2004).

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). In California, eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix* spp.) are the dominant native seagrasses (den Hartog 1970; CalEPPC 1999). Eelgrass grows in shallow, subtidal, or intertidal unconsolidated sediments and surfgrass grows on wave-beaten rocky shores (den Hartog 1970). A few locations of seagrass beds known for eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix* spp.) have been mapped in **Figure 2-17**; however, the areas where seagrasses may be expected to occur (i.e., in protected areas of suitable depth [<20 m]) within the SOCAL/Pt. Mugu Study Area are designated as potential seagrass range.

- 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. 1980b; Airamé et al. 2003). Eelgrass is commonly found in bays and estuaries of soft sediment at intertidal and subtidal depths (up to approximately 20 m) and in semi-sheltered areas with moderate currents (Airamé et al. 2003; Coyer et al. 2008). 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 2002c). 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; Zimmerman 2003).

  Within the SOCAL/Pt. Mugu Study Area, eelgrass has been recorded at 37 sites in the Channel Islands over the past 25 yr (Coyer et al. 2008). The largest beds of eelgrass in the Channel Islands occur at Smugglers Cove, Canada del Agua, and Prisoners Harbor on Santa Cruz Island and at Bechers Bay on Santa Rosa Island (NOAA 2007). In 2003, Green and Short (2003) reported that eelgrass covered approximately 440 ha in San Diego Bay. In 2007, Hovel and Regan (2007) reported that eelgrass covered more than 650 ha in San Diego Bay. In San Diego Bay, eelgrass serves as a habitat for a variety of invertebrate and vertebrate species such as juvenile giant kelp fish, barred and spotted sand bass, calico bass, and spiny lobster (Hovel and Regan 2007). Eelgrass beds in San Diego Bay also provide important habitat for migrating waterfowl and wading birds, and a substrate for the laying of the Pacific herring (*Clupea harengus pallasi*) roe (Green and Short 2003).

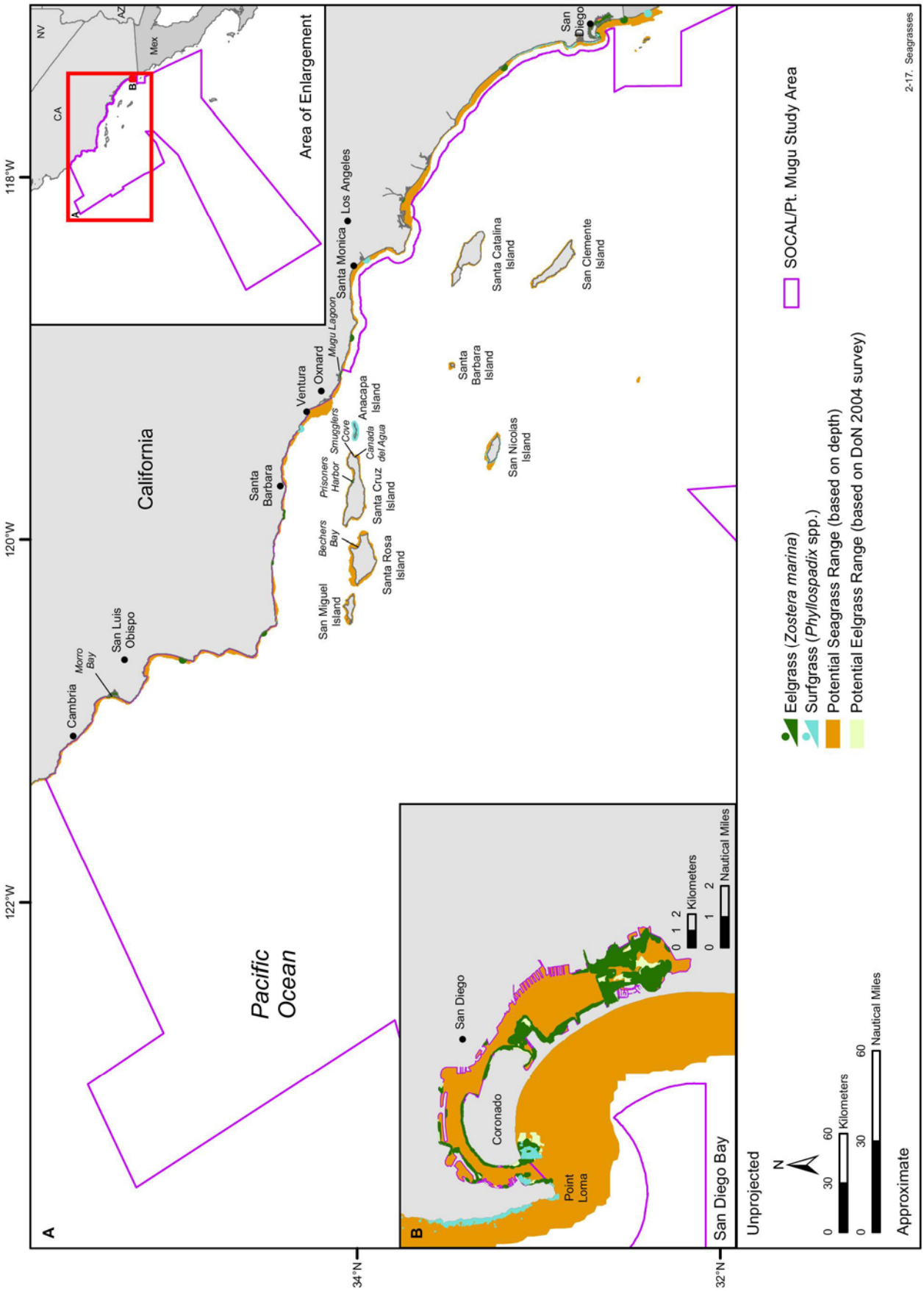

Figure 2-17. Seagrass habitat and potential seagrass range (based on historic seagrass cover and the 20 m depth profile) in the SOCAL/Pt. Mugu Study Area. Source data: NOS (2001), TerraLogic GIS and Copps (2004), NAVAIR Environmental (2006), and NOS (2006). Source maps (scanned): DoN (2000), DoN (2004), and UNEP-WCMC (2008).

It was documented by Coyer et al. that out of 37 sites of identified eelgrass habitats in the Channel Islands over the past 25 yr, 7 sites experienced natural extinction and only 2 of the sites experienced colonization. Aerial cover was constant for most of the eelgrass beds and ranged from <0.01 to >10 ha (Coyer et al. 2008). The Channel Island eelgrass populations are important to the SOCAL/Pt. Mugu Study Area because mainland populations along central and southern California have been severely depleted by coastal development (Coyer et al. 2008). In San Diego Bay and elsewhere, eelgrass is damaged from moorings, anchors, coastal construction, boat propellers, and jet skis (Hovel and Regan 2007). Nixon et al. (2002) demonstrated that loss of an eelgrass bed substantially increased the shoreline erosion of adjacent beaches. The southern California Eelgrass Mitigation Policy of 1991 currently protects the eelgrass beds in southern California (Leet et al. 2001).

- Asian eelgrass—Asian eelgrass (*Zostera asiatica*) has been a recent discovery in three subtidal regions along the southern and central California coasts. They are known to form underwater forests up to 3 m in height. Asian eelgrass is currently not listed as an invasive species (CalEPPC 1999). Little is known about its current status and additional work is necessary to unveil the habitat value of this species in this region (Green and Short 2003). A wide-leaved eelgrass leaf morphology and a narrow-leaved eelgrass leaf morphology has been observed among the Channel Islands. The wide-leaved form has been reported on Santa Cruz Island, Santa Rosa Island, and San Nicolas Island. The narrow-leaved form has been reported on San Clemente Island and Santa Catalina Island. This narrow-leaved form has been observed on the islands and the mainland and it has been identified as *Z. marina*, whereas the wide-leaved form has been regarded as *Z. marina 'latifolia'*, *Z. pacifica*, or *Z. asiatica* (Coyer et al. 2008).

- Surfgrass—Surfgrass (*Phyllospadix* spp.) is the dominant species in the rocky subtidal and intertidal zones of central and southern California where it has adapted to life in high wave exposure environments by clinging to rocky surfaces (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. 1980b). 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 SOCAL/Pt. Mugu Study Area (**Figure 2-17**). *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). *Phyllospadix torreyi* provides important habitat for spiny lobsters (*Panulirus interruptus*) during their larval pelagic stage (Green and Short 2003) and for deep-sea benthic fauna where it has been found in the macrophyte detritus layers of submarine canyons in southern and central California (Ramírez-García et al. 2002).

  Over the course of a study, *Phyllospadix* was observed to be able to withstand the grazing pressure of purple urchin populations, which appear unable to graze it. *Phyllospadix* was also able to be competitively dominant to macroalgal species by producing anaerobic conditions in the root systems that are lethal to algal holdfast systems. However, *Phyllospadix* is unable to become dominant in the intertidal zone because of its susceptibility to desiccation during daytime low-tide periods (Littler 1980).

- Widgeon grass—Widgeon grass (*Rupia maritima*) is another native seagrass that occurs from Alaska to Mexico in many brackish water coastal lagoons (Kantrud 1991; CalEPPC 1999). It has worldwide importance as food for waterfowl; waterfowl, wading birds, and shorebirds eat the leaves, rhizomes, and seeds. Widgeon grass inhabits warm, calm, relatively unpolluted, and well-lit waters up to 2 m in depth (Kantrud 1991).

- Shoal grass—Shoal grass (*Halodule wrightii*) is native to the Pacific coast (CalEPPC 1999); however, it is more common in the Gulf of California and in the warm waters associated with San Diego Bay. During the 1997, 1998 El Niño, waters in the San Diego Bay warmed sufficiently to support a significant amount of shoal grass habitat. In general, during high stress conditions, eelgrass habitats decline and make way for the colonization of shoal grass.

2.7.4.4 Unvegetated Shallows

Unvegetated subtidal habitats are an important microhabitat found in the California waters; they can range from the more shallow areas of the subtidal to the intertidal zone. They harbor extensive algal mats, generally the dense red alga *Gracilaria verrucosa*, interspersed with areas of exposed sediment (Adams et al. 2004). The algal mats also include other red algae species including *Hypnea valentiae* and *Griffithsia pacifica* (DoN 2000). These mats drift just above the sediments or are loosely anchored to the sediments and can get up to 0.3 to 0.6 m thick during warmer months. These mats provide refuge from predators and forage areas for many species of motile invertebrates and fishes (Adams et al. 2004). In addition, they provide food for fish (e.g., California killifish), invertebrates (e.g., crabs, isopods, and mollusks), and some aquatic birds (Leet et al. 2001). An important commercial and recreational fish, the juvenile California halibut, is restricted primarily to these unvegetated shallow subtidal environments (Adams et al. 2004).

2.7.4.5 Live/Hardbottom

Rocky substrate can provide support to extensive communities of marine plants and animals that require attachment for survival. For example, subtidal rocky substrates provide attachment sites for macroflora, which in turn provide habitat for a diverse ecosystem of fish and invertebrates including seaweeds, sponges, octopus, feather stars, and the commercially valuable spiny lobster and abalone (Chess and Hobson 1997). These areas can also be termed live bottoms or live/hardbottom habitat (**Figures 2-18**). 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). Within the SOCAL/Pt. Mugu Study Area, rocky substrates can be most commonly found along the mainland shelf inshore near rocky headlands, along edges of submarine canyons, and at the shelf break. Along the mainland shelf rocky outcrops rarely occur in deeper water (i.e., Santa Monica Bay and San Pedro Bay); however, rocky substrate is more common along the shelf of the Channel Islands and at some offshore banks where the supply of sand and silt is minimal (Schiff et al. 2000). In the SOCAL/Pt. Mugu Study Area, the marine benthic invertebrate assemblages are extremely diverse and include representatives of nearly all phyla. Several locations of deep rocky substrate, rock, rocky reef monitoring sites, and foul ground are depicted in **Figure 2-18** where live/hardbottom assemblages can be expected to occur within the SOCAL/Pt. Mugu Study Area.

2.7.4.5.1 Rocky reef

The SOCAL/Pt. Mugu Study Area shoreline can be characterized as having steep, often rocky margins that contain ecologically important and diverse habitats. Nearshore rocky reefs in the Study Area are usually characterized by a heterogeneous hard substrate rich in crevices and other shelter, and a dense cover of erect macroalgae (CDFG 2006). Rocky reefs can be comprised of a variety of substrates including sedimentary bedrock, boulders, or smaller rocks, such as cobble or gravel, coral skeletons, volcanic upwellings, submarine canyons, and extensions of rocky coastlines (CDFG 2006). The SOCAL/Pt. Mugu Study Area has a significant amount of rocky reef habitat located primarily along the coastlines and headlands of the Channel Islands (**Figure 2-18**; NMFS-NWR 2005). Most often, rocky reef habitats in the SOCAL/Pt. Mugu Study Area generally coincide with kelp forest communities and the associated invertebrate assemblages. Thereby, the common flora and fauna that occur on rocky reef habitats are similar to those found in kelp habitats (**Table 2-8**).

Rocky reef communities, comprised of animals and plants, colonize the substrate and co-exist in a competitive manner. These communities are subjected to environmental factors including physical forcing (e.g., wave action, currents, tides, thermal changes, illumination) and the types of seafloor substrate (e.g., rock quality gradient, cavernous nature) (Bellan 1985). Fish species richness, fish abundances, fish condition, and reproductive potential in the waters off of California have been connected to habitat structure (García-Rubies and Macpherson 1995; Guidetti 2000; Lloret and Planes 2003). Rocky reefs serve as essential spawning and nursery habitats for commercial and recreational marine species (Lloret and Planes 2003). Rocky substrates also are important habitats for some fishery species in deepwater

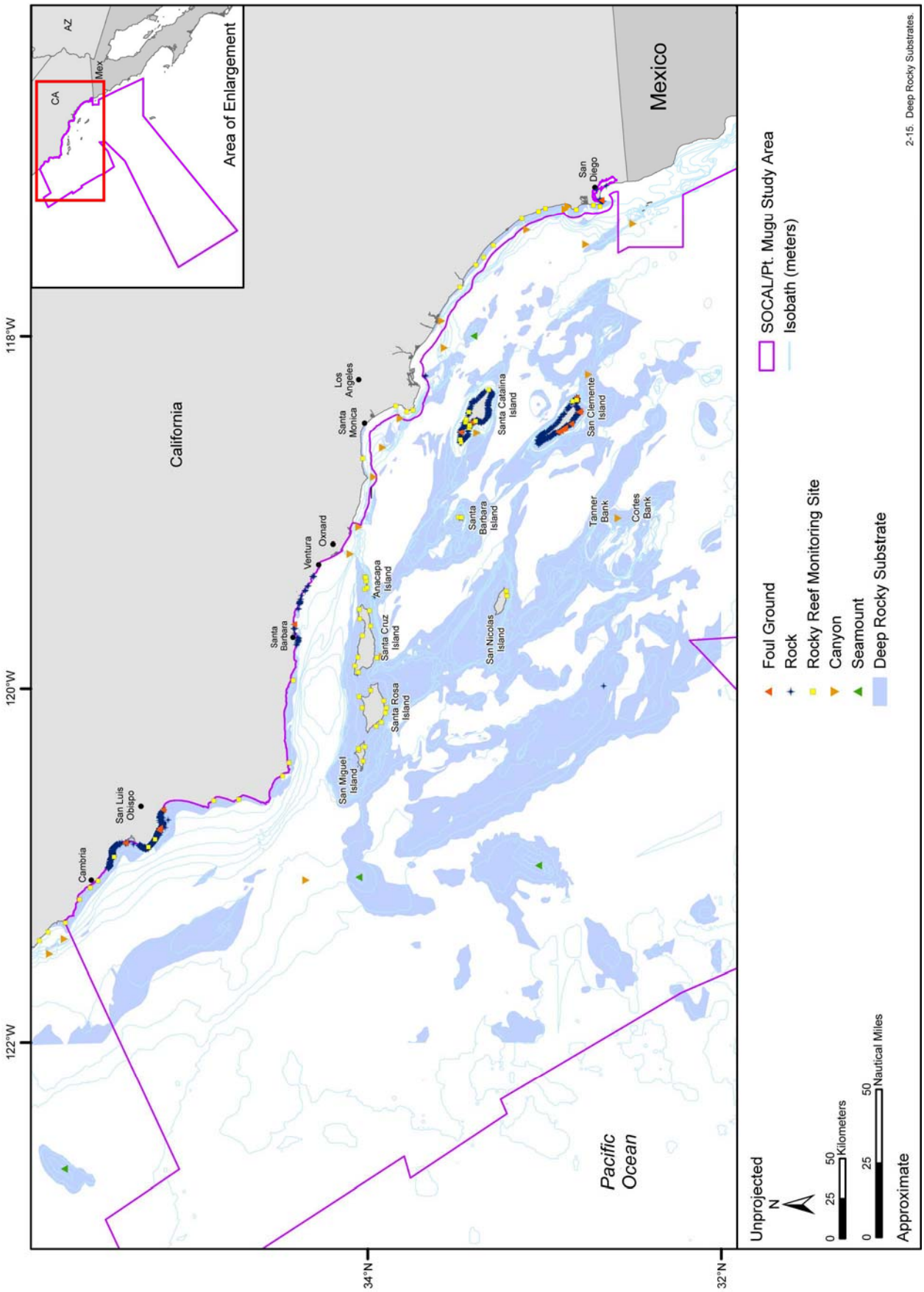

Figure 2-18. Deep rocky substrate habitat in the SOCAL/Pt. Mugu Study Area. Source data: Smith and Sandwell (1997), CSU (2001), Veridian Corporation (2001), NOAA (2002), and NGA (2007). Source Information: CDFG (2006).

and submarine canyons (Lloret and Planes 2003). Numerous commercially, recreationally, and ecologically important species use rocky substrates which may indicate their importance as essential fish habitats (Lloret and Planes 2003).

In the SOCAL/Pt. Mugu Study Area, underwater surveys (maximum depth of 20 m) of nearshore rocky reef communities were conducted at 88 sites (**Figure 2-18**) during the summer and fall of 2004 for a project referred to as CRANE (Cooperative Research and Assessment of Nearshore Ecosystems) (CDFG 2006). The project was a collaborative effort among scientists at six institutions and involved 113 separate days of observations by 71 diver-biologists. Fish and invertebrate species were quantified at each site to describe their geographical distributions and measure similarity among site assemblages. Most of the rocky reef habitat sites supported giant kelp beds. Because the sites were distributed throughout the Study Area, the oceanographic conditions differed widely between the sites located north of Point Conception, those located south of Point Conception, those located nearshore of the Channel Islands, and those located nearshore of the mainland. At all sites, over 225,000 fishes were observed that represented 83 distinct species, most of which were the rockfishes (14 species) followed by the surfperches (10 species) and sculpins (6 species). At all sites, a standardized list of 23 sessile invertebrate taxa and 37 motile invertebrate taxa were surveyed, among which were abalones, sea urchins, lobsters, and sea cucumbers. Purple, red, and crowned sea urchins were the most abundant motile invertebrate observed, accounting for over 75% of all invertebrates counted at all sites. The giant-spined sea star was the most ubiquitous macroinvertebrate with a 95% frequency of occurrence among all sites. At all sites, bladder chain kelp was the most frequently occurring habitat-forming kelp species, having an 89% frequency of occurrence followed by giant kelp having a 73% frequency of occurrence. Other conspicuous invertebrates that were common at many sites included bat star, sunburst anemone, wavy top snail, warty sea cucumber, red gorgonian, orange puffball sponge, sunflower star, and Kellet's whelk (CDFG 2006).

2.7.4.6 Benthic Macrophytes

California's benthic macrophytes are represented by over 700 varieties of seaweeds, coralline algae, brown algae, green algae, and seagrasses (Leet et al. 2001). In the SOCAL/Pt. Mugu Study Area, benthic macrophytes are designated to specific ecological groups based upon substrate type (Murray and Bray 1993). Benthic macrophytes are intensely zone specific and individual species dominate a specific substrate at a specific depth profile. The most common macrophytes found on sandy substrates at all depths are the turf algae; the most common turf algae include rhodophytes (e.g., *Tiffaniella snyderae*, *Polysiphonia pacifica*, *Hypnea valentiae*) and a common chlorophyte, *Chaetomorpha linum*. In the SOCAL/Pt. Mugu Study Area, the chlorophyte *Enteromorpha* spp. is the most common species found in the intertidal zone; it is found in both muddy and salt panne habitats and is a tolerant species resistant to desiccation and hypersaline environments. Rocky substrate at shallow subtidal and intertidal depths harbors the most abundant and diverse species of all the zones. This zone contains rhodophytes (e.g., *Aglaothanmion cordatum*), chlorophytes (e.g., *Ulva expansa* and *Cladophora* spp.), phaeophytes (e.g., *Dictyota flabellata* and *Colpomenia sinuosa*), and many epiphytic species (e.g., *Antithamnion* spp., *Polysiphonia* spp., and *Ceramium eatonianum*). The microalgae found in the deep subtidal are generally epiphytic and include rhodophytes (e.g., *A. cordatum*, *Griffithsia pacifica*, *C. eatonianum*, and *Dasya* spp.) and a common chlorophyte, *Cladophora* spp. (Murray and Bray 1993). The most conspicuous benthic communities are kelp beds; they form the fundamental element for many important ecosystems in central and southern California (Rodriguez et al. 2001).

2.7.4.7 Benthic Macrofauna

In general, the distribution of invertebrate assemblages in central and southern California 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); however, the Channel Islands are situated in a transitional location between cold and warm biogeographic provinces and thereby, support an exceptionally wide variety (may well be in excess of 5,000 species) of macrofauna (NOAA 2007).

The benthic macrofauna associated with rocky reef habitats in central and southern California are located synonymously with kelp and other benthic macrophytes. This habitat is characterized by continuous bottom surge produced by passing swells. Strong vertical zonation is present and rivals that of rocky intertidal habitats (Rodriguez et al. 2001). Over 260 species of sponges, hydroids, sea fans, mollusks, echinoderms, and ascidians have been identified in the nearshore subtidal rocky reefs of central and southern California (Chess and Hobson 1997). In general, the biomass and abundance of epifauna decreases from the top of a rocky outcropping to its base. Rock oysters (*Chama pellucida*), mussels (*Mytilus edulis* and *M. californianus*), and green and pink abalone (*Haliotis fulgens* and *H. corrugata*) dominate the tops. Deeper, the substrate is covered by patches of calcareous bryozoans, gorgonians, stony corals, purple sea urchins (*Strongylocentratus purpuratus*), rock scallops, and red and white abalone (*Haliotis rufescens* and *H. sorensoni*). The white abalone is classified as a federal endangered species; it usually occurs at depths from 20 to 60 m although some have been found in water as shallow as 5 m (Hobday et al. 2001). Near the bottom, there are relatively few species found and populations are sparse. The most conspicuous organisms are stony corals, gorgonians, sponges, barnacles, red urchins (*Strongylocentratus franciscanus*), and the threaded abalones (*Haliotis assimilis*) (Chess and Hobson 1997). According to Thompson et al. (1993), at Santa Catalina Island, red, purple, and diadematid urchins (*Centrostephanus coronatus*) are common but abundance varies with depth. Purple urchins are most common in depths less than 5 m, red urchins dominate at intermediate depths, and diadematid urchins are the most numerous species below 10 m.

2.7.4.8 Corals

Within the Study Area, corals are located in shallow-water areas on hardbottom habitats of the inner continental shelf as well as in deeper waters along the continental shelf edge, on island shelves and slopes, the continental slope, submerged banks, submarine canyons, and seamounts (Bythell 1986; Lissner 1988; Thompson et al. 1993; Chess and Hobson 1997; Etnoyer and Morgan 2003; Roberts and Hirshfield 2004; TerraLogic GIS 2004; Etnoyer and Morgan; Whitmire and Clarke 2007). Live/hardbottom substrates, as depicted in **Figure 2-18**, are potential sites for coral colonization considering that they generally offer suitable substrate upon which coral spat may settle and form colonies (see **Section 2.7.4.5.1** for more formation on rocky reefs and **Section 2.7.5.1** for more information on deep water rocky substrate).

Corals of the Study Area include anthozoans and hydrozoans (or hydrocorals); anthozoans include hexacorals and octocorals. Hexacorals are represented by scleractinians (stony corals), antipatharians (black corals), and corallimorpharians (coral-like organisms lacking a calcium carbonate skeleton); octocorals include soft corals and gorgonians (e.g., sea fans). The following discussion will emphasize stony corals and deep-sea corals of the Study Area (deep-sea corals occur in water depths exceeding 200 m) (Etnoyer and Morgan 2005). Most of the habitat-forming (structure-forming) deep-sea corals are anthozoans and hydrozoans (Etnoyer and Morgan 2003; Etnoyer and Morgan 2005; Tissot et al. 2006; Whitmire and Clarke 2007).

- Stony Corals—Stony corals of the Study Area (**Figure 2-19**) and vicinity are typically ahermatypic (non-reef building species) and azooxanthellate (the animal tissue of the corals does not host algal symbionts also known as zooxanthellae) (Bythell 1986; Cairns 1994). Reef building stony corals are characteristic of tropical western margins of the Pacific, Atlantic, and Indian oceans (Veron 2000); true coral reefs closest to the Study Area are located approximately 100 km north of Isla Cedros, Mexico (28°22'N; 115°15'W) on the Pacific side of the Baja California peninsula and at the northern and southern ends of the Gulf of California (Spalding et al. 2001). While there are no true coral reefs in the Study Area, stony corals that can host zooxanthellae occur in shallow water regions of the Study Area (e.g., *Astrangia haimei*; *Dendrophyllia* spp.) (Seapy and Littler 1993b; Cairns 1994; Etnoyer and Morgan 2005). The majority of stony corals of the Study Area are, however, azooxantellate and obtain energy from detritus, zooplankton, and nekton they capture from the surrounding water (Cairns 1994; Roberts and Hirshfield 2004). Since azooxanthellate corals do not depend on sunlight and a symbiotic existence with zooxanthellae, they can be found in water depths exceeding 6,000 m (Lissner 1988; Cairns 1994; Roberts and Hirshfield 2004; Etnoyer and Morgan 2005). Even though corals of the Study Area are classified as non-reef building, recent surveys of

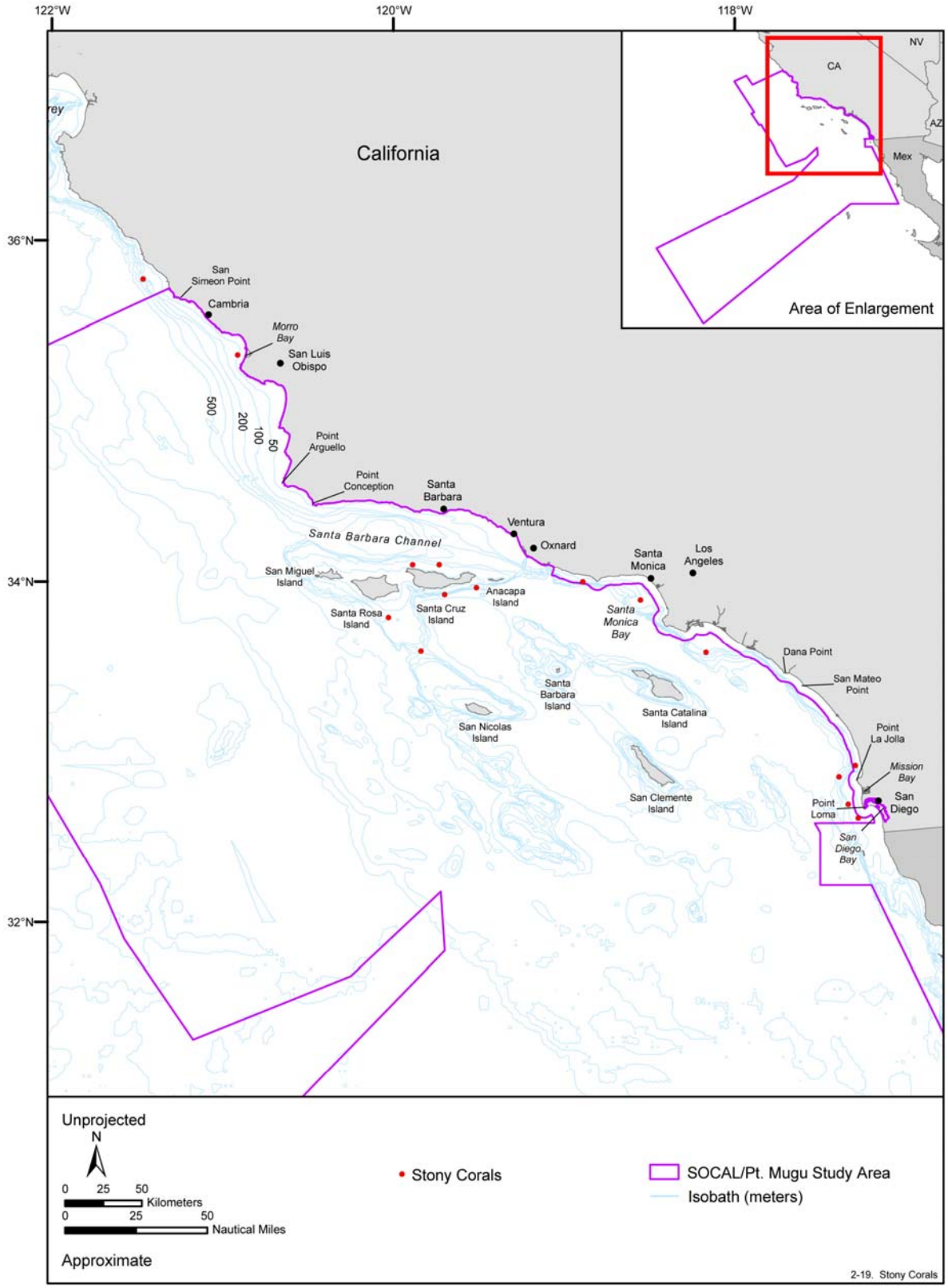

Figure 2-19. Locations of stony corals in the SOCAL/Pt. Mugu Study Area. Source data: Smith and Sandwell (1997), NOAA (2002), Whitmire and Clarke (2007), and NOAA/NWFSC/FRAM/AT&SML (2008).

deep-water areas of the Atlantic and Pacific oceans revealed that deep-ocean corals can form large reefs, be structure-forming, and be associated with a number of other species (Roberts and Hirshfield 2004; Tissot et al. 2006; Whitmire and Clarke 2007). Further, invertebrates other than corals can also form three-dimensional structures. In 2002, Tissot et al. (2006) observed a number of structure-forming invertebrates (i.e., that provide vertical structure) on rocky banks within the cowcod conservation areas located south of the Channel Islands. These invertebrates included black corals, gorgonians, crinoids, basket stars, brittle stars, brachiopods, sea urchins, anemones, and sponges. Corals and sponges of the cowcod conservation areas were the largest structure-forming benthic invertebrates. Tissot et al. (2006) also found that black corals were associated with the highest numbers of other organisms including (in decreasing order of observation frequency) crinoids, sponges, crabs, fishes, basket stars, brittle stars, anemones, algae, and salps. Fishes were most commonly seen associated with black corals (including cowcod, *Sebastes levis*, bank rockfish, *S. rufus*, swordspine rockfish, *S. ensifer*, shortbelly rockfish, *S. jordani*, pinkrose rockfish, *S. simulator*, and individuals of the rockfish subgenus *Sebastomus*) (Tissot et al. 2006).

Zoogeographically, stony corals of the Study Area are located within the Oregon and California Provinces (Cairns 1994). The Oregon Province is contained within the cold temperate region and extends from Dixon Entrance (international boundary between Alaska and British Columbia) to Point Conception, California (34°26'52.84"N, 120°28'19.66"W) (Briggs 1974). The California Province is found within the warm temperate northeastern Pacific region (Seapy and Littler 1980; Cairns 1994); the boundaries are Point Conception, California to the north and Isla Magdalena, Mexico (24°48'N; 112°17'W) to the south (Cairns 1994). The Oregon Province contains 16 scleractinian species, 13 of which are probably found in the Study Area and 3 of which are endemic: *Javania californica*, *Paracyathus montereyensis*, and *Oculina profunda* (Cairns 1994) (**Table 2-9**). There are 17 known species of stony corals within the California Province, all of which are probably found in the Study Area (**Table 2-9**). Two of the coral species, *Nomlandia californica* and *Dendrophyllia californica*, are endemic to the California Province. The California Province is a transition zone for stony corals of the northeastern Pacific from the tropical to the temperate zoogeographic regions and contains both eurythermic (that can tolerate a wide range of temperature) tropical and eurythermic temperate species (Cairns 1994).

The orange cup coral (*Balanophyllia elegans*) is a common stony coral in hardbottom habitats of the shallow subtidal and sublittoral zones of the Study Area and vicinity (McConnaughey and McConnaughey 1985; Bythell 1986; Kushner et al. 1999). Although most stony coral species of the Study Area are found in water depths greater than 45 m (Bythell 1986) (**Table 2-9**), orange cup corals are found from the intertidal zone to depths of 500 m (McConnaughey and McConnaughey 1985; Hellberg and Taylor 2002). Common stony corals of the shallow rocky insular shelf of Santa Catalina Island and Channel Islands are *Paracyanthus stearnsii, B. elegans,* and *Astrangia lajollensis* (Cairns 1994; Chess and Hobson 1997; Kushner et al. 1999).

Many of the stony corals found in the Study Area form solitary polyps the skeleton of which is approximately 1 to 2 cm in height and diameter (Bythell 1986). The colonial coral *Madrepora oculata* occurs within the Study Area but is rare (Cairns 1994). Individual branching colonies of stony corals found in the Study Area are relatively small and consist of tens of polyps. Yet, clusters of these stony coral colonies can produce extensive live cover on hard substrates (e.g., the Channel Islands) (Bythell 1986). Further, *Lophelia pertusa* which is relatively abundant in the Study Area (Whitmire and Clarke 2007), can build large yet delicate reef structures that support diverse benthic organisms and fish (Rogers 1999). Sizes of the deep-water *Lophelia* reefs found in the Atlantic Ocean range from 50 m to 4 km across and 35 to 165 m in height. The growth rate of *L. pertusa* is slow and ranges from 4 to 25 mm/yr. Hence, large reefs made of *Lophelia* can be several thousand years old (Rogers 1999). Recent observations of fish aggregation on such deep-water reefs suggest that *Lophelia* reefs may function as breeding and feeding areas (Roberts and Hirshfield 2004). Other significant structure-forming corals in the Study Area include *Dendrophyllia oldroydae* (California Province) and *Oculina profunda* (Oregon Province) (Whitmire and Clarke 2007).

Table 2-9. Azooxanthellate stony corals of the Oregon and California Provinces: list of species, depth of occurrence, and regional distribution (Seapy and Littler 1993b; Cairns 1994) [* = endemic]**.**

Species	Depth (m)	Regional Distribution
Oregon Province		
Fungiacyathus marenzelleri	2,999 to 6,328	Off California and Washington; Aleutian Trench
Leptopenus discus	3,599 to 5,000	Off Washington; Aleutian Trench
Astrangia haimei (=A. lajollaensis)	1 to 53	From off Peru to Monterey Bay, California
*Oculina profunda**	119 to 742	Off the Santa Lucia Range and Bodega Bay, California
Caryophyllia arnoldi	40 to 656	From San Diego, California to Prince William Sound, Gulf of Alaska (including Channel Islands and surrounding Banks)
Caryophyllia alaskensis	102 to 399	Strait of Georgia, British Columbia; Alexander Archipelago, Gulf of Alaska, Aleutian Islands
Labyrinthocyathus quaylei	37 to 293	Point Loma, San Diego to Cordell Bank (including Channel Islands)
Paracyathus stearnsii	20 to 134	Baja California to Queen Charlotte Islands, British Columbia
Paracyathus montereyensis	75 to 146	Off Monterey, California and Oregon Dunes, Oregon.
Coenocyathus bowersi	9 to 302	Baja California to Monterey Bay, California (including Channel Islands and, Cortez Bank)
Desmophyllum dianthus	33 to 1,097	Baja California (Isa Guadalupe); San Diego, California to Cobb Seamount, Washington (including Channel Islands, Cordell Bank, and Fieberling Seamount); Vancouver Island, British Columbia
Lophelia pertusa	82 to 488	Offshore seamounts and islands: off Baja California (Isla Guadalupe); off La Jolla (Bird Rock), California; Channel Islands; and Cobb Seamount, Washington.
Javania cailleti	1,280 to 1,371	Off British Columbia
*Javania californica**	62 to 170	Monterey Bay and Cordell Bank, California
*Polymyces montereyensis**	69 to 212	Channel Islands, Cortez and Tanner Banks to Monterey Bay, California
Balanophyllia elegans	0 to 293	Baja California (Sacramento Reef) to Snipe Bay, Alaska (including Cortez, Tanner, and Cordell Banks, California, and Queen Charlotte Islands and Vancouver Island, British Columbia)

Table 2-9 (*continued*). Azooxanthellate stony corals of the Oregon and California Provinces: list of species, depth of occurrence, and regional distribution (Seapy and Littler 1993b; Cairns 1994) [* = endemic]**.**

Species	Depth (m)	Regional Distribution
California Province		
Fungiacyathus marenzelleri	2,999 to 6,328	Off Pacific coast of Baja California
Leptopenus discus	3,599 to 5,000	Off Baja California
Astrangia haimei (=A. lajollaensis)	1 to 53	From Peru to Monterey, California; including Channel Islands
Madrepora oculata	84 to 488	Anacapa Island, California
Caryophyllia arnoldi	40 to 656	San Diego and Channel Islands, California
Labyrinthocyathus quaylei	37 to 293	San Diego and Channel Islands, California
Crispatotrochus foxi	82 to 274	San Miguel and Santa Catalina Islands, California
Paracyathus stearnsii	20 to 134	Baja California
Coenocyathus bowersi	9 to 302	Baja California to Channel Islands, California
*Nomlandia californica**	82	San Miguel Island, California
Desmophyllum dianthus	33 to 1,097	Baja California; San Diego and Channel Islands, California
Lophelia pertusa	82 to 488	Baja California; off La Jolla and Channel Islands, California
Polymyces montereyensis	69 to 212	Channel Islands, California
Balanophyllia elegans	0 to 293	San Diego, Cortez Bank, Tanner Bank, and Cordell Bank, California
Balanophyllia cedrosensis	66 to 119	Baja California Sur
Dendrophyllia oldroydae	99 to 366	Baja California to Redondo, California
*Dendrophyllia californica**	42 to 93	Baja California

Within the California Province and 20 km west of Point Conception (Santa Maria Basin), Hardin et al. (1994) documented *L. pertusa* and *D. dianthus* growing on hardbottom substrates amongst speciose epifauna in water depths ranging from 105 to 212 m. The most common anthozoans on low relief hard substrates (<0.5 m) were *Paracyathus stearnsii* (brown cup coral), *Caryophyllia* spp. (cup coral), *Lophogorgia chilensis* (red gorgonian), and *Metridium giganteum* (giant plumose anemone). Together they represented 4.2% cover. On high relief substrates (>1 m), common anthozoans included *Desmophyllum cristagalli* (stony coral), *L. pertusa*, *Amphianthus californicus* (anemone), *Stomphia didemon* (apple anemone), and *M. giganteum* which totaled 11.4% cover (Hardin et al. 1994).

- Black Corals and Corallimorpharians—In addition to stony corals, hexacorals of the Study Area include black corals (antipatharians) and corallimorpharians. Species of black corals of the SCB include *Antipathes* spp., *Bathypathes* spp., and *Parantipathes* spp. (Etnoyer and Morgan 2003; Tissot et al. 2006; Whitmire and Clarke 2007). The Christmas tree coral (*Antipathes dendrochristos*) is a new species of antipatharian recently discovered in the SCB (33º57.914'N, 119º29.579'W) at 96 m (Opresko 2005) (**Figure 2-20**). They were observed within a 96 to 200 m water depth range. Colonies of *A. dendrochristos* resemble pink, white, and red flocked Christmas trees, although this antipatharian can also be white, orange/gold, pinkish-orange, pink, red, and reddish-brown (Opresko 2005). Colonies of *A. dendrochristos* are structure-forming and associated with many other species (Tissot et al. 2006). Corallimorpharians of the Study Area include *Corallimorphus denhartogi* which

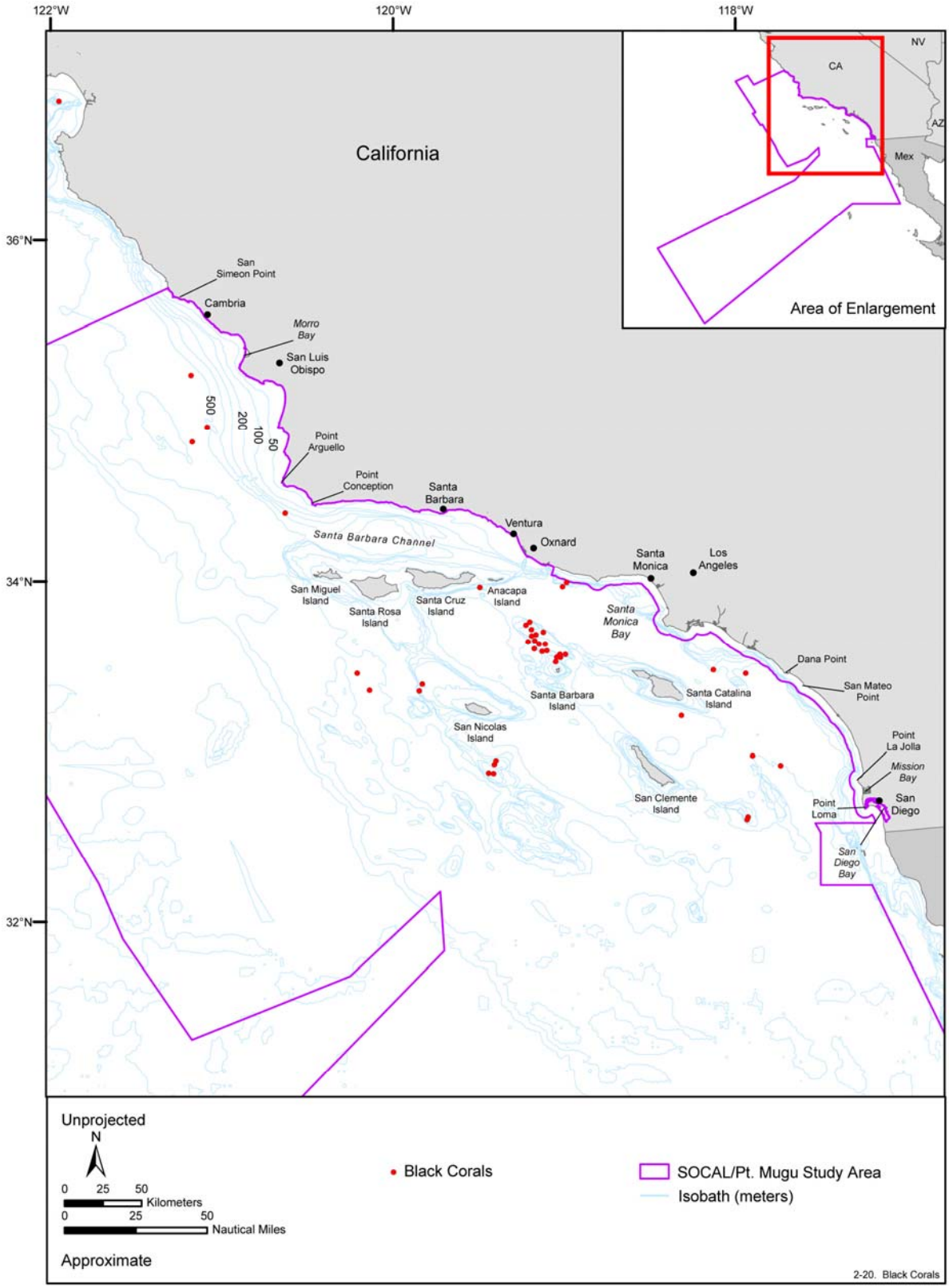

Figure 2-20. Locations of black corals in the SOCAL/Pt. Mugu Study Area. Source data: Smith and Sandwell (1997), NOAA (2002), Tissot et al. (2006), Whitmire and Clarke (2007), and NOAA/NWFSC/ FRAM/AT&SML (2008).

occurs in water depths ranging from 2,550 to 4,300 m and *C. pilatus* found in water depths of 198 to 900 m (Fautin et al. 2002). *Corynactis californica* is a common corallimorpharian found on hard substrates in shallow waters of Santa Catalina Island (McConnaughey and McConnaughey 1985). Tissot et al. (2006) found the black coral *A. dendrochristos* in water depths averaging 183 m on rocky banks within the cowcod conservation areas (**Figure 2-20**). There was an average of 10 black coral colonies per hectare. The height of black corals ranged from 10 to 250 cm and averaged 33.6 cm (±1.9 Standard Error [SE]) (Tissot et al. 2006).

- Octocorals—A common octocoral on rocky shores of the Study Area is the red soft coral *Gersemia rubiformis* (McConnaughey and McConnaughey 1985). In shallow waters (5 to 18 m water depth) off Santa Catalina Island and the Channel Islands, other common octocorals are *Muricea californica*, *M. fruticosa,* and *Lophogorgia chiliensis* (red gorgonian) (Engle 1994; Chess and Hobson 1997; Kushner et al. 1999). Tissot et al. (2006) documented gorgonians (unidentified) on rocky banks within the cowcod conservation areas (located off Los Angeles; **Figure 2-21**) in water depths ranging from 144 to 163 m. The height of gorgonians ranged from 10 to 40 cm (average height was 22 cm). Unlike black corals, gorgonians of the cowcod conservations areas were not associated with other organisms (such as crinoids, sponges, fishes, crabs, basket stars, brittle stars, sea stars, anemones, algae or salps) (Tissot et al. 2006). In the Pt. Mugu OPAREA, the NOAA, NMFS, Alaska Fisheries Science Center mapped gorgonaceans including the genus *Swiftia* as well as other anthozoans (pennatulaceans and alcyonaceans) (1984 to 2001, Slope and Triennial trawl surveys) (**Figures 2-21 and 2-22**) (TerraLogic GIS 2004). *Swiftia* was found in a 500 m water depth and unidentified gorgonacea in 900 m (TerraLogic GIS 2004). Pennatualceans (sea pens) are by far the most common coral within the Study Area (most common coral retrieved in bottom trawls within the 44 to 1,500 m depth range) and the most speciose taxon (27 species, 11 families) (**Figure 2-22**). The three most common sea pens in the Study Area are *Stylatula* sp., *Anthoptilum grandiflorum*, and *Umbellula* sp. (Whitmire and Clarke 2007).

  Seamounts of the Study Area potentially support abundant *Paragorgia arborea* cover as witnessed on Davidson Seamount located north of the Study Area (DeVogelaere 2005). Indeed, *P. arborea* is relatively abundant within the Study Area, is structure-forming (>1 m in height), and is typically associated with many other species (Whitmire and Clarke 2007). Other structure-forming gorgonians commonly found on the continental slope include *Isidella* spp., *Keratoisis* spp., and *Primnoa pacifica* (Whitmire and Clarke 2007). True soft corals (alcyonaceans) commonly encountered within the Study Area include *Anthomastus* spp. (Whitmire and Clarke 2007).

- Hydrocorals—A common hydrocoral of the SCB and Study Area on rocky reefs and banks is *Stylaster californicus* (California hydrocoral, formerly *Allopora californica*), which is generally found in water depths ranging from 15 to 90 m (Richards et al. 1990; Cairns 1999).[12] The California hydrocoral is characterized by extensive and delicate branches. The deepest record of *S. californicus* is 823 m (Etnoyer and Morgan 2005). The hydrocoral widely distributed within the Oregon Province is *Stylaster venustus* (Etnoyer and Morgan 2005; Whitmire and Clarke 2007).

- Deep-Sea Corals—Gorgonaceans belonging to the family Coralliidae (*Corallium* spp.) are the only corals of the Northeast Pacific Ocean that occur exclusively in deep water, (i.e., below the 200-m isobath) (Etnoyer and Morgan 2003; Etnoyer and Morgan 2005). All other deep-sea coral taxa of the Northeast Pacific Ocean are also found in water depths shallower than 200 m. These include stony corals (*L. pertrusa, M. oculata*); black corals (*Antipathes* spp., *Bathypathes* spp., *Parantipathes* spp.); gorgonaceans belonging to the families Isididae (e.g., the bamboo coral, *Isidella* spp.), Paragorgidae and Primnoidae; and hydrocorals (including *S. californicus*). The Primnoidae family contains the greatest species diversity for the Northeast Pacific (63 species) and its members are the most common occurrence in the deep sea (greater than 60%) (Etnoyer and Morgan 2005). The most commonly observed deep-sea corals within the Study Area are those of the Stylasteridae family (hydrocorals) (Etnoyer and Morgan 2003). Tissot et al. (2006) observed the black coral *A. dendrochristos* within the cowcod conservation areas south of the Channel Islands down to a water depth of 225 m. Corals found in waters deeper than 200 m in the Study Area are shown in **Figures 2-19 through 2-22**.

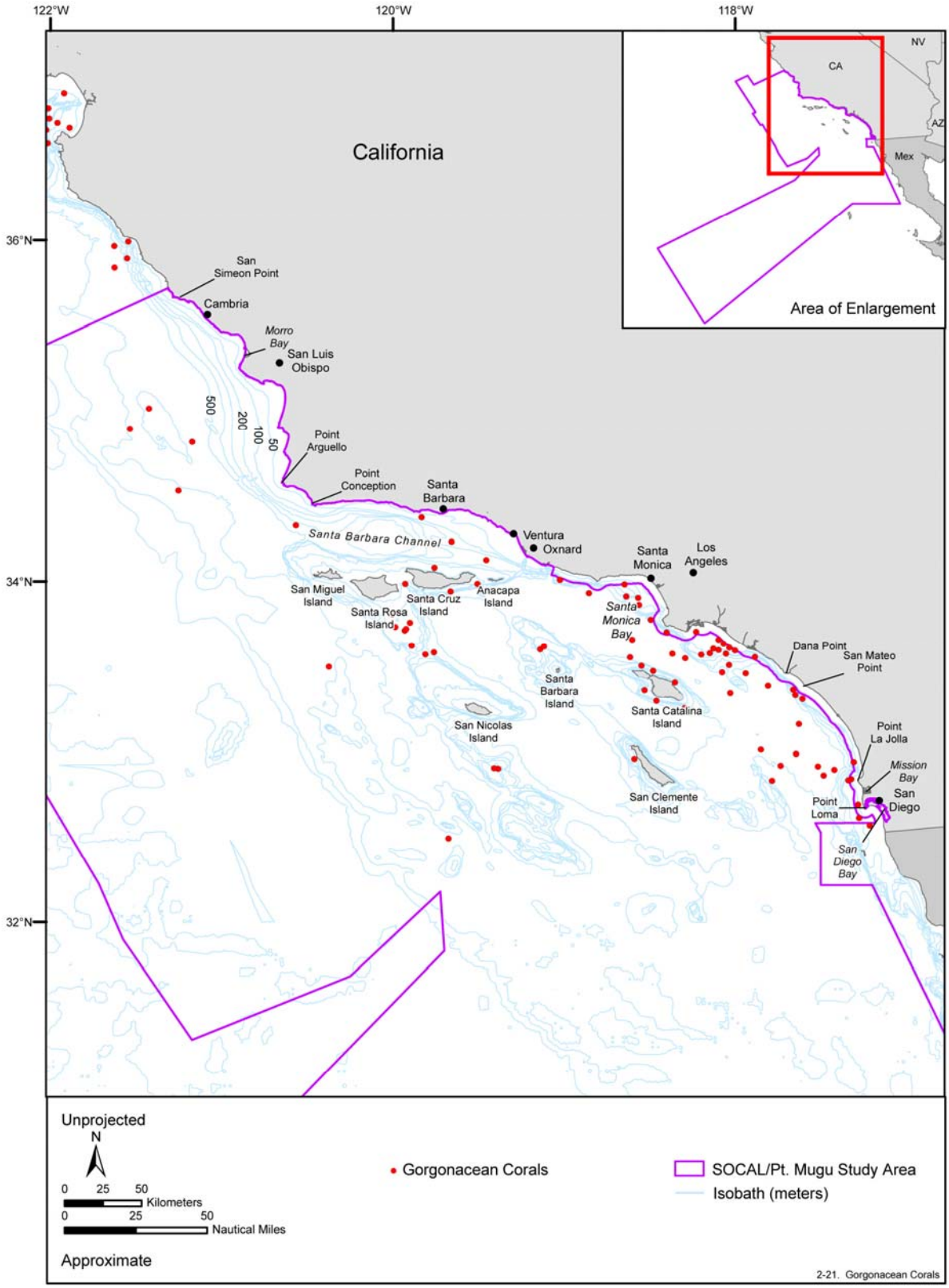

Figure 2-21. Locations of gorgonacean corals in the SOCAL/Pt. Mugu Study Area. Source data: Smith and Sandwell (1997), NOAA (2002), Tissot et al. (2006), Whitmire and Clarke (2007), and NOAA/NWFSC/FRAM/AT&SML (2008).

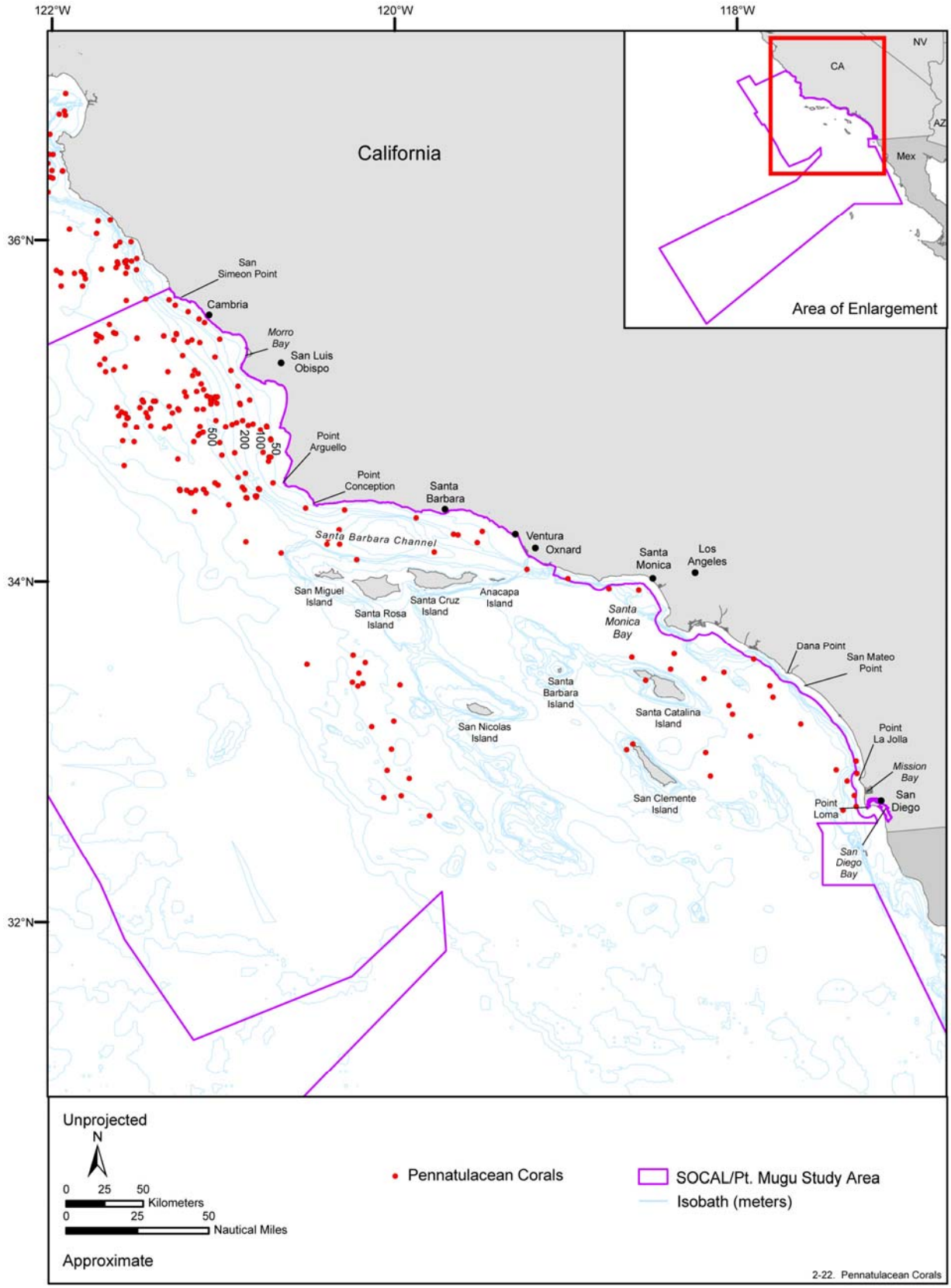

Figure 2-22. Locations of pennatulacean corals in the SOCAL/Pt. Mugu Study Area. Source data: Smith and Sandwell (1997), NOAA (2002), and NOAA/NWFSC/FRAM/AT&SML (2008).

As mentioned previously, deep-sea corals can form large but delicate reef habitats used by numerous benthic and pelagic organisms (Roberts and Hirshfield 2004). The abundance of fish on such habitats is well known to fishermen. Deep-sea trawling conducted over deep-sea coral habitats in water depths up to 2,000 m can cause severe impacts such as reducing to rubble thousands of years of coral growth (Roberts and Hirshfield 2004). The benthic invertebrates that Tissot et al. (2006) encountered were in relatively good condition even though there were some incidences of damages and mortality on black corals, sponges, and gorgonians. The few damages observed may indicate low levels of commercial bottom trawling fishing pressure for this particular area located off Los Angeles (Tissot et al. 2006). Nevertheless, bottom trawling remains the most significant threat to deep-sea coral communities found within the Study Area and vicinity (Whitmire and Clarke 2007). Other potential sources of human impacts on corals within the Study Area may include commercial fishing (bottom longlines and gillnets, traps [pots]), hydrocarbon exploration and production, the emplacement of pipelines and communication cables, and bottom sediment resuspension (bottom trawling). The main source of natural change affecting corals in the Study Area is probably sedimentation (Whitmire and Clarke 2007).

2.7.4.9 Islets

Islet habitats support an abundant biota comparable to the benthic communities found on fringing and barrier reefs (Maragos 1998). Coastal islets occur sporadically along the central and southern California coastline except at the mouths of large bays and estuaries and almost continuously along the Channel Islands coastline. Headlands also occur along the central and southern California coastline and are very common along the open rocky coasts of the Channel Islands; headlands are very similar in habitat to islets (Proctor et al. 1980b). Islets and headlands along the California mainland and Channel Islands coastline 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 that increase local plant productivity (Airamé et al. 2003).

Human impact on islets and associated marine habitats 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. Yet, historically, fauna associated with islets have been substantially affected by hunting, resulting in the near extinction of some animals such as the northern elephant seal.

2.7.5 Deep Water (Open Ocean)

Although the open ocean is the largest habitat on earth, its biology is the least known and explored (Nybakken 2001). The deep sea can be divided into two primary areas: pelagic (associated with the open water) and benthic (Nybakken 2001). The open ocean pelagic habitat can be described as having a light zone and a dark zone. Each zone is distinct in its characteristics of water movement, quantity of sunlight, temperature, pressure, availability of food, oxygen, and salinity. In the light zone, sunlight reaches approximately 100 to 200 m below the water's surface; this zone is where primary production (photosynthesis) occurs. In the dark zone life is sparse because little or no nutrients, sunlight, and food reach this zone. Cold temperatures and extreme water pressure also characterize this zone and the dark zone is stable and unchanging over time. In the mesopelagic zone (the transition area between the light and dark zone) deep-living zooplankton and nekton undergo diurnal vertical migration, moving upwards into the light zone at night to feed on the abundant phytoplankton and downwards during the day to avoid predation. These pelagic biological oceanographic communities (i.e., phytoplankton and zooplankton) are discussed in **Section 2.6** of this chapter. In the benthos, biomass diminishes and diversity increases with increasing distance offshore. Benthic animals rely on the input of food or falling detritus from the surface waters. In general, animals living on or in the benthos in the open ocean grow slower, live longer, and have smaller broods than animals living in shallow waters (Nybakken 2001; O'Dor 2003); however, there are very productive microhabitats associated with the deep benthic environment including deep rocky substrates (i.e., seamounts), deep-water corals, and chemosynthetic communities (Levin et al. 2003;

Smith et al. 2003; Andrews et al. 2007; Love and Schroeder 2007). These benthic habitats are discussed in further detail in the sections that follow.

2.7.5.1 Deep Rocky Substrate

Beyond the depths of kelp beds (>30 m), approximately 3% of the seafloor is comprised of rocky outcroppings, rubble, and talus. The bottom substrate of the deep benthic environment of California is typically covered with silts, clays, and fine sediments; however, there is the occasional hardbottom substrate (e.g., rocky outcroppings, rubble, talus, vertical wall, submarine canyons, and seamounts) that support a diverse assemblage of deep-sea invertebrates and fishes. Although there have been many descriptive studies detailing the macroflora and macrofauna assemblages associated with deep rocky substrate habitats, these habitats are challenging to study because they usually lie beyond the range of SCUBA and mechanical sampling is difficult. Abundances of most species increase with water depth due to the lack of terrigenous sediments and increased nutrients of the open ocean (Thompson et al. 1993). Most deep hardbottom species are suspension feeders; sponges, corals, gorgonians, anemones, ophiuroids, and crinoids are all common suspension feeders found in these areas (Lissner 1988). Lissner (1988) found patterns of species distribution and abundance to be a function of the substrate relief. Low relief assemblages contained ophiuroids (*Ophiacantha diplasia*), sponges, gorgonians (*Stenella* spp.), shrimp, brachiopods, amphipods, polychaetes, and ectoprocts; whereas, medium to high relief assemblages contained mainly anemones (*Corynactis californica*) and corals (*Lophelia californica*); however, in a later study, Hardin et al. (1994) found no zonation of assemblages based upon relief but did find the assemblages to be highly dependent upon water depth; the dominant species found was a mat of hydroids that encrusted over 72% of the rock surfaces.

There is a variety of deep rocky substrate habitat types located in the SOCAL/Pt. Mugu Study Area (**Figure 2-18**). These habitats are comprised of bedrock outcrops, isolated pinnacles and large rock banks, boulder fields, mixtures of low-relief sand or mud and cobble fields, and offshore islands (Love and Yoklavich 2006). Examples of these habitats in the SOCAL/Pt. Mugu Study Area include extensive rock and boulder fields located off headlands such as Point Sur; base rock and rocky outcrops located at Cordell Bank off central California and Tanner and Cortes Banks in the offshore waters of southern California; and several submarine canyons containing slumps of rock talus piles, scarps, and ledges of the shelf and slope systems (Love and Yoklavich 2006). In general, deep rocky substrate habitats are often located offshore from major headlands and islands, as well as on the highest parts of submerged ridges, banks, and pinnacles (NOAA 2007).

Structure-forming megafaunal invertebrates on deep rocky banks and outcrops off California include deep-sea corals, such as gorgonians (sea fans), antipatharians (black corals), scleractinians (stony corals), hydrocorals, and other megafaunal invertebrates such as crinoids, basket stars, and sponges (**Table 2-10**) (Love and Yoklavich 2006). Specific information regarding coral communities is discussed in **Section 2.7.4.8** in this chapter. In the SOCAL/Pt. Mugu Study Area, 15 taxa were found to be associated with megafaunal, structure-forming invertebrate habitats (**Table 2-10**). Deep sea corals and sponges were the largest structure-forming invertebrates; however, they were relatively uncommon (2% of total). The most common (98% of total) structure-forming invertebrates included crinoids (40%), brittle stars (33%), brachiopods (11%), white sea urchins (9%), fragile sea urchins (4%), and sea pens (2%) (Tissot et al. 2006).

Love et al. (2006a) conducted a study in 2004 along low ledges in deep waters off Anacapa Island. This habitat was determined to be the preferred habitat for some species of fishes (e.g., flag, squarespot, vermilion rockfishes, and bocaccio) due to the sheltering crevices in the rocky outcrops. In another survey, Love and Schroeder (2007) observed the deep rocky outcrops of the Anacapa Passage during 1995, 1999, and 2001 to 2004 and determined that rockfishes dominated the assemblage both in diversity and abundance. This area was important in that it represented a transition between nearshore rocky reef and deeper-water rocky substrates (Love and Schroeder 2007).

Table 2-10. Structure-forming invertebrates and fish commonly found on deep rocky banks and outcrops of the SOCAL/Pt. Mugu Study Area (Tissot et al. 2006).

Common Name	Taxa	Common Name	Taxa
Macrofauna		***Fish***	
Black coral	*Antipathes dendrochristos*	Unknown *Sebastomus*	*Sebastomus*
Flat sponge		Swordspine rockfish	*Sebastes wilsoni*
Barrel sponge		Pygmy rockfish	*Sebastes simulator*
Vase sponge		Pinkrose rockfish	*Sebastes hopkinsi*
Sea pen	Order Pennatulacea	Shortspine combfish	*Zaniolepis frenata*
Basket star	*Gorgonocephalus eucnemis*	Bank rockfish	*Sebastes rufus*
White-plumed anemone	*Metridium farcimen*	Halfbanded rockfish	*Sebastes semicinctus*
Foliose sponge		Shortbelly rockfish	*Sebastes jordani*
Shelf sponge		Cowcod	*Sebastes levis*
Gorgonian	Order Gorgonacea	Starry rockfish	*Sebastes constellatus*
Crinoid	*Florometra serratissima*	Greenstriped rockfish	*Sebastes elongatus*
Brittle star	Family Ophiuridae	Rosy rockfish	*Sebastes rosaceus*
Fragile sea urchin	*Allocentrotus fragilis*	Dwarf-red rockfish	*Sebastes rufinanus*
White sea urchin	*Lytechinus anamesus*	Greespotted rockfish	*Sebastes chlorostictus*
Brachiopod	Order Terebratulida	Blackeye goby	*Rhinogobiops nicholsii*
		Lingcod	*Ophiodon elongatus*
		Bocaccio	*Sebastes paucispinis*

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 for rockfish management (Williams and Ralston 2002); rockfish occurrence associated with these habitat types is discussed in more detail in **Chapter 4 – Section 4.4.3.**

2.7.5.1.1 Seamounts

Seamounts are isolated submerged mountains rising from 900 to 3,000 m above the surrounding deep soft sandy bottom (**Figure 2-18**). In general, they are cone-shaped and have a characteristic depression at the summit similar to a crater (Rogers 1994). 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). The research conducted on seamounts along the California coasts suggests that they 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).

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). Currents generated by seamounts retain rockfish larvae and zooplankton, a principal source for rockfish (Dower and Perry 2001). 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 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 yr 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 SOCAL/Pt. Mugu Study Area; refer to **Section, 2.3.2.3**, in this chapter for a full description (**Figures 2-3** and **2-18**).

2.7.5.1.2 Submarine canyons

The submarine canyons of California are ecologically important to many fish, cetaceans, and crustaceans (Vetter 1995; Vetter and Dayton 1998, 1999; Yoklavich et al. 2000; Yen et al. 2004). 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 water depths of more than 500 m, little or no light, cold water temperatures (5º to 12ºC), and tremendous pressure (up to 318 atmospheres [atm]) (Airamé et al. 2003).

In general, density and biomass of organisms is greater within a canyon than at comparable depths outside of a canyon due in part to the delivery and storage of macrophyte detritus (Vetter 1993; Vetter and Dayton 1998, 1999). Rocky substrates of submarine canyons provide habitat and cover for numerous fish species (e.g., rockfish, which seem to prefer high topographic relief). Localized populations of groundfish may take refuge in the structure-forming invertebrate macrofauna (i.e., sea whips, deep-sea corals) that can be found in submarine canyons (Brodeur 2001). The complex structure of the rocky substrate in submarine canyons can help to protect these species from over-fishing and predation because they tend to be difficult to locate and target (Yoklavich et al. 2000).

Some of the production in submarine canyons is introduced from adjacent habitats. Drift kelp 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; 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 originate from coastal development (Airamé et al. 2003) .

There are many submarine canyons located in the SOCAL/Pt. Mugu Study Area; refer to **Section 2.3.2.4**, in this chapter for a full description (**Figures 2-3** and **2-18**).

2.7.5.2 Deep Soft Sandy Bottom

Extensive areas (>10^7 ha) of deep benthic habitats exist in southern California. In the CINMS, over 90% of deep water benthic habitats are deep soft sandy bottoms that consist of fine sands in shallower portions and silt and clay sediments in deeper portions (NOAA 2007). Deep soft sandy bottom environments can vary in water depth, sediment type, organic content, terrestrial influence, oceanographic conditions, and contaminant inputs (Grassle 1991). As a result, the soft substrate benthic assemblages of the region are complex and diverse. In general, organism abundance is high and diversity is low in nearshore sandy bottom habitats; in the offshore habitats, abundance decreases and diversity increases with depth. The nearshore area from approximately 30 to 900 m of water depth includes the mainland shelf, the upper slope, the lower slope, and the basins. The deepest point of the SOCAL/Pt. Mugu Study Area is 4,500 m. The seafloor features of the Study Area include shelves, ridges and banks (15 to 1,160 m), the lower slope (540 to 1,760 m), basins (1,350 to 2,500 m), the Patton Escarpment (3,000 m), and the abyssal plain (3,000 to 4,500 m). In a survey by Thompson et al. (1993), polychaetes (e.g., *Spiophanes missionensis*, *Maldane sarsi*, *Anobothrus trilobata*, *Chloeia pinnata*, *Tharyx* spp., and *Paraonidae* spp.) were the most prevalent organisms at all depths of soft sandy bottom habitats. Other frequently observed organisms included gastropods (e.g., *Mitrella permodesta*),

crustaceans (e.g., *Munida quadrispina*, *Munidopsis hystrix*, *Sicyonia ingentis*, and *Pleuroncodes planipes*), ophiuroids (i.e., *Amphiodia urtica*), echinoderms (e.g., *Lytechinus pictus* and *Brissopsis pacifica*), pelecypods (e.g., *Parvilucina tenuisculpta*), and amphipods (*Byblis* spp.).

2.7.5.2.1 Submerged basins

Due to the geologic formation of the SOCAL/Pt. Mugu Study Area, submerged basins make up a large portion of the continental borderland in the Study Area. Offshore basins contain waters from currents that move over offshore sills (Eganhouse and Venkatesan 1993); because of differences in sill depth along the continental borderland, dissolved oxygen and temperature signatures can uniquely characterize the waters of each basin. Inshore basins are within the depths of the oxygen minimum zone (OMZ); these basins have low dissolved oxygen content and the sediments within these inshore basins may turn anoxic during the year (Eganhouse and Venkatesan 1993). The basins (**Figure 2-3**) generally have a lower biomass and species diversity than surrounding benthic habitats. Some nearshore basins have areas that are devoid of macrofauna; due to the ephemeral nature of the benthos in these areas, macrofaunal assemblages have extremely low levels of species diversity (Thompson et al. 1993). Submerged basins in the SOCAL/Pt. Mugu Study Area are discussed in more detail in **Section 2.3.2.5** of this chapter.

2.7.5.2.2 Abyssal plain

An abyssal plain typically 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 5 feet (ft) 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 highly diverse marine biota (Wilson 1976; Beaulieu 2001b, 2001a; 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. In the SOCAL/Pt. Mugu Study Area, the abyssal plain covers the seafloor seaward of the Patton Escarpment. The depth range is 3,000 to 4,500 m. While abyssal plains tend to be flat, the one contained within the Study Area has substantial topographic relief.[22]

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.[13]

2.7.5.3 Chemosynthetic Communities

In a typical marine ecosystem, primary producers are plants (e.g., phytoplankton and seagrasses) which produce carbon by way of photosynthesis (a photosynthetic ecosystem). In environments rich in methane and sulfides and where oxygen is present, chemosynthetic symbioses between bacteria (chemosynthetic bacteria, sulfur-oxidizing bacteria, methane-oxidizing bacteria, and sulfide-reducing bacteria) and marine invertebrates are the basis for chemosynthetic communities (Cavanaugh 1994).[13] These communities are a significant source of biological productivity on the deep-sea floor (Corliss et al. 1979) (**Figure 2-23**). In some locations, vast fields of hydrothermal vents can support benthic communities (Corliss et al. 1979) (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 temporary chemosynthetic habitat and each of these habitats appears to foster a characteristic fauna (Airamé et al. 2003). 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 SOCAL/Pt. Mugu Study Area are characterized by tubeworms, giant white clams, mussels, gastropods, and sponges (Kojima 2002).

2.7.5.3.1 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 coast; they occur along the continental margins of the SOCAL/Pt. Mugu Study Area 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).

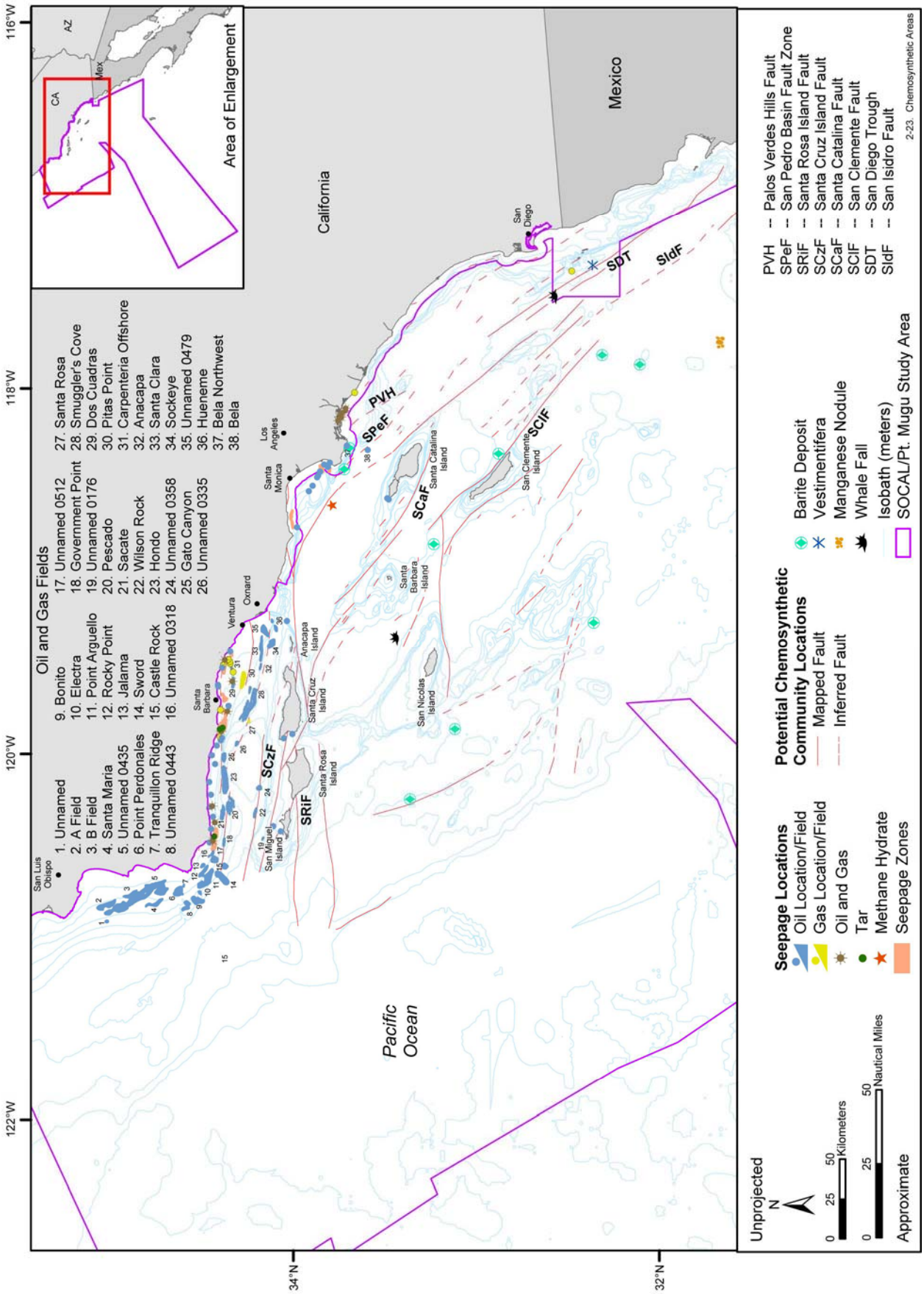

Figure 2-23. Potential chemosynthetic community areas, seepage locations, and known chemosynthetic communities in the SOCAL/Pt. Mugu Study Area. Source data: Dahlgren et al. (2004) and USGS (2008). Source data and maps (scanned): Wilkinson (1976). Source maps (scanned): Lonsdale (1979), Anderson et al. (1993), Astiz and Shearer (2000), Dunkel (2001), Grant and Shearer (2004), Legg et al. (2004), and Hein et al. (2007). Source Information: Frazee et al.[14]

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 are 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 have been documented from 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 govern 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).

- Hydrocarbon seeps—Hydrocarbon seeps are found on many of the world's continental shelves (10% to 30%) yielding a global flux between 8 and 65 terragrams (Tg) of methane per year (Hovland et al. 1993). Petroleum seepage in the SCB has been well documented; in the Study Area, most seeps occur on the mainland shelf (**Figure 2-23**) but others have been reported around the Channel Islands and offshore ridges (Wilkinson 1976; Anderson et al. 1993). Typically, hydrocarbon seeps originate from relatively young sediments and are common along basin margins (Anderson et al. 1993); the seepage in this region results from hydrocarbon-containing rocks being close to the seafloor. In the SOCAL/Pt. Mugu Study Area and vicinity, four major seepage zones exist: Point Conception, Coal Oil Point, Santa Barbara/Rincon, and Santa Monica Bay.

  The Coal Oil Point seep area is the focus of most of the detailed geologic, chemical, and biological studies of hydrocarbon seeps in southern California. Coal Oil Point seep covers over 1,000 m^2 in area; it is located in 13 to 30 m of water and is a thin, narrow seep following a 1 km long, south to southeast axis from Coal Oil Point (Anderson et al. 1993). In some cases, bubbles of methane, ethane, and propane can be seen escaping from the sediments (Anderson et al. 1993; Clark et al. 2000). Released gas bubbles range in size from several millimeters to more than 1 cm in diameter. Plumes of these seeped gases can float through the water column at least 12 km offshore (Clark et al. 2000). Gas bubbles coated with oil can result in a sheen of oil on the surface of the water (Anderson et al. 1993).

  There are no accurate estimates of seepage in the SCB region; however, Anderson et al. (1993) estimated that active areas near Coal Oil Point emit 3 milliliters (mL) of hydrocarbons (methane, tar, or petroleum) per square centimeter per hour (cm^2/hr) (Anderson et al. 1993) and, in early 1988, the ARCO Gas Company collected over 42,500 m^3 of oil per day off the coast south of Coal Oil Point (Anderson et al. 1993).

The seepage into surrounding waters has a profound effect on microbial populations, productivity, and metabolic activity of sediments. Sediments containing hydrocarbon seeps are often more productive than the surrounding sediments (Montagna et al. 1986) with the increased production likely due to the increased concentration of sulfides as well as high alkalinity in the sediments (Anderson et al. 1993). Hydrocarbon-degrading microbes often comprise a large percentage of the microflora in sediments associated with hydrocarbon seeps. Although, there have been reports of depressed macrofaunal and meiofaunal abundances close to seeps, generally, they are not significantly different than non-seep regions (Spies et al. 1980; Montagna et al. 1986).

- Methane hydrates—In the SOCAL/Pt. Mugu Study Area, one chemosynthetic community is known to be associated with a methane hydrate (33.8°N, 118.64°W) (**Figure 2-23**).[14] Methane hydrates (frozen methane deposits) are abundant in marine sediments; their structure looks very much like water ice, it is a crystalline solid of methane surrounded by a cage of water molecules.[15] Methane hydrates are stable in oceanic sediments at appropriate water depths (>300 m) and temperatures; they are capable of cementing loose sediments into a surface layer several hundred meters thick. The methane hydrate located within the boundaries of the SOCAL OPAREA, is located in silty mud and is surrounded by clams (*Vesicomya* spp.) that are typically associated with cold-seep communities (Aiello et al. 2001; Little and Vrijenhoek 2003).[14] Large concentrations of methane and hydrogen sulfide in the surrounding sediments suggest that the site is actively venting methane gas into the environment.[14]

2.7.5.3.2 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 (Haag 2005). 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 160 metric ton [mt] adult body weight) yield massive pulses of labile organic matter to the deep-sea floor (Smith and Baco 2003).

At least two whale falls are known to occur off the coast of southern and central California (**Figure 2-23**), both of which were implanted at depth for scientific study (Dahlgren et al. 2004). The first is located in San Diego Trough (33°35'N, 117°30'W) and is the remnants of a juvenile gray whale. The second whale fall, a 35,000 kilogram (kg) gray whale, is located farther to the north in Santa Cruz Basin (33°27'N, 119°22'W); both of these locations support a diverse assemblage of organisms (Dahlgren et al. 2004). In addition, the US Navy surveyed more than 300 km^2 of the Pacific sea floor in the early 1990s in search of a lost missile. During this survey they found eight whale skeletons (no coordinates were recorded); however, when researchers went in search of the whale falls, they could only find one of the eight (Haag 2005).

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).

2.7.5.3.3 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 (Little and Vrijenhoek 2003).[16] 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 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 is a high potential for there to be hydrothermal vent communities in the SOCAL/Pt. Mugu Study Area because the area encompasses the southern California Continental Borderland which is part of the broad San Andreas transform-fault plate boundary. The San Andreas transform-fault plate boundary consists of a series of fault-bounded, petroleum-generating basins (Hein et al. 2007). In this area, the thinned continental crust and Neogene volcanism has produced high heat flow and geothermal gradients. There are several different indicators of hydrothermal activity. For example, barite deposits can be found along the faults in the SOCAL/Pt. Mugu Study Area. Barites in the area are formed from hydrothermal fluids and cold seeps. In addition, significant concentrations of mercury, silver, arsenic and a large manganese nodule have been found in this area. These metals presumably come from hydrothermal vents in the area; however, hydrothermal vents may be very difficult to locate with such few seafloor observations from submersibles and deep tow systems (Hein et al. 2007).

In the late 1970s, submersible dives in the vicinity of the Navy Fan, near San Clemente Island were conducted and hydrothermal vents and communities were documented (Lonsdale 1979); however, after further investigaton these hydrothermal vents were shown to be cold seeps of barite-rich solutions that were probably related to the San Clemente fault (Lonsdale 1979). In 1996, Woods Hole Oceanographic Institute (WHOI) conducted submersible dies along the Catalina Escarpment near Farnsworth Bank on the backside of Santa Catalina Island. However, hydrothermal communities were not found. In 2001, submersible dives were conducted along the Santa Cruz-Catalina Ridge and near Anacapa Island; however, again, no hydrothermal communities were found. In 2000, submersible dives were conducted along the Redondo submarine canyon, near King Harbor, Redondo Beach, and methane seeps were found. Bubbles of methane and mats of bacteria and “branches” of sintered sands were observed coming out of the seabead (Legg, M.R., Legg Geophysical, pers. comm., 17 April 2008). Since then hydrothermal communitites (Vestimintifera) have been found along many of the escarpments in the area (**Figure 2-23**).

Considering the abundance of active faulting with prominent seafloor expression throughout the Study Area, there are likely to be significant true hydrothermal vents to be discovered in the area. Fortunately, there are very good maps of the active faults where these vents are most likely to occur (**Figure 2-23**). There are no known hydrothermal vent communities in the SOCAL/Pt. Mugu Study Area.

2.7.6 Artificial Habitats

Artificial habitats (artificial reefs, shipwrecks, oil and gas structures, and FADs) physically alter the structure of the seafloor and the water column and under optimal conditions, artificial habitats generate and enhance benthic and fish communities, which in turn benefit offshore/onshore economies. Solid objects with numerous and varied surfaces placed on the seafloor are three-dimensional substrates that benthic organisms (including algae, sponges, barnacles, mussels, amphipods, soft corals, sea anemones, and hydroids) and fish will occupy (Bohnsack et al. 1991; Love and Schroeder 2006; Love et al. 2006b). The artificial habitat colonization works to build communities that increase marine production; these habitats provide food, shelter (refuge), and nurseries for a variety of demersal and pelagic fishes (Ambrose and Swarbrick 1989; DeMartini et al. 1994; Love et al. 2005; Love and York 2006). Fishermen target artificial habitats for seabasses (e.g., kelp bass, *Paralabrax clathratus* and barred sand bass, *P. nebulifer*), wrasses (e.g., California sheephead, *Semicossyphus pulcher*), surfperches (e.g., black perch, *Embiotoca jacksoni*), and groundfishes (e.g., sculpins and rockfishes) (MBC AES 1987). Many other fishes use artificial habitats including pomacentrids, Garibaldi (*Hypsypops rubicundus*), toadfishes, and pelagic schooling species (e.g., mackerels and jacks) (DeMartini et al. 1989; Johnson et al. 1994). The most important commercial species in the SCB, rockfishes (*Sebastes* spp.), aggregate around physical structures in offshore areas (Wilson et al. 1990; Love et al. 2005; Love et al. 2006b). Kelp on man-made structures also provides habitat and forage areas for sport fishes (e.g., sea chubs [opaleye, *Girella nigricans* and blue perch, *Embiotoca larealis*]) and many invertebrates (Quast 1968; Feder et al. 1974). Artificial habitats enhance fish aggregation and production (Seaman and Sprague 1991; Love and York 2005).

2.7.6.1 Artificial Reefs

An artificial reef consists of one or more submerged structures of natural or man-made origin that are purposefully deployed on the seabed to influence the physical, biological, or socioeconomic processes related to living marine resources (Baine 2001). Artificial reefs are defined both physically, by the design and arrangement of materials used in construction, and functionally, according to their purpose (Seaman and Jensen 2000). A large number of items are used for artificial reef creation including natural objects, such as wood (weighted tree trunks) and shells; quarry rock; or man-made objects, like vehicles (automobile bodies, railroad cars, and Sherman tanks), aircraft, steel-hulled vessels (Liberty ships, landing ship tanks [LSTs], barges, and tug boats), home appliances, discarded construction materials (e.g., concrete culverts), scrap vehicle tires, oil and gas platforms, ash byproducts (solid municipal incineration, and coal/oil combustion), and prefabricated concrete structures (e.g., reef balls) (ARS 1997). The purpose of deploying artificial reefs in the marine environment is to: (1) enhance commercial fishery production and harvest, (2) enhance recreational activities (fishing, SCUBA diving, and tourism), (3) restore/enhance water and habitat quality, (4) provide habitat protection and aquaculture production sites, and (5) control fish mortality (Seaman and Jensen 2000). McGurrin et al. (1989) provide an excellent summary of the history of artificial reef development in the U.S.

In California, the CDFG manages the state's artificial reefs and construction program. The CDFG began a program of artificial reef research and construction in 1958 (Bedford 2001). The first artificial reef was placed in northern Santa Monica Bay (Paradise Cove) in May 1958; it consisted of 20 automobiles set in a 15 m water depth. Then, in September 1958, six wooden street cars were used as artificial reefs in the area of Redondo Beach (18 m water depth). CDFG scientists monitored the Paradise Cove artificial reef from 1958 to 1960. They recorded substantial increases in fish abundance and diversity (totaling 24,000 individuals and 49 species). The streetcars placed at Redondo Beach were equally successful. Three main factors contributing to the abundance and diversity of fish were the schooling behavior of the fish, the artificial reef as a source of shelter and food, and the relief (three dimensional structure) of the artificial reef (Bedford 2001). Following these initial successes, the CDFG rigorously compared the

effectiveness of various artificial reef building materials including streetcars, automobiles, quarry rock, and concrete boxes (Wilson et al. 1990). Years of monitoring revealed that concrete boxes and quarry rock were the most efficient artificial reef materials. Other substrates were tested including concrete rubble, tires, and ships. Concrete rubble proved to be adequate. Tire reefs were never successful off California and not widely used. Sunken vessels also proved to be inadequate. From 1962 to 1979, the CDFG constructed 15 recreational fishing reefs and augmented 13 existing reefs using quarry rock, cobble rock, and heavy iron objects (e.g., barges and ship hulls). Quarry rock reefs were also constructed adjacent to seven fishing piers from Venice (Los Angeles County) to Oceanside (San Diego County) (Wilson et al. 1990).

Starting in 1980, the CDFG substantially increased artificial reef research and construction. In particular, from 1980 to 1984, CDFG scientists developed and carefully studied a quarry rock reef, the Pendleton Artificial Reef (PAR), located in northern San Diego County (Carter et al. 1985a; Carter et al. 1985b; Anderson et al. 1989). Using this reef, the CDFG was able to develop the optimal artificial reef for fish, shellfish, and plants (including kelp). The success of PAR was one of the CDFG's accomplishments for the Nearshore Sportfish Habitat Enhancement Program (NSHEP) designed to restore or enhance sport fish habitat along the southern California coastline (Wilson et al. 1990; McGinnis et al. 2001). Artificial reefs have been carefully designed to increase fish production and not solely attract fish. Fish production was achieved by providing a habitat within which fish find shelter, forage, and can reproduce and grow (Bedford 2001).

While the CDFG manages the research and construction of artificial reefs, several other agencies play a role in the pre-construction permitting process. Siting artificial reefs in California state waters requires a federal permit for ocean dumping from the USACE, a coastal development permit from the CCC, and a lease from the CSLC for activity on submerged state lands. In waters outside the 3-mile (mi) state jurisdiction, a CSLC permit is not required, but the CCC must issue a consistency finding before the USACE will issue a permit (McGinnis et al. 2001). Artificial reefs must also conform to requirements of the California Environmental Quality Act (CEQA) (Wilson et al. 1990).

Since 1958, 33 artificial reefs have been constructed in nearshore waters of southern California (Wilson et al. 1990). The last reef, International Beach Artificial Reef (located near the international border), was constructed in 1991 with additional cobble rubble added in 2001. Nine of the thirty-three reefs were partially or completely lost due to: 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).

At present, there are 32 artificial reefs (16 individual reefs and 16 reef complexes consisting of hundreds of modules) off Southern California (Bedford 2001).[17] Four of these artificial reefs (three individual reefs and one reef complex) are located within the SOCAL/Pt. Mugu Study Area (**Table 2-11**; **Figure 2-24**). A reef complex is an aggregation of artificial reefs that are located within 500 m of one another; they can be composed of more than one type of reef material. In addition to these artificial reefs, quarry rock was added to various public fishing/municipal piers to create artificial fishing reefs. These artificial fishing reefs are located at the Los Angeles (Venice) Manhattan Beach and Hermosa Beach public fishing piers; in Orange County at Seal Beach, Huntington Beach, and San Clemente municipal piers; and in San Diego County at the Oceanside municipal pier (Bedford 2001).

As part of the Eelgrass Mitigation Plan for the Nimitz Class Carrier Vessel Nuclear (CVN) Naval Air Station, four fish enhancement structures (artificial reefs) were placed within San Diego Bay in close proximity to an eelgrass transplant region to further enhance the ecosystem of the area (Pondella II and Allen 2003) (**Figure 2-24**). The reefs were placed in a north to south orientation and placed 33 to 71 m apart (33 m has been described as the primary foraging distance around artificial reefs in the southern California region) (Johnson et al. 1994). Two of the placed structures were composed of concrete, while the remaining two were composed of quarry rock in attempt to distinguish differences in reef construction (Pondella II and Allen 2003).

Table 2-11. Artificial reefs located within the SOCAL/Pt. Mugu Study Area (Bedford 2001).

Artificial Reef	Depth (m)	Material	Size (ton)	Latitude North	Longitude West
Atascadero	17	Quarry rock	3,500	35°23'36"	120°52'32"
San Luis Obispo	13-16	Concrete tribar/rubble	27,000	35°11'25"	120°49'55"
Pitas Point	9	Quarry rock	7,200	34°18'8"	119°22'6"
Bolsa Chica Complex	26-30	Concrete rubble	10,400	33°39'33"	118°6'3"

2.7.6.2 Shipwrecks

There are 1,754 shipwrecks known in the SOCAL/Pt. Mugu Study Area, 195 of switch are within the Pt. Mugu Sea Range (DoN/NAWC 1999; Veridian Corporation 2001; Spira 2004) (**Figure 2-24**). They are found throughout the Study Area, in the nearshore area (e.g., La Jenelle; 34°7'30" N, 119°17'40" W; (Spira 2004)), on the outer continental shelf (OCS), and around offshore islands (Santa Barbara, Santa Catalina, San Clemente, San Miguel, Santa Rosa, Santa Cruz, Anacapa, and San Nicolas) and inner (Six Mile, Nine Mile) and outer banks (Tanner, Cortez, Sixty Mile, Thirty Mile) (Morris and Lima 1996; DoN/NAWC 1999; Spira 2004).

Shipwrecks are documented from the period of Spanish exploration (fifteenth century) through the modern age of shipping and commerce (twentieth century). Shipwrecks of the sixteenth through the eighteenth centuries are less known, because the documentation of their exact locations is rarely accurate (e.g., Manilla galleons: Santa Marta, Nuestra Senora de Ayuda, San Sebastian, San Pedro, Santa Domingo off Santa Catalina and San Clemente islands 1582 to 1754) (Gibbs 1957; Spira 2004).

The best-known shipwrecks in the SCB are from the 1800s and 1900s (Spira 2004). Shipwrecks in the SOCAL/Pt. Mugu Study Area are the result of navigational hazards (storms, reefs and/or shoals), human errors (navigational errors, nautical equipment breakdowns, fire/explosions, strandings, foundering [i.e., ships that filled with water and sunk], groundings, and collisions), and intentional sinkings (target practice, movie industry productions, wars [World War Two (WWII)], and artificial reefs) (Morris and Lima 1996; DoN/NAWC 1999; Spira 2004).[18]

Recently, various vessels such as barges, motorized sloops, and schooners wrecked along the southern California coast from Santa Barbara County to the U.S./Mexico border as a result of navigational hazards and/or human errors (Spira 2004). Other recent shipwrecks include retired naval vessels used for Navy gunfire and/or underwater demolition practice, as well as vessels used as movie props and destroyed during production (**Table 2-12**) (Krival 2001; Waterproof Charts Inc. 2003; Spira 2004).[18]

During WWII, limited military activities occurred along the west coast of the U.S. Yet, following the attack on Pearl Harbor, Japanese submarines sailed the west coast in pursuit of enemy targets. The tanker Montebello is an example of one such target sunk off Cambria in the northern part of the Study Area (Ellis 2003).

2.7.6.3 Oil and Gas Structures

There are currently 27 oil and gas structures in the waters off California; 23 occur in federal waters and 3 are in state waters (Love and York 2006; MMS 2007). **Section 5.6** in **Chapter 5** provides further discussion on oil and gas structures. They are comprised of a latticework superstructure of pilings, beams, and pipes; support diverse fish (dominated by 35 species of rockfish) (Love et al. 2006b) and invertebrate populations (mussels, barnacles, and anemones) (Love et al. 2000); and are considered *de facto* artificial reefs (Helvey 2002; Love et al. 2006b; Love and York 2006; Love et al. 2007).

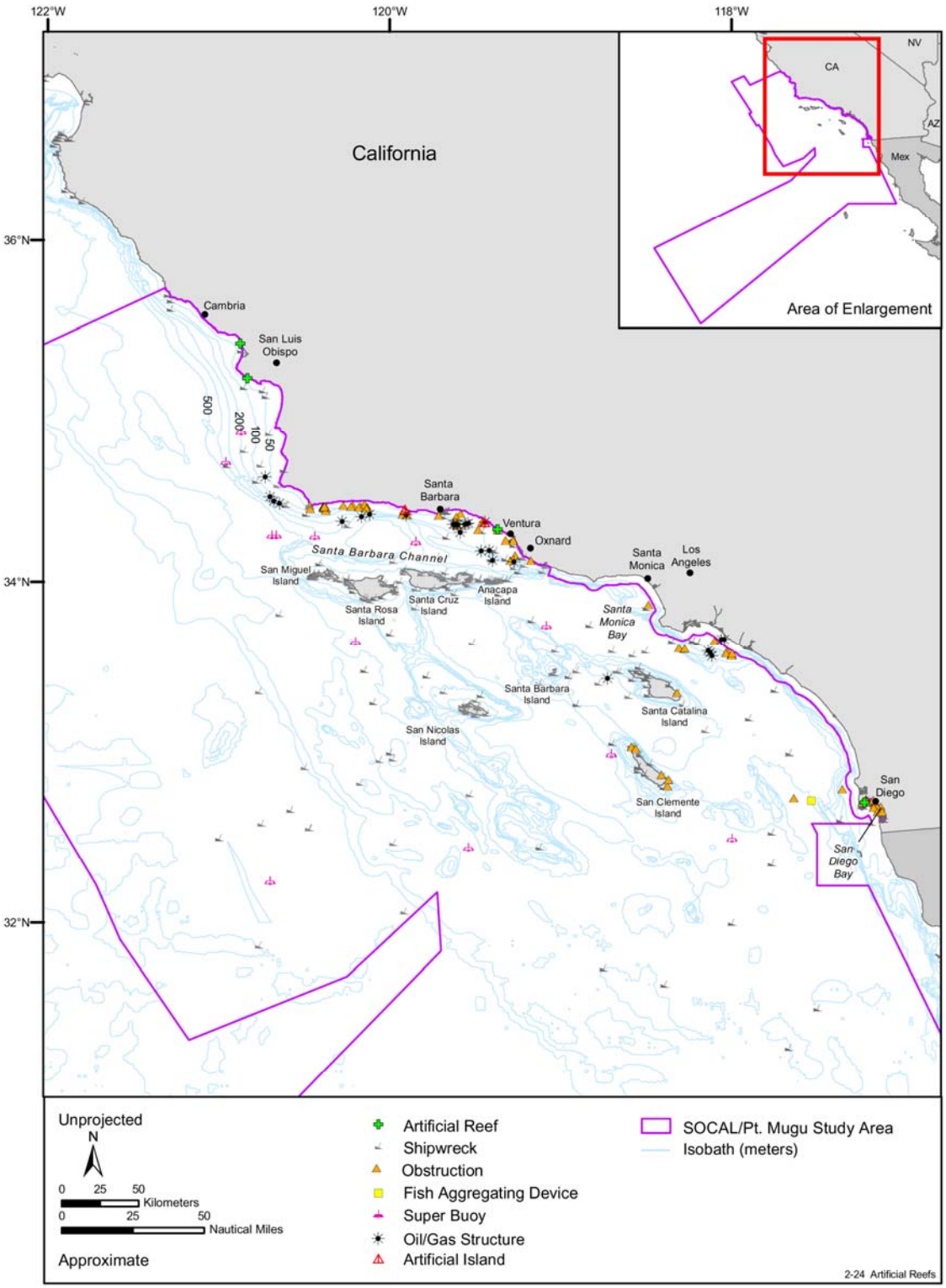

Figure 2-24. Locations of artificial reefs and reef complexes, shipwrecks, and FADs located in the SOCAL/Pt. Mugu Study Area. An artificial reef complex consists of multiple artificial reefs that are located within 500 m of one another. Source data: Smith and Sandwell (1997), AMEC Earth and Environment (1999), Bedford (2001), Veridian Corporation (2001), NOAA (2002), Pondella II and Allen (2003), Waterproof Charts, Inc. (2003), CSLC (2004), CARE (2007a, 2007b, and 2007c), NODC (2007), MMS (2007), and NOAA/Office of Coast Survey (2008).

Table 2-12. Examples of ships sunk due to navigational hazards, human errors, and intentional sinkings in the SOCAL/Pt. Mugu Study Area (Krival 2001; Waterproof Charts Inc. 2003; Spira 2004).[18]

Ship	Date Sunk	Location	Reason
Johanna Smith (world's most famous gambling ship)	7/22/1932	Long Beach	Fire
Olympic II (full rigged ship/fishing barge)	9/4/1940	Horseshoe Kelp Bed off San Pedro	Collision
Dominator (WWII Liberty Ship)	3/13/1961	Rocky Point, Palos Verdes	Ran aground
Avalon (passenger steam ship)	9/16/1964	Off Palos Verdes	Foundered in storm
Sacramento (side wheeler — world's largest fishing barge)	12/1968	2 mi off Redondo Beach	Foundered
Valiant (luxury yacht)	12/13/1980	Off Descanso Beach, Santa Catalina Island	Fire
S-37 (S-1 Class Submarine)	2/20/1945	Imperial Beach	Parted tow
Koka (Ocean going tug)	12/7/1937	Northwest Harbor, San Clemente Island	Stranded
Hogan (Wickes/Clemson Class Destroyer DD-178)	11/8/1945	San Diego	Bombing Target
Ace 1 (Landing Craft Infantry [LCI])	4/29/1948	San Pedro/Long Beach	Shellfire
John C. Butler (Destroyer Escort DE-339)	12/1971	Northwest Harbor, San Clemente Island	Underwater demolition teams
Gregory (DD-802)	1972	San Clemente Island	Bombing target
UB-88 (WWI UB Class German Submarine)	3/1/1921	San Pedro Bay	Shellfire (target vessel)
Ning Po (3 Masted Chinese Junk)	c.1938	Catalina (Cat) Harbor	Beached and later burned for movie
Charles F. Crocker (4 Masted Barkentine)	c.1929	Catalina (Cat) Harbor	Blown up for movie, beached, and later Burned
Moody (Wickes/Clemson Class Destroyer DD-277)	2/21/1933	San Pedro Bay	Blown up for movie "Hell Below"
Ruby E (retired Coast Cutter)	6/18/1989	Mission Bay	Mission Bay Park Artificial Reef (Wreck Alley)
El Rey (Kelp harvester)	4/2/1987	Mission Bay	Mission Bay Park Artificial Reef (Wreck Alley)
HMCS Yukon (Canadian Mackenzie Class Destroyer)	7/14/2000	Mission Bay	Mission Bay Park Artificial Reef (Wreck Alley)
Palawan (Liberty ship)	1977	Off Redondo Beach	Palawan Artificial Reef
Cuba (Steamship)	1923	Off Point Bennet	Grounded
Golden Horn (Bark)	1892	Santa Rosa Island	Stranded
Yankee Blade (Sidewheel steam)	1854	Point Pedernales	Grounded
Ex-USS Delphy (Destroyer)	1923	Point Honda	Stranded

In addition, shell mounds found at the foot of platforms are spatial refuges for adult and subadult fishes (Love et al. 2000; Love et al. 2006b; Love and York 2006). The relief of the shell mounds found at the foot of platforms results from the semicircular accumulation of drilling muds and cuttings (CSLC and CCC 2001). Shell mounds at the foot of the removed platforms Hazel, Hilda, Hope, and Heidi can measure up to 82 m in diameter. Shells (mussels, clams, and barnacles) of these mounds coat the drilling discharge mounds (CSLC and CCC 2001). Fish abundance decreased on the shell mounds following the removal of platforms Hazel, Hilda, Hope, and Heidi. Love et al. (2000) found that there were at least 40 species of fish at the bottom of platforms off California, the majority of which were rockfishes (27 species). Further, more than 92% of the fish on the bottom were rockfish (Love et al. 2000). Following the removal of platforms, shell mounds ceased to function as spatial refuge for rockfishes. Yet, benthic organisms persisted on the shell mounds the most abundant of which were bat stars (*Asterina miniata*) and cerianthid anemones (CSLC and CCC 2001). Exposed pipeline structure and remnants of concrete platform legs (of removed platform Hazel) also act as artificial substrates by providing habitat for rockfish (*Sebastes* spp.) and benthic invertebrates including bat stars, giant pink stars (*Pisaster brevispinus*), giant sea star (*Pisaster giganteus*), sea cucumbers (*Parastichopus* spp.), and gorgonians (*Lophogorgia chilensis*; *Muricea* sp.) (CSLC and CCC 2001). In addition to actual oil and gas platforms located off the California coastline, there are six man-made oil and gas production islands located in state waters (Bird Island, Rincon Island, Grissom Island, White Island, Freeman Island, and Chaffee Island) (McCrary et al. 2003).[17,19] The submerged portions of the artificial islands provide artificial habitat for fishes and invertebrates. For example, Rincon Island supports substantial amounts of lobster as well as diverse and abundant marine fauna and flora which differ significantly from the surrounding seafloor (Johnson and DeWit 1978).[20] Further, sand spits and sand bars of the artificial islands Grissom, White, and Freeman are good fishing spots for California corbina (*Menticirrhus undulates*), giant black sea bass (*Stereolepis gigas*), barracudas, Pacific halibut (*Hippoglossus stenolepis*), and sea basses.[21]

2.7.6.4 Fish Aggregating Devices

FADs consist of single or multiple structures that are free-floating or connected to the ocean floor by ballast or anchors (Seaman and Sprague 1991). They provide surface area at a designated height above the ocean's floor or below the ocean's surface (depending upon water depth at the location where the FADs are deployed). FADs are designed to concentrate target species or bait fishes and improve sport or commercial catches (Klima and Wickham 1971). Deployment is in pre-arranged alleys (rows) or in random patterns (Beets 1989). In the U.S., there are two fundamentally different oceanic and coastal types: large, floating FADs and small, mid-water FADs. Large, floating FADs have been successfully deployed in water depths up to 1,829 m for ocean pelagic commercial and recreational fisheries. Small, mid-water FADs have been used for coastal (5 km offshore) pelagic recreational fisheries in waters ranging from 14 to 30 m (Rountree 1989). FADs placed in the vicinity of artificial reefs or attached to artificial reefs have been reported to improve catches of pelagic sport fishes (Stephan and Lindquist 1989) and demersal finfishes (Kellison and Sedberry 1998).

Within the Study Area, there is a FAD ("FAD B" in (Waterproof Charts Inc. 2003) (**Figure 2-24**) plotted approximately 14 nm west of Ocean Beach, San Diego County (32°43.80'N, 117°32.80'W) in a 788 m water depth (Waterproof Charts Inc. 2003). Further, there are buoys within the Study Area that may function as FADs; these include lighted marks, super buoys (meteorological/oceanographic data buoy) (NODC 2007), and mooring buoys as depicted in NOAA navigational charts 18700, 18720, and 18740 (NOAA 2007a; NOAA 2007b; NOAA 2007c).

2.8 MARINE PROTECTED AREAS AND MARINE MANAGED AREAS

2.8.1 Marine Protected Areas

MPAs have become a recent popular tool in ecosystem management in various locations throughout the world. In the U.S. MPAs became established with the implementation of Presidential EO 13158 (65 FR 34909).

As defined in EO 13158, MPAs are "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Section 5 of the EO 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." The EO also directs federal agencies to prepare annual reports describing the actions they have taken over the previous year to implement the order. Overall, the intent of MPAs is to be an effective conservation tool for sustaining ocean ecosystems (Agardy 1999; NRC 2000).

The previous MPA classification system was designed to objectively define MPAs using the following fundamental characteristics: primary conservation goal, level of protection, permanence of protection, constancy of protection, scale of protection, and allowed extractive activities (NMPAC 2004); however, in July, 2006, NOAA's Office of Ocean and Coastal Resource Management, National Marine Protected Areas Center published a draft framework report to implement a better systematic approach for developing and managing the National MPAs system (NMPAC 2006). The draft frame report defined and standardized the five EO 13158 terms used for describing MPAs: marine environment, reserved, lasting, area, and protection. In addition, the draft framework report proposed a systematic system for nominating, approving, designating, including, and removing areas of concern from the National MPA system. Overall, the draft framework report (NMPAC 2006) stated the goals of the National MPA system were to: (1) advance comprehensive conservation and management of the nation's significant natural heritage, cultural heritage, and sustainable production marine resources through ecosystem-based MPA approaches; (2) promote sound stewardship and improve the effectiveness of National System MPAs; and (3) enhance effective coordination and integration among National System MPAs and within the broader ecosystem-based management context.

On March 17, 2008, the MPA Center released another Revised Draft Framework for Developing the National System of MPAs due to the significant number (11,000) of comments and recommendations received on the draft framework report. The MPA Center plans to develop a final, revised Framework, and formal response to comments based on the input received and subsequent federal agency review during the next few months (NMPAC 2008b).

Similar to the draft report, the Revised Draft Framework provided an overarching guidance for collaborative efforts among federal, state, tribal, and local governments and stakeholders to develop an effective National System of MPAs. The Revised Draft Framework outlines collaborative processes for MPA programs at all levels of government to work together at regional, national, and international levels, with public participation, to achieve common conservation objectives through comprehensive MPA planning, identification of enhanced or new MPAs that may be needed, and support for improved MPA science, stewardship and effectiveness (NMPAC 2008b). The Revised Draft Framework highlights three goals: (1) Advance comprehensive conservation and management of the nation's biological communities, habitats, ecosystems, and processes, and the ecological services, uses, and values to this and future generations through ecosystem-based MPA approaches; (2) Advance comprehensive conservation and management of cultural resources that reflect the nation's maritime history and traditional cultural connections to the sea, as well as the uses and values they provide to this and future generations through ecosystem-based MPA approaches; and (3) Advance comprehensive conservation and management of the nation's renewable living resources and their habitats, including, but not limited to, spawning, mating, and nursery grounds, and the areas established to minimize incidental bycatch of species, that are important to the nation's social, economic, and cultural well-being through ecosystem-based MPA approaches (NMPAC 2008b).

Many U.S. marine waters already receive some level of managed protection. Presently, as a sequence of steps for developing the MPA National system, through partnerships, NOAA and 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 defined criteria of either a MMAs or an MPA. MMAs are similar to MPAs in that they have conservation or management purpose, defined boundaries, and some legal authority to protect resources. 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 the EO 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). In general, MPAs are sites implemented with conservation measures that do not vary on a yearly basis (NMPAC 2008a)

The first MMA on the U.S. west coast was established as a National Park (Olympic National Park, Washington) in 1909 and the first MMA in California was the Cabrillo National Monument in 1913 (NMPAC 2008a). To date, there are 1,800 MMAs in the U.S. that are managed by federal, state, tribal, and local authorities. To assist with environmental planning, one of the responsibilities of the MPA Center is to maintain a list of MPAs and to regularly publish an updated, summary version (name, location, managing authority or program, name of point of contact). Several federal and one federal/state partnership MPA programs are already established in the U.S. As described below, these federal MPA programs include the DoI's National Park System and National Wildlife Refuge System, and NOAA's National Marine Sanctuary System, National MPA Center, NMFS programs, and the National Estuarine Research Reserve System (NMPAC 2006). In addition to the federal MPA programs, most coastal states have a variety of MPA programs and authorities, often at both the state and local government levels. Federal MPAs are implemented for a variety of reasons and have different conservation goals including protecting biodiversity and habitats, sustainable production of fisheries, and conserving cultural and natural heritage values (NMPAC 2008a). Most MPAs implemented have single conservation focus while others have multiple conservation focuses (NMPAC 2008). In California, more MMAs focus on natural heritage conservation than both natural and cultural heritage combined. MMAs focus State MPA programs can include: historic preservation offices, fish and wildlife agencies, Coastal Zone Management programs, fishery management agencies, parks and recreation agencies, and other authorities. Actually, most MMAs are managed by coastal states (NMPAC 2006).

The National MMA system is continuing to expand. Recently, MMAs on the west coast increased from 6% to 47% as result of NMFS implementing EFH for 52 fish species (NMPAC 2008a). Of the 1,800 MMAs in the U.S., a total of 296 are located on the U.S. west coast (California, Oregon, and Washington State) (NMPAC 2008a). There are 204 MMAs in California, 34 in Oregon, and 61 in Washington (NMPAC 2008a). A few MMAs range across multiple states. Of the total number of MMAs located on the U.S. west coast, 188 (64%) are under the authority of local governments and 81 (27%) are under the authority of the federal government. The remaining 27 (9%) MMAs are managed under partnerships and local government programs (NMPAC 2008a). Although most MPAs are state managed, federal MPAs manage larger geographical areas. Depending on the area, some user activities are prohibited altogether and others are not. Most (80%) west coast MPAs are multiple use and offer year around protection and others (20%) offer no spatial protection or no-take prohibition and only have seasonal protection (NMPAC 2007; NMPAC 2008a). In California, almost every MMA, except for two, provides permanent or long-term protection. The restricted no-take MMAs represent only 0.3% of the total MMA area, whereas multiple use represent 99.7% (NMPAC 2008). In general, multiple use MMAs are managed federally and no take and no access MMAs are managed by state government (NMPAC 2008a). Sixty-six percent of west coast MPAs focus on protecting whole ecosystems, while the remainder protect specific species or habitat features. In California, most MMAs (81%) focus on the protection of ecosystems while the remainder (19%) protect focal species. MMAs implemented to manage entire ecosystems only represent a small segment (8%), in terms of geographical area, whereas 92% of west coast MMAs were implemented to protect specific species or groups of species, which represent larger geographical areas (NMPAC 2008a). In the U.S., California leads the nation in developing comprehensive MPA state systems and has jurisdiction over the majority (69%) of MPAs. MPAs located off California (n = 189) protect about 47% or 14,984 km^2 of state waters (NMPAC 2007). Most MMAs have overlapping boundaries with often different regulations (NMPAC 2008a). In these situations, all regulations apply. According to the current List of MPAs,[23] various sites are located within the boundaries of the SOCAL/Pt. Mugu Study Area and are described below (**Figure 2-25**).

2.8.1.1 National Marine Sanctuaries

Of the total number of federally managed MMAs, the National Marine Sanctuaries Program (NMSP) manages the second largest portion of MMAs on the U.S. west coast (NMPAC 2008a). Under the authority of the National Marine Sanctuaries Act (U.S.C. 1431 et. seq.), the NMSP oversees 14 MPAs, encompassing around 150,000 m^2 of marine and Great Lakes waters from Washington State to the Florida Keys, including Lake Huron to American Samoa. The system includes 13 NMS and the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, which is currently being considered for sanctuary status (NMPAC 2006). Each NMS has its own established management plan that guides the activities, sanctuary programs, sets priorities, and contains relevant regulations. NMSs have been designated in some of the most unique marine areas providing habitats for many marine resources. Recently, new research points out that NMS waters provide habitats for many cetacean species (Forney 2007). In fact, Forney (2007) found that the densities for some cetaceans were greater within NMS waters than previously found for other areas (Forney 2007).

Of the 13 U.S. designated NMSs, only the CINMS and Monterey Bay NMS (MBNMS) are located within the boundaries of the SOCAL/Pt. Mugu Study Area (**Figure 2-25; Table 2-13**). The CINMS encompasses a variety of unique marine habitats including kelp forests, surf and eel grasses, intertidal, nearshore subtidal, deep water benthic habitat, and water column habitat (NMPAC 2006). Because of the ecological uniqueness, the CINMS provides habitat to 492 species of marine algae, 4 species of seagrasses, over 5,000 species of invertebrates, 481 species of fish, 4 species of sea turtles, 33 cetaceans, 7 pinnipeds, sea otters, and over 195 species of birds (NMPAC 2006).

NOAA designated the CINMS in 1980 and set aside 1,252 square nautical miles (nm^2) of protected area (NOAA 1980). In accordance with Title III of the Marine Protection, Research and Sanctuaries Act, the waters within 6 nm of the northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa islands) and Santa Barbara Island were formally designated as a NMS. The sanctuary lies between 8 nm and 40 nm off the southern California mainland, north of Los Angeles and immediately south of the Santa Barbara Channel. California state waters extends 3 nm from the shores off each these islands.[24] Within these boundaries there are several regulatory agencies (i.e., federal, state, and local) that have overlapping jurisdiction and various activities which are prohibited “except as may be necessary for national defense”.[25] Recently, NOAA issued a final rule on May 24, 2007 (NMSP 2007) to establish a network of marine zones (marine reserves and marine conservation areas) within the state and federal waters of the CINMS. Further information about these regulations is available from the CINMS website.[24,25] By adding four more marine reserves, the new regulations expanded the overall CINMS size by 15 nm^2. The action also refined the estimated size of the CINMS to 1,128 nm^2 which was an improvement to the previous estimated size. The new total area designated as marine reserve was 110.5 nm^2 and the new marine conservation area encompassed an additional 1.7 nm^2. As a result of this action, the CINMS is now the largest marine zoning network in the U.S.

The second and largest NMS in the U.S. is the MBNMS, which was designated in 1992.[26] The MBNMS, encompasses more than one-quarter (approximately 563 km) of the California coast. The MBNMS (4,024 nm^2) extends from Rocky Point (just north of San Francisco's Golden Gate Bridge) to Cambria (just north of Morro Bay), and from mean high tide to a seaward boundary an average of 56 km offshore.

Similar to the CINMS, the MBNMS was established for the purpose of resource protection, research, education, and public use. The sanctuary has many unique features including the nation's largest kelp forest, one of North America's largest underwater canyons, and the closest-to-shore deep ocean environment in the continental U.S. The MBNMS is home to one of the most diverse marine ecosystems in the world, providing habitat for 33 species of marine mammals, 94 species of seabirds, 345 species of fishes, and numerous invertebrates and plants.[26] The geology of the area is also unique, consisting of sandy beaches, rocky cliffs, rolling hills, and steep mountains. As stated above, each NMS has its own governing rules and regulations and management plan. There are no current new or proposed regulations, but the MBNMS is an area of intense research activity.

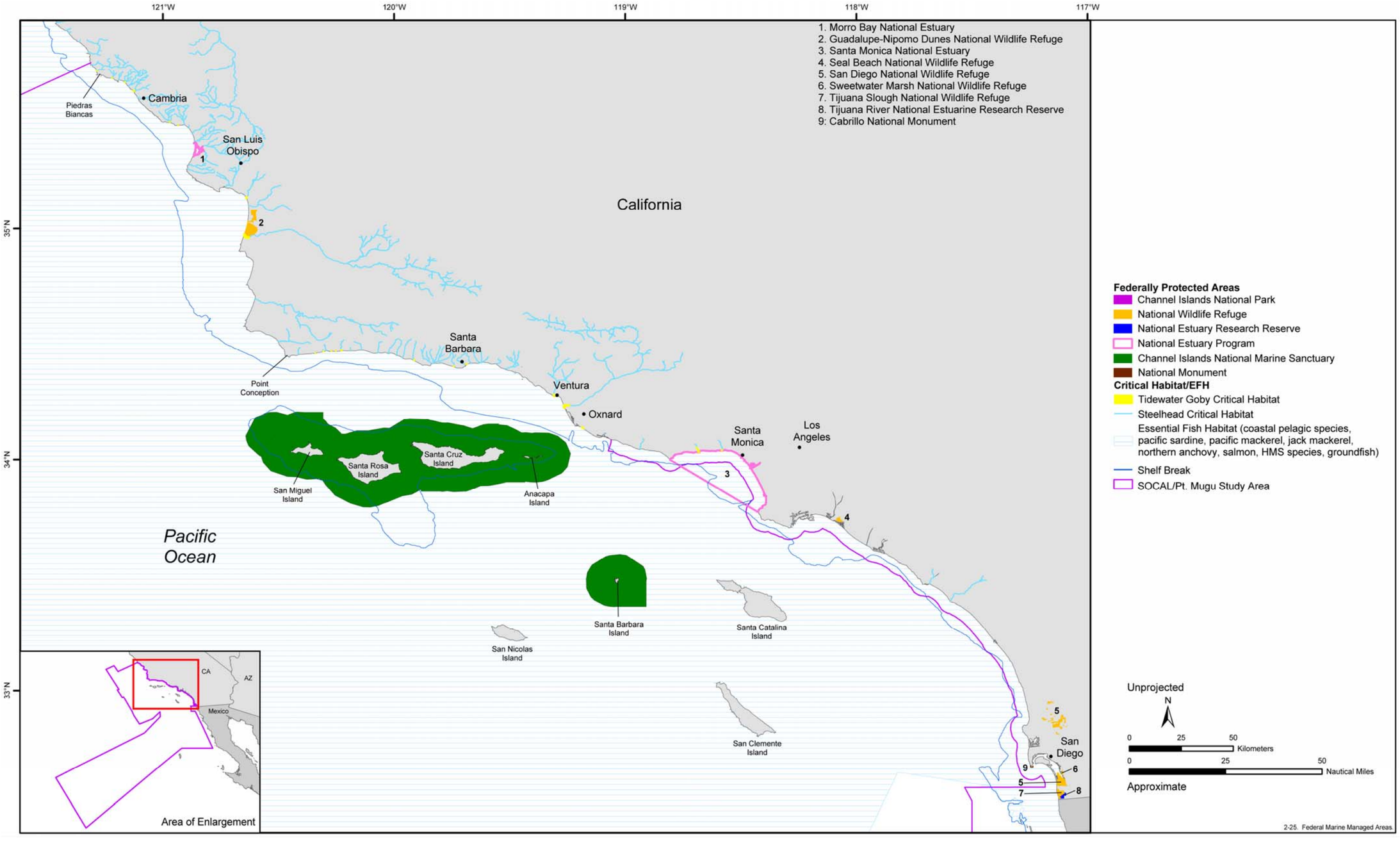

Figure 2-25. Locations of federal marine managed areas in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Hobday and Tegner (2000), NPS (2004), TerraLogic GIS and S. Copps (2004), USFWS (2004), NMFS (2005), EPA (2008), MPAC (2008), and USFWS (2008a,b).

2.8.1.2 National Seashores

One key type of MPA is a designated National Seashore. The National Park Service (NPS) has designated ten national seashores on the Atlantic, Gulf and Pacific coasts. The only national seashore in California is Point Reyes National Seashore, which is located off the coast of central California just north of San Francisco Bay. There are no national seashores located within the boundaries of the SOCAL/Pt. Mugu Study Area.[27]

2.8.1.3 National Parks and National Monuments

Other types of MPAs are National Parks and National Monuments. The National Park (NP) System is composed of 391 areas covering more than 33,858,000 ha (83.6 million ac) in 49 states, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the U.S. Virgin Islands (USVI).[28] NPs are generally large natural areas, with a wide variety of attributes or significant historic assets.[28] The NPS Organic Act of 1916 established the National Park System with "the fundamental purpose to conserve the scenery and the natural and historic objects and the wild life 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".[29]

There are nine NPs located in California that are managed under the NPS (**Figure 2-25**; **Table 2-13**). One National Monument (NM) and one NP are located within the boundaries of the SOCAL/Pt. Mugu Study Area.[27] Cabrillo National Monument is the only NM found inside the SOCAL OPAREA. This lighthouse monument is located in San Diego, California on 64.8 ha (160 ac) of the southern most point of the Point Luma peninsula.[28] Cabrillo National Monument was dedicated in 1913 to commemorate Juan Rodríguez Cabrillo, who was the first European to set foot on the west coast of the U.S., landing at San Diego Bay in 1542. A variety of marine bird species utilize this park, and its rocky coastline provides habitat for a variety of marine plants and invertebrates. Additionally, many marine mammal species can be observed migrating along the coast from this monument.

The only NP located within the boundaries of the SOCAL/Pt. Mugu Study Area is the Channel Islands NP. The Channel Islands NP consists of a chain of five islands (San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara) near Los Angeles covering 100,911 ha (249,353 ac), half of which are underwater.[30] The park boundaries extend 1 nm from each of the island's shorelines, which is within California state waters.

In addition to NPs managed under the NPS, the BLM also oversees NPs. The only other NP located within the boundaries of the SOCAL/Pt. Mugu Study Area is the California Coastal National Monument (CCNM) which consists of approximately 1,221 km (1,100 mi) or 405 ha (1,000 ac) of the California coastline. The CCNM consists of more than 20,000 BLM administered small islands, rocks, exposed reefs, and pinnacles. The area is described as those public lands that are exposed above the mean high tide line and within the corridor extending 12 nm from the shoreline between Mexico and Oregon.[31] The CCNM is among the most viewed but the least recognized of any of the Nation's national monuments. The primary purpose of the CCNM is to protect the important geologic features and the unique habitat they provide for both terrestrial and marine plants and animals found within its boundaries. In addition, the proclamation recognizes the CCNM as containing "irreplaceable scientific values vital to protecting the fragile ecosystems of the California coastline." [34] The management of CCNM focuses on the following four areas: (1) Preservation; (2) Partnerships; (3) Landscape; and (4) Communities.

The Channel Islands as mentioned in **Section 2.8.1.1** are also a NMS. In addition, these islands are designated as a Biosphere Reserve, which is internationally recognized under the U.N. Educational, Scientific, and Cultural Organization's (UNESCO's) Man and the Biosphere (MAB) Programme. Despite this international designation, the Channel Islands remain under the jurisdiction of the U.S. government (Chape et al. 2003).

2.8.1.4 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 and the statutory requirements of the ESA, the NMFS uses ESA designated critical habitats and protected areas as one of several tools to conserve and mange marine resources. ESA designated critical habitat areas exist in the SOCAL/Pt. Mugu Study Area for the steelhead salmon and tidewater goby(**Figure 2-25**; **Table 2-13**) (NMFS 2000; USFWS 2000; USFWS 2008). White abalone is also protected, but ESA critical habitat has not officially been designated. Further information regarding critical habitat is available in **Section 3.4** of this MRA.

2.8.1.5 Essential Fish Habitat

As a requirement of the MSFCMA, another type of MPA is EFH designation. Within the SOCAL-Pt. Mugu Study Area, there are various fish group EFH designations. Among these include, CPS (finfish (Pacific sardine, Pacific (chub) mackerel, northern anchovy and jack mackerel), krill, and market squid), salmon, HMS species (sharks, tunas, billfish, swordfish), and groundfish. There are a total of 107 fish and invertebrate species with designated EFH that occur in the SOCAL/Pt. Mugu Study Area (**Table 4-1**; **Appendix D)**. As such, the NMFS manages and designates the largest fraction of MMAs within the SOCAL/Pt. Mugu Study Area (NMPAC 2008a).

In addition to EFH, the MSFCMA encourages Councils to designate HAPCs. Within the SOCAL/Pt. Mugu Study Area, there are defined HAPCs that include estuaries, canopy kelp, seagrass, rock reefs, and “areas of interest”. There are also various defined HAPCs for Pacific groundfish. Further information regarding EFH and HAPC is available in **Section 4.4** (**Figure 4-1**).

2.8.1.6 Fishery Closures

NMFS has the responsibility of evaluating declining fish stocks and utilizing tools to conserve and maintain fishery and marine resources. For the purpose of protecting and rebuilding localized commercial and recreational fishery populations to harvestable levels, temporary, seasonal, or permanent fishery closures are sometimes implemented as a management approach. Fishery closures occur around the Channel Islands and other ecological important areas such as banks and seamounts. In total there are 23 closed areas within the SOCAL/Pt. Mugu Study Area. Further information regarding Fishery closures is available in **Section 4.5** (**Figure 4-2**).

2.8.1.7 National Wildlife Refuges

One of the oldest types of MPA is the NWR. The USFWS, which oversees the NWR System (NWRS), protects a significant amount of marine habitat within U.S. waters. The first NWR was designated in 1903 at Florida’s Pelican Island. Today, the NWRS is comprised of 548 established NWRs, of which approximately 140 to 150 contain marine and estuarine habitat. There is at least one NWR in every state. NWRs provide habitat for many marine plants and animals including various endangered and threatened species. NWRs are usually located in estuarine, wetlands, salt marshes, and intertidal zone areas and usually not designated in offshore marine areas (NMPAC 2008a).

Located within the SOCAL OPAREA is the San Diego Wildlife Refuge Complex,[32] which is composed of a series of small NWRs: San Diego NWR (3,839 ha or 9,478 ac), Seal Beach NWR (369 ha or 911 ac), Tijuana Slough NWR (426 ha or 1,051 ac), and Sweetwater Marsh NWR (128 ha or 316 ac) (**Figure 2-25**; **Table 2-13**).

Also located within the vicinity of the SOCAL/Pt. Mugu OPAREA is the Guadalupe-Nipomo Dunes Refuge Complex (1,094 ha or 2,700 ac).[32] Both complexes were established to preserve and protect rare bird and plant species of southern California’s coastal ecosystem (i.e., salt marshes, mudflats, eel grass beds) (USFWS n.d.).

2.8.1.8 National Estuarine Research Reserves

The National Estuarine Research Reserves (NERR) System (NERRS) is a partnership between NOAA and the coastal states that consists of a network of 27 relatively pristine estuarine areas representing different biogeographic regions of the U.S. These reserves contain key habitat areas that are protected for long-term research, water-quality monitoring, education, and coastal stewardship. Each reserve is managed on daily basis by a lead state agency or university, with input from local partners. The reserves also provide reference sites for research, monitoring, and educational programs that focus on functional estuarine ecosystems. NERRSs provide habitats for a variety of rare, endangered, and threatened species.

Of the 27 NERRS, only one NERR is located within the boundaries of the SOCAL OPAREA. Designated in 1982, the Tijuana River National Estuarine Research Reserve is located in San Diego County on the U.S./Mexico border (**Figure 2-25**; **Table 2-13**). The 1,013 ha (2,500 ac) reserve contains a variety of habitats, including salt marshes, mudflats, beaches, dunes, riparian zones, and coastal sage environments.[33] The reserve provides habitat for eight threatened and endangered species, including the light-footed clapper rail, California least tern, Least Bell's vireo, salt marsh bird's beak, cordgrass, white and brown pelicans, and numerous shorebirds. The reserve environment is a saline marsh habitat for most of the year with the Tijuana River being an intermittent stream system in a Mediterranean environment. Under the NERR regulations, the DoD (15 CFR 921) is not exempt from evaluating the potential impacts from any activities conducted within any NERR.

2.8.1.9 National Estuary Program

The National Estuary Program (NEP) was established in 1987 to improve the quality of estuaries of national importance. Section 320 of the CWA directs the EPA to develop plans for attaining or maintaining water quality in an estuary. This includes protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, and allows recreational activities, in and on water, requires that control of point and nonpoint sources (NPSs) of pollution to supplement existing controls of pollution (PSAT 2000). Presently, there are 28 designated estuaries in the U.S. Of these, two (Morro Bay and Santa Monica Bay) are located within the SOCAL/Pt. Mugu Study Area (**Figure 2-25**; **Table 2-13**).

The Morro Bay Estuary was classified under the NEP in July 1995. It encompasses 242 km^2 and contains the most significant wetland system on California's south central coast.[34] This NEP serves a critical environmental function of the Pacific coast by sustaining many species of migratory birds and provides a protected harbor for various off-shore marine fisheries.

In 1988, Santa Monica Bay was classified under the NEP.[35] Encompassing 1465 km^2; Santa Monica Bay is one of Southern California's prime recreational destinations. One of the primary goals of the Santa Monica Bay Restoration Project has been to attend to water quality. Due to public concerns regarding potential health risks to bay swimmers, this NEP's focus has been to evaluate storm water runoff. To help achieve the overall goal, a landmark epidemiology study--the first of its kind--was conducted in 1995 to assess the health risks of swimming in bay waters contaminated by storm drain runoff.

2.8.1.10 Ecological/Historical Preserves

Ecological and historical preserves are managed by the NPS. There are no known federal ecological or historical preserves within the vicinity of the SOCAL/Pt. Mugu Study Area.

2.8.2 State Marine Managed Areas

California Marine Managed Areas

NOAA and USFWS are working with states to collect data on sites managed by their state agencies for inclusion in the National MMA Inventory. A State Advisory Group was established with regional

representatives to guide the development of the state data collection process. Data collection has been initiated for most states and is in various stages of completion.[23] In California, there are various types of state marine managed areas including: ecological reserves, marine reserves, refuges, marine conservation areas, recreational management areas, and marine parks. Each has its own defining criteria, regulations, and management (**Figure 2-26**; **Table 2-13**).

In California, the authority for state marine managed areas was established with the MLPA (Assembly Bill 993).[36] The MLPA 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” (CDFG 2008).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 (CDFG 2008).

There are six MLPA goals established in California Fish and Game Code Section 2853(b).[36] The goals 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, to the extent possible, as a network (CDFG 2008).

In addition to the MLPA, the state of California manages its marine resources under the authority of the California Coastal Act and the California Coastal Sanctuary Act (CCSA) of 1994. In 1994, the California Coastal Sanctuary, established under the CCSA, included all California state waters from the northern Oregon border south to the Mexico border. The boundary is defined as the mean high tide line to the 3-nm limit and includes all offshore rocks and islands. The Department of Fish and Game has estimated California’s state water surface area to be approximately 8,391 km^2 (5,212 square miles [mi^2]), which does not include any estuaries, lagoons, or any other bays such as San Francisco Bay. The primary purpose of the CCSA is to prohibit the establishment of oil and gas development within state waters.

2.8.2.1 Ecological Reserves

State Ecological Reserves have a boundary that extends seaward out to 1 nm. Some reserves allow for the limited taking of some invertebrate or aquatic plant species, while some reserves prohibit the taking of any marine life. Enforcement on these Reserves is usually the responsibility of the CDFG (see CDFG 2002 for more details). Of the total 262 California protected areas, there are 22 California State Ecological Reserves within the boundaries of the SOCAL/Pt. Mugu Study Area (**Figure 2-26**; **Table 2-13**).

2.8.2.2 State Marine Reserves

According to the California Marine Life Protection Act Initiative,[36] a "SMR," is defined as a non-terrestrial marine or estuarine area that is designated so the managing agency may achieve one or more of the following: (1) protect or restore rare, threatened or endangered native plants, animals or habitats in marine areas; (2) protect or restore outstanding, representative or imperiled marine species, communities, habitats and ecosystems; (3) protect or restore diverse marine gene pools; or (4) contribute to the understanding and management of marine resources and ecosystems by providing the opportunity for scientific research in outstanding, representative or imperiled marine habitats or ecosystems.[25]

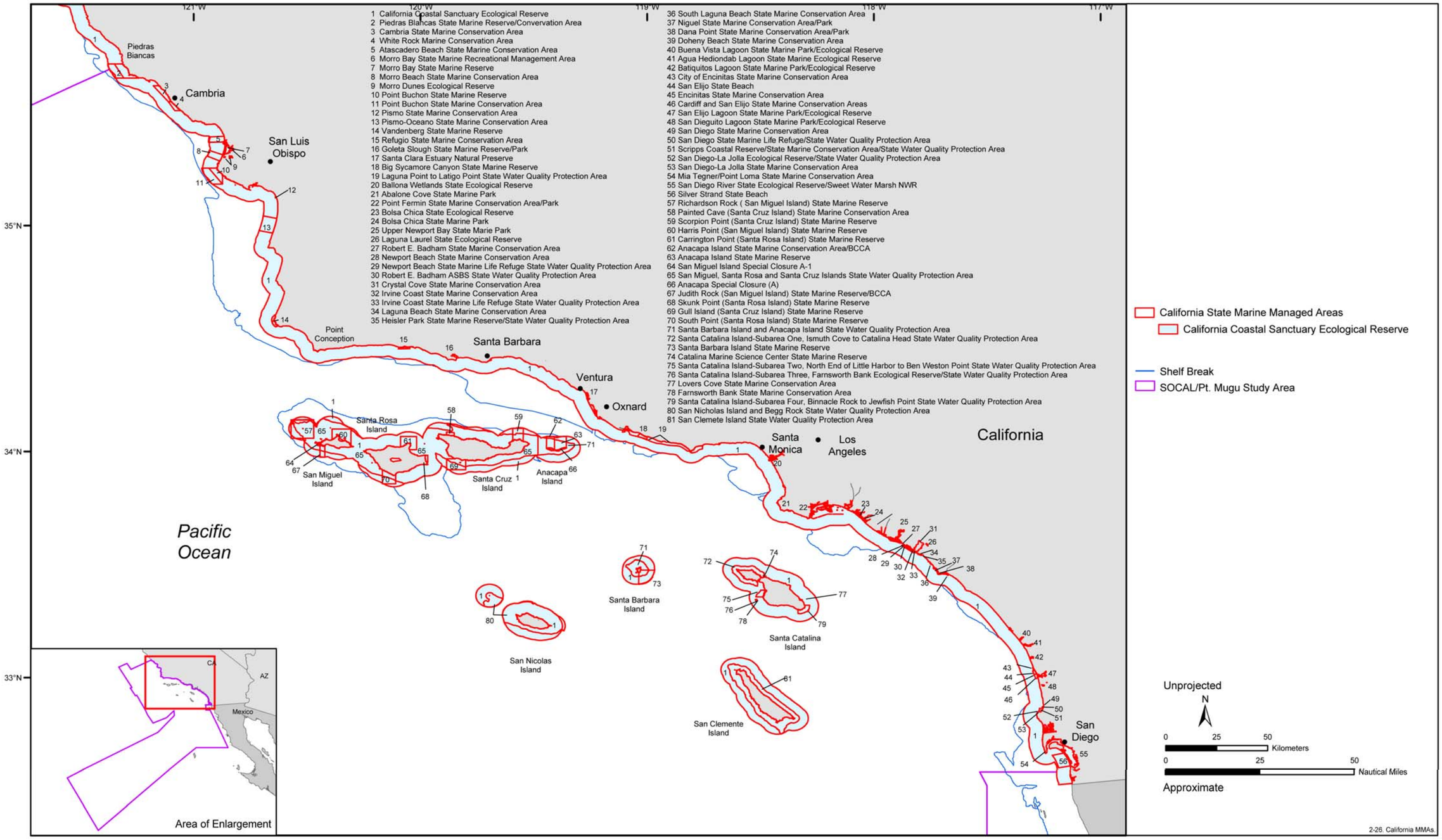

Figure 2-26. Locations of state marine managed areas in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: MPAC (2008) and USFWS (2008a,b).

Table 2-13. Marine Protected Areas found within SOCAL/Pt. Mugu Study Area.

Federal MPA	
NMS	CINMS and MBNMS
National Seashores	None
National Parks and Monuments	Channel Islands National Park, Cabrillo National Monument, and California Coastal National Monument
ESA Critical Habitats	Steelhead salmon, and tidewater goby. White abalone protected, but ESA-critical habitat not "officially" designated.
EFH	Coastal pelagic species (CPS) (finfish (Pacific sardine, Pacific (chub) mackerel, northern anchovy and jack mackerel), and market squid), salmon, HMS species (sharks, tunas, billfish, swordfish), and groundfish (82 species).
Fishery Closures	Point Sur Deep, TNC/ED Areas 1, 2, 3, Potato Bank, Cherry Bank, Hidden Reef/Kidney Bank, Catalina Island, Cowcod Conservation Area East, Davidson Seamount, Anacapa Island SMCA, Anacapa Island SMR, Carrington Point, Footprint, Gull Island, Harris Point, Judith Rock, Painted Cove, Richardson Rock, Santa Barbara, Scorpion, Skunk Point, and South Point
HAPC	Estuaries, canopy kelp, seagrass, rocky reefs, and "areas of interest".
National Wildlife Refuges	San Diego NWR, Seal Beach NWR, Tijuana Slough NWR, and Sweetwater Marsh NWR, Guadalupe-Nipomo Dunes Refuge Complex
State MPA	
Ecological Reserves	Abalone Cove Ecological Reserve, Farnsworth Bank Ecological Reserve, San Diego-La Jolla Ecological Reserve, Heisler Park Ecological Reserve, Point Loma Reserve, Lovers Cove Reserve, Morro Beach Pismo Clam Preserve, San Miguel Island Ecological Reserve, Anacapa Island Ecological Reserve, Anacapa Island Ecological Reserve Natural Area, Santa Barbara Island Ecological Reserve, Aqua Hedionda Lagoon, Buena Vista Lagoon, Goleta Slough, San Elijo Lagoon, Ballona Wetlands, Burton Mesa, Laguna laurel, San Diego River, Batiquitos Lagoon, Bolsa Chica, and San Dieguito Lagoon
State Marine Reserves	Piedras Blancas State Marine Reserve, Morro Bay State Reserve, Point Buchon State Marine Reserve, Vandenberg State Marine Reserve, Richardson Rock State Marine Reserve (San Miguel Island), Judith Rock State Marine Reserve (San Miguel Island), Harris Point State Marine Reserve (San Miguel Island), South Point State Marine Reserve (Santa Rosa Island), Carrington Point State Marine Reserve (Santa Rosa Island), Skunk Point State Marine Reserve (Santa Rosa Island), Gull Island State Marine Reserve (Santa Cruz Island), Scorpion State Marine Reserve (Santa Cruz Island), Santa Barbara Island State Marine Reserve, Anacapa State Marine Reserve, Big Sycamore Canyon State Marine Reserve, Catalina Marine Science Center State Marine Reserve, Heisler Park State Marine Reserve, and Agua Hedionda Lagoon State Marine Reserve.
State Marine Life Refuges	Point Fermin Marine Life Refuge, Catalina Marine Science Center Marine Life Refuge, Newport Beach Marine Life Refuge, Irvine Coast Marine Life Refuge (encompasses the inshore area of Crystal Cove State Park), Laguna Beach Marine Life Refuge, South Laguna Beach Marine Life Refuge, Niguel Marine Life Refuge, Dana Point Marine Life Refuge, San Diego Marine Life Refuge, Doheny Beach Marine Life Refuge, and City of Encinitas Marine Life Refuge.
State Marine Conservation Areas	Piedras Blancas State Marine Conservation Area, Atascadero Beach, Morro Beach, Cambria State Marine Conservation Area, Cambria (White Rock) State Marine Conservation Area, Point Buchon State Marine Conservation Area, Painted Cave State Marine Conservation Area (Santa Cruz Island), Refugio State Marine Conservation Area, Anacapa State Marine Conservation Area, Farnsworth Bank State Marine Conservation Area, Lover's Cove State Marine Conservation Area, Robert E. Badham State Marine Conservation Area, Crystal Cove State Marine Conservation Area, Doheny State Marine Conservation Area, Encinitas State Marine Conservation Area, Cardiff and San Elijo State Marine Conservation Area, San Diego-Scripps State Marine Conservation Area, La Jolla State Marine Conservation Area, Mia J. Tegner State Marine Conservation Area, Buena Vista Lagoon State Marine Park, Batiquitos Lagoon State Marine Park, San Elijo Lagoon State Marine Park, and San Dieguito Lagoon State Marine Park.

Table 2-13 (*continued*). Marine Protected Areas found within SOCAL/Pt. Mugu Study Area.

State MPA	
State Marine Recreational Management Areas	Morro Bay State Marine Recreational Management Area
State Parks	Abalone Cove State Marine Park, Point Fermin State Marine Park, Bolsa Chica State Marine Park, Upper Newport Bay State Marine Park, Robert E. Badham State Marine Park, Irvine Coast State Marine Park, Laguna Beach State Marine Park, South Laguna Beach State Marine Park, Niguel State Marine Park, Dana Point State Marine Park, Doheny State Marine Park, Buena Vista Lagoon State Marine Park, Batiquitos Lagoon State Marine Park, San Elijo Lagoon State Marine Park, and San Dieguito Lagoon State Marine Park.
Other MPA	
Habitats of Concern	Castle Rock Complex, Hurricane Point Offshore, Point Sur to Pfeiffer, Point Sur South, J. Pfeiffer Inshore, J. Pfeiffer Offshore Canyons, Partington Canyon, Big Creek, Gamboa Point, Lopez Point, Gorda, Plaskett Ragged Point, Pt. Pideras Blancas, P.B. Offshore, Cambria North, South Cambria, Morro Bay Estuary, Atascadero Beach, Morro Beach, Point Buchon, Diablo, Oceano, Point Sal, North Seabird Colony, South Seabird Colony, Offshore Habitat, Point Argrello, Offshore Nutrient Zone, and Espada Bluff Nutrient Zone.
Particularly Sensitive Sea Area	None
Ocean Sanctuaries	None
State Water Quality Protection Areas	Channel Islands, South Channel Islands, Newport Beach, Irvine Coast, Heisler Park, Catalina Head, Little Harbor, Ismuth Cove to Catalina Head, Farnsworth Bank, North End of Little Harbor to Ben Weston Point, Robert E. Badham, Binnacle Rock to Jewfish Point, San Nicolas Island, San Clemente Island, Scripps, Laguna Point to Latigo Point, La Jolla, San Diego.
California Critical Coastal Areas	Morro Bay, Chorro Creek, Los Osos Creek, San Luis Obispo Creek, Santa Ynez River, Goleta Slough, Carpinteria Marsh, Santa Barbara and Anacapa Islands, San Miguel, Santa Rosa, and Santa Cruz Islands.

Per the requirements of the Act, the Fish and Game Commission was required to establish along the California coast four marine ecological reserves, with the purpose "to provide for scientific research related to the management and enhancement of marine resources" (CDFG 2002). Enforcement on these reserves is the responsibility of the CDFG (see (CDFG 2002) for more details). There are 18 California SMRs within the boundaries of the SOCAL/Pt. Mugu Study Area (CDFG 2007) (**Figure 2-26**; **Table 2-13**).

2.8.2.3 State Marine Life Refuges

State marine life refuges allow some commercial or recreation takes of various invertebrate or aquatic plant species, while others prohibit the take of any marine life all together. Enforcement in these refuges is the responsibility of the CDFG (see (CDFG 2002) for more details). There are 11 California State Marine Life Refuges within the boundaries of the SOCAL/Pt. Mugu Study Area (**Figure 2-26**; **Table 2-13**).

2.8.2.4 State Marine Conservation Areas

State Marine Conservation Areas (SMCAs), among other things, limit recreation and commercial fishing activities. There are 23 California SMCAs within the boundaries of the SOCAL/Pt. Mugu Study Area(**Figure 2-26**; **Table 2-13**) (CDFG 2007).

2.8.2.5 State Marine Recreational Management Areas

Morro Bay State Marine Recreational Management Area (SMRMA) is the only one California SMRMA located within the vicinity of the SOCAL/Pt. Mugu Study Area (**Figure 2-26**; **Table 2-13**) (CDFG 2007).

2.8.2.6 State Parks

The California State Park system protects over 450 km of coastline, 1,006 km of freshwater frontage, wetlands, beaches, estuaries, and dune systems, totaling half a million ha of coverage (RAC 2000). State parks are designed to preserve and protect the natural, scenic, cultural, and marine and terrestrial environments and ecosystems for future generations. State park enforcement is the responsibility of the CDFG (see (CDFG 2002) for more details). There are 15 California State Parks within the boundaries of the SOCAL/Pt. Mugu Study Area (**Figure 2-26**; **Table 2-13**).

2.8.2.7 State Water Quality Protection Areas

The state of California designated 34 coastal regions under the 1972 California Ocean Plan as State Water Quality Protection Areas (SWQPAs), formally known as ASBSs, in an effort to preserve these unique and sensitive marine ecosystems for future generations (Baggett et al. 2007). The list of SWQPA was designated to be used for identifying areas in planning in regards to non-point discharge sources. The Ocean Plan was adopted by the State Water Board in 1972 and amended in 1978, 1983, 1988, 1990, 1997, 2001, and 2005. Under the SWQPA, there are four designated California regions (North Coast Region, San Francisco Bay Region, Central Coast Region, and South Coast Region) which are also defined as California Critical Coastal Areas (CCAs) (Baggett et al. 2007). Although non-regulatory, the CCA program is an innovative program to foster collaboration among local stakeholders and government agencies, to better coordinate resources and focus efforts on coastal watersheds in critical need of protection from polluted runoff. Under the program, waste discharges are prohibited. The CCA program has identified an initial list of 101 CCAs along the coast and in San Francisco Bay. Within the boundaries of the SOCAL/Pt. Mugu Study Area, there are 18 designated SWQPA sites and 12 designated CCA sites (**Figure 2-26**; **Table 2-13**).

2.8.3 Mexico Marine Managed Areas

There are no Mexican protected areas located within the boundaries of SOCAL/Pt. Mugu Study Area; however, only one Mexican protected natural area, Guadalupe Island, is found within the vicinity.[37]

2.8.4 Additional Unofficial Marine Habitats of Concern

In some sensitive areas, like off the central and southern coast of California, there are various areas that are unofficial types of MPAs called habitats of concern. Ecologically sensitive areas are often proposed by various world non-government organizations (NGOs), such as Oceana. Recently, Oceana published a report highlighting and designating 51 important ecological areas of the central California coast.[38]. The areas were designated important on the basis of fish, seabird, marine mammal, habitat, and geologic data. Although many of the 51 designated areas are already protected by the state and federal government, some are not. MPAs often become officially protected by state and federal governments through campaigns initiated by NGOs; thus, these unofficial marine habitats of concern also need to be considered when evaluating MPAs within the SOCAL/Pt. Mugu Study Area. Grass-roots campaigns and environmental lobbyist should always be considered important constituents when evaluating any potential impacts to the local environment. Most of the 51 areas already have been designated under either state or federal governments.[38] Of the 51 Oceana designated areas, 31 are found within the SOCAL/Pt. Mugu Study Area (**Table 2-13**).

2.8.5 International Marine Protected Areas

2.8.5.1 Particularly Sensitive Sea Area

A special international type of MPA is called a Particularly Sensitive Sea Area (PSSA). PSSA is an area that "needs special protection through action by the IMO because international shipping activities may negatively impact an ecological, socio-economic, or scientific importance area (WWF-UK and The Wildlife Trusts 2003). Eleven PSSAs have been designated world-wide. Only one is located in the United States (Florida Keys) and none are located off the coast of California or within the SOCAL/Pt. Mugu Study Area (**Table 2-13**).[39]

2.8.6 Marine Environmental High Risk Area

Marine Environmental High Risk Areas (MEHRAs) were initially implemented as a United Kingdom national initiative in 1994 (WWF-UK and The Wildlife Trusts 2003).The emphasis of MEHRAs is ship routing measures. The aim is to encourage ships to follow routes where vessels are less likely to collide with each other in areas that have highly sensitive marine resources. Overall importance is maritime safety and the marine environment. There are no MEHRAs located off the coast of California or within the SOCAL/Pt. Mugu Study Area (**Table 2-13**).

2.8.7 Ocean Sanctuaries

International and domestic Ocean Sanctuaries (OSs) were initiated as a basis for whale conservation and management, but these designated areas are now used as a tool for protecting the environment. The first ocean sanctuary was established in 1938 in the South Pacific sector of the Southern Ocean (south of 40°S between longitudes 70°W and 160°W).[40,41] It was deregulated on the advice of the International Whaling Commission (IWC) Scientific Committee in 1955 in an attempt to relieve pressure on the other, overexploited areas of the Antarctic. Since then, two additional sanctuaries have been adopted: the Indian Ocean Sanctuary (IOS) in 1979 (renewed in 2002) and the Southern Ocean Sanctuary in 1994 (Zacharias et al. 2006). There are no international or U.S. OS located off the coast of California or within the SOCAL/Pt. Mugu Study Area (**Table 2-13**).

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3.0 SPECIES OF CONCERN

This chapter provides detailed information for protected marine mammals and sea turtles as well as birds, fish, and invertebrates which are endangered, threatened, species of concern, and one candidate species. These species are of particular interest to the Navy due to their protected status and potential to be impacted by Navy activities.

Marine mammals, which include cetaceans (whales, dolphins, and porpoises); pinnipeds (seals, fur seals, and sea lions); and sea otters, are the taxon group with the largest number of federally-protected species in the SOCAL/Pt. Mugu Study Area. **Section 3.1** of this chapter provides information on the 46 marine mammal species with potential occurrence in the SOCAL/Pt. Mugu Study Area and vicinity. All marine mammals are protected by the MMPA; six cetacean, two pinniped, and one sea otter species are also listed as threatened or endangered under the ESA. An overview of marine mammals, as well as a brief introduction to acoustics and hearing, is included. A detailed narrative has been prepared for each marine mammal species, consisting of a species' description, status, habitat associations, distribution (including a focus on the SOCAL/Pt. Mugu Study Area and vicinity), behavior and life history, and an account of its vocalizations and hearing capabilities (when available). Migration, critical habitat, and haulout site maps are embedded within this section (**Figures 3-1** through **3-10**). Maps depicting the seasonal occurrence records and predicted areas of occurrence for each marine mammal species in the Study Area and vicinity are found in **Appendix B** (**Figures B-1a** through **B-41b**).

Five sea turtle species are known or have the potential to occur in the SOCAL/Pt. Mugu Study Area and all are either threatened or endangered under the ESA. **Section 3.2** of this chapter consists of an overview on sea turtle biology and life history and provides basic information on the hearing capabilities of these animals. Each of the sea turtle species is described in detail by its physical description, status, habitat associations, distribution (including a focus on the SOCAL/Pt. Mugu Study Area and vicinity), and behavior and life history. Tagging tracks and conservation zone maps are embedded within the section (**Figures 3-11** through **3-14**). Maps depicting the seasonal occurrence records and predicted areas of occurrence for each sea turtle species in the Study Area and vicinity are found in **Appendix C** (**Figures C-1a** through **C-6**).

Seven bird species that may occur in the SOCAL/Pt. Mugu Study Area and vicinity are discussed in this chapter. Five are listed as endangered or threatened under the ESA, one is a candidate species, and one is listed as a species of special concern for the state of California. **Section 3.3** of this chapter provides information about the physical description, status, habitat associations, distribution (including a focus on the SOCAL/Pt. Mugu Study Area and vicinity), and behavior and life history of these species. Maps depicting the occurrence records (if any) and predicted distributions (e.g., breeding and foraging) of each bird species in the Study Area and vicinity are embedded in this section (**Figures 3-15** through **3-24**).

The steelhead trout (*Oncorhynchus mykiss*) and tidewater goby (*Eucyclogobius newberryi*) are the only threatened or endangered fish species occurring in the SOCAL/Pt. Mugu Study Area and vicinity while the white abalone (*Haliotis sorenseni*) is the only ESA-listed invertebrate species. **Section 3.4** of this chapter includes a discussion of the physical description, status, habitat associations, distribution (including a focus on the SOCAL/Pt. Mugu Study Area and vicinity), and behavior and life history of each species. Maps depicting the distribution and/or critical habitats of these fish and invertebrate species in the Study Area and vicinity are embedded in this section (**Figures 3-25** through **3-27**).

The locations of literature citations in Chapter 3 differ from other MRA chapters. Literature cited in the marine mammal section is found at the end of **Section 3.1**, literature cited in the sea turtle section is found at the end of **Section 3.2**, and so forth.

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3.1 MARINE MAMMALS

3.1.1 Introduction

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

The vast majority of the 46 marine mammal species with confirmed or possible occurrence in the SOCAL/Pt. Mugu Study Area are cetaceans (whales, dolphins, and porpoises). 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. In addition to contrasts in feeding methods, there are life history and social organization differences (see Tyack 1986).

Nine of the marine mammal species occurring in the SOCAL/Pt. Mugu Study Area are pinnipeds. 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 behavioral and life history differences (see Riedman 1990).

Only one species of fissiped occurs in the Study Area. The sea otter is part of the order Carnivora and the Mustelidae family. Three subspecies are currently recognized; the southern sea otter subspecies (*Enhydra lutris nereis*) ranges from central to southern California. The sea otter is the only true marine otter in its range.

3.1.1.1 Adaptations to the Marine Environment: Sound Production and Reception

Marine mammals display numerous anatomical and physiological adaptations for survival in an aquatic environment that are discussed in detail by Pabst et al. (1999). Sensory changes from the basic mammalian scheme have also occurred in response to the various challenges an aquatic environment imposes. Sound travels faster and farther 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 animals 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 (Leventhall 2007) and those higher than 20 kiloHertz (kHz) as ultrasonic (Leighton 2007). Baleen whales primarily use the lower frequencies, producing both amplitude-modulated and tonal (frequency-modulated) sounds in the range of 14 to 3,000 Hz depending on the species. Most mysticete sounds can be characterized as moans, simple (pulsed) or complex calls, and songs (Wartzok and Ketten 1999). 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, passively listening to received echoes to navigate and orient relative to physical features of the ocean. The toothed whales produce a wide variety of sounds that are commonly grouped into three general categories: species-specific, amplitude-modulated (AM) broadband “clicks”

with peak energies between 10 and 200 kHz; individually variable “burst pulse” click trains; and constant-frequency or frequency-modulated (FM) whistles ranging from 1 to 20 kHz (Wartzok and Ketten 1999). The general consensus is that the tonal vocalizations (whistles) produced by toothed whales play an important role in social activity (e.g., communication, maintenance of contact between dispersed individuals, etc.) while broadband clicks are used during echolocation (Wartzok and Ketten 1999; Tyack 2000; Tyack 2002); however, several species of toothed whale [e.g., sperm whales (Whitehead 2003), Commerson’s dolphins (Dawson 1991), and dusky dolphins (Yin et al. 2001) produce only click sounds, which are used for both communication and echolocation. Burst pulses, trains with repetition rates ranging from hundreds to thousands of clicks per second, are used to share information between individuals by species that whistle and those that do not. Burst pulses have been documented during playful interactions (e.g., Herzing 1996; Blomqvist et al. 2005), agonistic encounters (McCowan and Reiss 1995), and other social behaviors. These sounds have been suggested to represent “emotive” signals in a broader sense, possibly representing graded communication signals (Herzing 1996). Echolocation, or sonar, is produced by all toothed whales studied to-date and is used during foraging (Janik 2000), short-range navigation (Au 1993), and communication (Tyack 1999; Dudzinski et al. 2002). Recent evidence shows that dolphins are capable of echoic eavesdropping (Xitco Jr. and Roitblat 1996; Xitco Jr. et al. 2004; Götz et al. 2006; Gregg et al. 2008), which could represent another avenue for these animals to share information. (Echoic eavesdropping refers to one animal listening to the click production and returning echoes from a second dolphin to gain useable information.)

Pinnipeds are amphibious; they produce both airborne and underwater sounds primarily in the sonic range (i.e., roughly between 20 Hz and 20 kHz) (Thomson and Richardson 1995). Their vocalizations primarily include grunts, barks, rasps, and growls in addition to the moans, whistles, and possibly pulsed calls. In general, phocids are far more vocal underwater than are otariids. Phocid calls commonly range between 100 Hz and 15 kHz, with peak spectra less than 5 kHz, but can range as high as 40 kHz (Ketten 1998b; Wartzok and Ketten 1999). Otariid calls are somewhat variable with most having a more narrow frequency range (~1 to 4 kHz) than those of phocids (Wartzok and Ketten 1999; Frankel 2002). Otariid calls include barks, groans, and grunts although their vocalizations are assumed to be less socially complex than those of phocids, which might be related to the differences in their mating strategies. Many phocids mate underwater while otariids mate on land and are relatively quiet at sea (Frankel 2002). 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 (see Thewissen 2002 for an overview on hearing in marine mammals) and more recently from some free-ranging species (Nachtigall et al. 2008). It is generally believed that cetaceans should at least be sensitive to the frequencies of their own vocalizations and the new data are confirming this assumption in the species studied. 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 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 in-air and in-water hearing sensitivity appear to correspond to the amphibious patterns of life history of many 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 better adapted for underwater hearing (Richardson et al. 1995; Kastak and Schusterman 1998; Ketten 1998b; 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 1998b; 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), Thewissen (2002), Hildebrand (2005), and Southall et al. (2007). 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. Time lags are particularly important when proxies such as chlorophyll data are used to indicate whale habitat (e.g., Littaye et al. 2004; Ferguson 2005). 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 4 mo (Jaquet et al. 1996; Gregr and Trites 2001). Littaye et al. (2004) determined that while food availability at a particular time and place was thought to be a function of environmental conditions occurring in previous months, fin whales in the Mediterranean adapted their movements and group size directly to prey availability instead of instantaneous environmental conditions. 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; Littaye et al. 2004; Ferguson 2005; Hastie et al. 2005; Laran and Gannier 2005; Panigada et al. 2005; Kaschner et al. 2006; Monestiez et al. 2006; Redfern et al. 2006; Becker 2007).

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, although 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 much of the same overall 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). 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 high-latitude feeding grounds. However, not all baleen whales within any given population migrate. Some individual gray, fin, Bryde's, minke, and blue whales may stay in a specific area year-round.

Cetacean movements can also reflect the distribution and abundance of prey (Gaskin 1982; Payne et al. 1986; Kenney et al. 1996). Cetacean movements have been linked to indirect indicators of prey, such as temperature variations, sea-surface chlorophyll 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 tend to be ephemeral in space and time, shifting geographically by 10 to 1,000 km depending on the season, the year, and climate events (Thurman 1997).

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). For instance, 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 (*Cystophora cristata*) and northern elephant seals (*Mirounga angustirostris*) are both good examples since they make extensive movements (Stewart and Huber 1993; Kovacs 2002). 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 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). Based on current data on human population growth and marine mammal fisheries interactions, DeMaster et al. (2001) predicted that in the future the most common types of competitive interactions will 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 purposes of breeding and molting. Like cetaceans, pinnipeds are often associated with either

transient (oceanographic features such as frontal systems) or non-transient physical features that serve to concentrate prey. Individual seal foraging behavior is probably related to oceanographic features in the water column, such as thermal discontinuities that act to concentrate prey species (Field et al. 2001). McConnell and Fedak (1996) hypothesized that seals out in the open ocean may be influenced by mesoscale frontal systems with locally-enhanced prey abundance. Thompson et al. (1991) observed that the spatial and temporal occurrence of feeding harbor seals was in response to fish distribution which also shifts spatially and temporally, with concentrations over trenches and holes more than 10 m deep during daylight hours.

All pinniped species leave the water periodically to haul out on land or ice to molt, sleep, mate, pup, or avoid marine predators (Riedman 1990). Seasonal changes in oceanographic conditions and ice cover condition 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 (*Phoca vitulina*), 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 (Learmonth et al. 2006). 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 may affect the distribution and abundance of marine mammal species, either directly or indirectly, through alterations of habitat characteristics and distribution (Harwood 2001; Forcada et al. 2005; Keiper et al. 2005; MacLeod et al. 2005; Shelden et al. 2005; Simmonds and Isaac 2007). 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; Ono et al. 1993; 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 to 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 (ETP) also suggests that animals cross stock boundaries during periods of significant environmental change (e.g., El Niño), moving to areas of lower-quality habitat when preferred habitat is reduced (Danil and Chivers 2005).

3.1.2 Marine Mammals of the Southern California/Point Mugu Study Area

Forty-six marine mammal species have confirmed or possible occurrence in the SOCAL/Pt. Mugu Study Area. These include 36 cetacean (whales, dolphins, and porpoises), 9 pinniped (seals, sea lions, and fur seals), and 1 fissiped species (the sea otter) (**Table 3-1**). Some species are resident year-round, while others occur only seasonally when migrating through the Study Area.

There has been some indication that the spinner dolphin (*Stenella longirostris*) and long-finned pilot whale (*Globicephala melas*) may also occur in the SOCAL/Pt. Mugu Study Area; however, the Study Area is clearly outside the normal ranges of these species (Jefferson et al. 2008). The spinner dolphin has a pantropical distribution; it probably reaches its northern range very close to the southern boundary of the

SOCAL OPAREA, but records do not indicate distribution inside the OPAREA (Jefferson, T.A., NMFS-SWFSC, pers. comm., 23 to 25 January 2008). Although Dohl et al. (1981) included the long-finned pilot whale in their summary of marine mammals found in the SCB, this species does not occur in the North Pacific Ocean (Jefferson et al. 2008). The records discussed in Dohl et al. (1981) should be attributed to the short-finned pilot whale (*Globicephala macrorhynchus*) which occurs in warm-temperate to tropical waters of the Pacific Ocean (Jefferson, T.A., NMFS-SWFSC, pers. comm., 23 to 25 January 2008). Based on this information, the spinner dolphin and long-finned pilot whale are not 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. Several authors have also noted the impact of the El Niño events of 1982/1983 and 1997/1998 on marine mammal occurrence patterns and population dynamics in the waters off California (e.g., Wells et al. 1990; Forney and Barlow 1998; Benson et al. 2002; Burtenshaw et al. 2004).

The SOCAL/Pt. Mugu Study Area is embedded within the California Current System (CCS), 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 biological oceanography of the region is largely influenced by the circulation within the CCS, the formation of eddies (e.g., the Southern California Eddy), and the topographical features of the SCB such as island slopes of the Channel Islands, nearby seamounts, and the shelf break south of Point Conception (Owen 1980; Dorman 1982; Fiedler et al. 1998). The combination of these forces creates turbulence, mixing, and increased surface nutrients that support dense aggregations of primary and secondary production (Fiedler et al. 1998). Because of this productive environment, there is a rich marine mammal fauna, as evidenced in abundance and species diversity (Leatherwood et al. 1988; Bonnell and Dailey 1993; Barlow and Forney 2007). In addition, the narrow continental shelf along the Pacific coast and the presence of the cold California Current sweeping south from Alaska allows cold-water marine mammal species to reach nearshore waters as far south as Baja California thus adding to the species diversity of the region.

The distribution of marine mammal records in the SOCAL/Pt. Mugu Study Area and vicinity is presented for the warm-water season (15 June through 15 December) and the cool-water season (16 December through 14 June) in the maps in **Appendix B**. An occurrence record does not reflect the actual 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 SOCAL/Pt. Mugu 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 SOCAL/Pt. Mugu Study Area. Protected species biologists with the NMFS-SWFSC ultimately devised these qualitative terms. "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. "Unknown" (hatched) is the areas 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, secondary, or rare occurrence).

Each marine mammal species is listed below with its description, status, habitat associations, distribution (including location and seasonal occurrence in the SOCAL/Pt. Mugu 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**.

Table 3-1. Marine mammal species with known or potential occurrence in the SOCAL/Pt. Mugu Study Area and vicinity. Taxonomy follows IWC (2006) for cetaceans and Rice (1998) for the other marine mammal species. [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].

	Scientific Name	ESA Status	Occurrence
Order Cetacea			
Suborder Mysticeti (baleen whales)			
Family Balaenidae (right whales)			
North Pacific right whale	*Eubalaena japonica*	Endangered	Rare
Family Balaenopteridae (rorquals)			
Humpback whale	*Megaptera novaeangliae*	Endangered	Regular
Common minke whale	*Balaenoptera acutorostrata*		Regular
Bryde's whale	*Balaenoptera edeni/brydei**		Rare
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*	**	Regular
Suborder Odontoceti (toothed whales)			
Family Physeteridae (sperm whale)			
Sperm whale	*Physeter macrocephalus*	Endangered	Regular
Family Kogiidae (pygmy sperm whales)			
Pygmy sperm whale	*Kogia breviceps*		Regular
Dwarf sperm whale	*Kogia sima*		Regular
Family Ziphiidae (beaked whales)			
Cuvier's beaked whale	*Ziphius cavirostris*		Regular
Blainville's beaked whale	*Mesoplodon densirostris*		Regular
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*		Regular
Hubbs' beaked whale	*Mesoplodon carlhubbsi*		Regular
Perrin's beaked whale	*Mesoplodon perrini*		Regular
Pygmy beaked whale	*Mesoplodon peruvianus*		Regular
Stejneger's beaked whale	*Mesoplodon stejnegeri*		Rare
Baird's beaked whale	*Berardius bairdii*		Regular
Longman's beaked whale	*Indopacetus pacificus*		Regular
Family Delphinidae (dolphins)			
Rough-toothed dolphin	*Steno bredanensis*		Rare
Common bottlenose dolphin	*Tursiops truncatus*		Regular
Pantropical spotted dolphin	*Stenella attenuata*		Regular
Striped dolphin	*Stenella coeruleoalba*		Regular
Short-beaked common dolphin	*Delphinus delphis*		Regular
Long-beaked common dolphin	*Delphinus capensis*		Regular
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*		Regular
Risso's dolphin	*Grampus griseus*		Regular
Northern right whale dolphin	*Lissodelphis borealis*		Regular
Melon-headed whale	*Peponocephala electra*		Extralimital
Pygmy killer whale	*Feresa attenuata*		Extralimital
False killer whale	*Pseudorca crassidens*		Regular
Killer whale	*Orcinus orca*	***	Regular
Short-finned pilot whale	*Globicephala macrorhynchus*		Regular
Family Phocoenidae (porpoises)			
Harbor porpoise	*Phocoena phocoena*		Regular
Dall's porpoise	*Phocoenoides dalli*		Regular

Table 3-1 (*continued*). Marine mammal species with known or potential occurrence in the SOCAL/Pt. Mugu Study Area and vicinity. Taxonomy follows IWC (2006) for cetaceans and Rice (1998) for the other marine mammal species. [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].

	Scientific Name	ESA Status	Occurrence
Order Carnivora			
Family Phocidae (true seals)			
Harbor seal	*Phoca vitulina*		Regular
Hooded seal	*Cystophora cristata*		Extralimital
Northern elephant seal	*Mirounga angustirostris*		Regular
Ringed seal	*Pusa hispida*		Extralimital
Ribbon seal	*Histriophoca fasciata*		Extralimital
Family Otariidae (sea lions and fur seals)			
Northern fur seal	*Callorhinus ursinus*		Regular
Guadalupe fur seal	*Arctocephalus townsendi*	Threatened	Regular
Steller sea lion	*Eumetopias jubatus*	Threatened	Regular
California sea lion	*Zalophus californianus*		Regular
Family Mustelidae (otters and weasels)			
Sea otter	*Enhydra lutris*	Threatened****	Regular

* Includes more than one species, but nomenclature is still unsettled.
** Only the population which occurs in the western North Pacific is listed as endangered.
*** The Southern Resident Killer Whale Distinct Population Segment is listed as endangered but is not known to occur as far south as the Study Area.
**** The San Nicolas sea otter population is listed as "Experimental Population, Non-Essential" under the ESA; however, under Public Law 99-625, sea otters within the translocation zone (San Nicolas Island) receive the standard protections of the ESA for threatened species. Note that with respect to defense-related activities, sea otters within the translocation zone are treated as a species that is proposed to be listed [50 CFR §17.84(d)(4)(iv)].

3.1.2.1 Threatened and Endangered Marine Mammals of the Southern California/Point Mugu Study Area

Nine marine mammal species with known or possible occurrence in the Study Area are currently listed as endangered under the ESA; five baleen whale species (North Pacific right, humpback, sei, fin, and blue whales), one toothed whale species (sperm whale), two pinniped species (Steller sea lion and Guadalupe fur seal), and one fissiped species (sea otter). A combined map of the threatened and endangered cetacean species occurring in the SOCAL/Pt. Mugu Study Area is located in **Appendix B**.

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—There is an area of primary occurrence seaward of the shoreline north of near the California/Mexico border during this time of year (**Figures B-1a** and **B-1b**). Primary occurrence also extends south of near the California/Mexico border in waters deeper than the 1,000-m isobath. Secondary occurrence is expected from the shore to the 1,000-m isobath south of near the California/Mexico border. The primary areas of occurrence in the offshore region are mainly driven by the expected occurrence of the sperm whale in deep (>1,000 m) offshore waters. Nearshore areas of primary and secondary occurrence are influenced by the expected occurrence patterns of blue, fin, and humpback whales.

- Cool-water period—An area of primary occurrence of threatened/endangered cetaceans is expected from the shore to seaward of the SOCAL/Pt. Mugu Study Area boundaries during this time of year (**Figures B-1a** and **B-1b**). This area of occurrence is driven by the expected occurrence patterns of the North Pacific right whale throughout much of the Study Area during this time of year, as well as the occurrence of fin and humpback whales primarily in nearshore waters in the northern potion of the Study Area.

- **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; NMFS 2008c).

Right whales have a robust body shape; overall body color is black although many individuals also have irregular white patches on their undersides (Reeves and Kenney 2003). There is no dorsal fin on the broad back. North Pacific right whales are larger than their North Atlantic counterparts (Reeves and Kenney 2003). The largest recorded North Pacific right whales are an 18.3-m female and a 16.4-m male (Omura et al. 1969). 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 (NMFS 2008c). 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 2008); 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 2005a; Wade et al. 2006). In the western North Pacific, the population may number 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 (**Figure 3-1**) (NMFS 2005c; NMFS 2008d). No critical habitat is designated within the Study Area.

Habitat Associations—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 for the North Pacific right whale 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 2005a). Historical whaling records provide virtually the only information on North Pacific right whale distribution. The North Pacific right whale historically

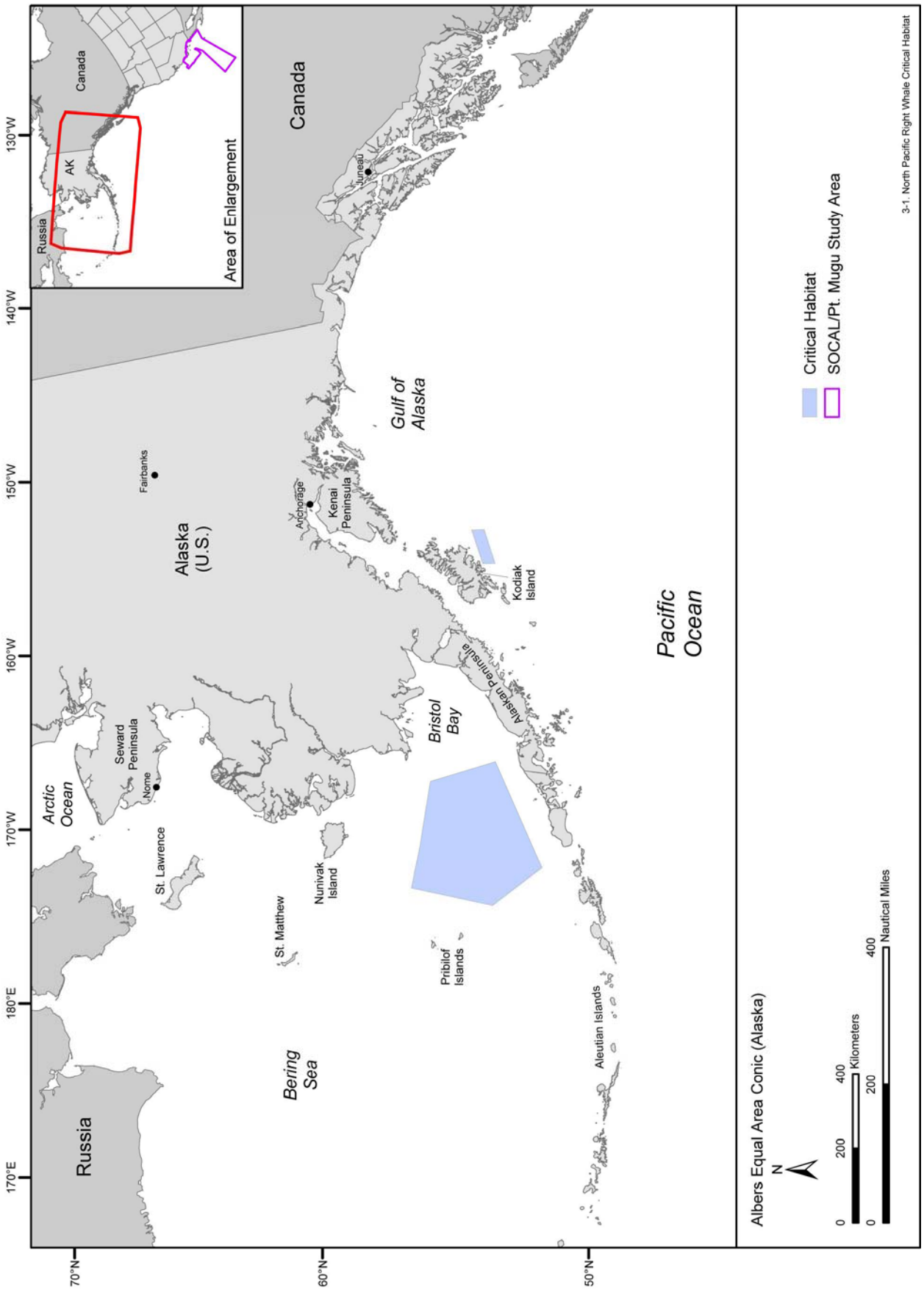

Figure 3-1. Designated critical habitat for the North Pacific right whale. Source data: NMFS (2005c, 2008d).

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 general 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 (March through May) from lower latitudes; 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, 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 2005a), 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 this as well (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 yr (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 SOCAL/Pt. Mugu Study Area—The critically-endangered status of the North Pacific right whale necessitates an extremely conservative determination of this species' occurrence in the Study Area. North Pacific right whale records in and near the SOCAL/Pt. Mugu Study Area include the northern Channel Islands, off Point Sur, off La Jolla, and off Baja California (Woodhouse and Strickley 1982; Scarff 1986; Carretta et al. 1994; Gendron et al. 1999; Brownell et al. 2001).

- Warm-water period—The area of secondary occurrence generally follows the 16.5°C isotherm north of Point Conception (**Figure B-2**). The North Pacific right whale is expected to have a rare occurrence throughout the rest of the Study Area during this time of year.

- Cool-water period—This period corresponds more to the breeding season when higher densities are expected at lower latitudes. The area of secondary occurrence extends north of Point Conception and generally follows the cold temperature gradient (15°C isotherm this time of year) (**Figure B-2**). Primary occurrence extends south of the secondary boundary throughout the rest of the Study Area, except for San Diego Bay which is an area of rare occurrence.

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 yr (Omura et al. 1969). Calves are born during December through March after 12 to 13 mo of gestation (Best 1994). Weaning occurs at 8 to 17 mo (Hamilton et al. 1995). There is usually a 3-yr 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 North Atlantic right whale dives were 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 s (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 4 hours (hr) (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 with a reference pressure of one micropascal 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). More recently, Parks et al. (2007) examined the inner ears from 13 stranded North Atlantic right whales to develop a model for this species' frequency range of hearing, which resulted in an estimated hearing range that matched previous work. Thus, right whale ear anatomy seems tuned to low frequency hearing (Ketten 1994; Parks et al. 2007). 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 17 m in length and are more robust than other rorquals; average females are 1 to 1.5 m longer than males. 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 (Clapham and Mead 1999; Jefferson et al. 2008). 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 California/Oregon/Washington stock, the Central North Pacific stock, and the Western North Pacific stock (Baker et al. 1998; Calambokidis et al. 2001; Carretta et al. 2007). 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 California/Oregon/Washington stock of humpback whales is 1,236 individuals (Carretta et al. 2007). Based on 2005 survey data, humpback whales appear to be more abundant along the U.S. west coast than during previous surveys through 2002 (Forney 2007).

Habitat Associations—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 (i.e., behind reefs) (Sanders et al. 2005; Rasmussen et al. 2007a). These areas provide calm seas and minimize the possibility of predation by sharks and harassment by male humpbacks (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 (including the Northwestern Hawaiian Islands), the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001; Johnston et al. 2007). 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 EPO. This apparently occurs through geographic overlap of some individuals from both ocean basins off the Central American coast (Acevedo and Smultea 1995; Rasmussen et al. 2007b); 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 populations (Carretta et al. 2007). 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; 2004). 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 (Baker et al. 1990; Calambokidis et al. 2000b; Calambokidis et al. 2001; **Figure 3-2**). Some humpback whales remain in some higher-latitude feeding grounds through the 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 (Clapham and Mead 1999). Rasmussen et al. (2007b) recently reported migration distances of over 8,400 km, which are the longest movements documented for any mammal. 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).

- <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

  - <u>Warm-water period</u>—An area of primary occurrence extends north of Mugu Lagoon and includes most of the northern Channel Islands (**Figure B-3**). This region accounts for feeding areas and is also based on available sighting data. A band of secondary occurrence includes waters farther offshore of the primary region and nearshore waters throughout the rest of the Study Area; this area captures possible offshore feeding areas and migratory pathways and includes available sightings (**Figure B-3**). There is a rare occurrence of humpback whales seaward of this area (and in San Diego Bay) which takes into account the possibility that some individuals might occur farther offshore, moving between breeding grounds.

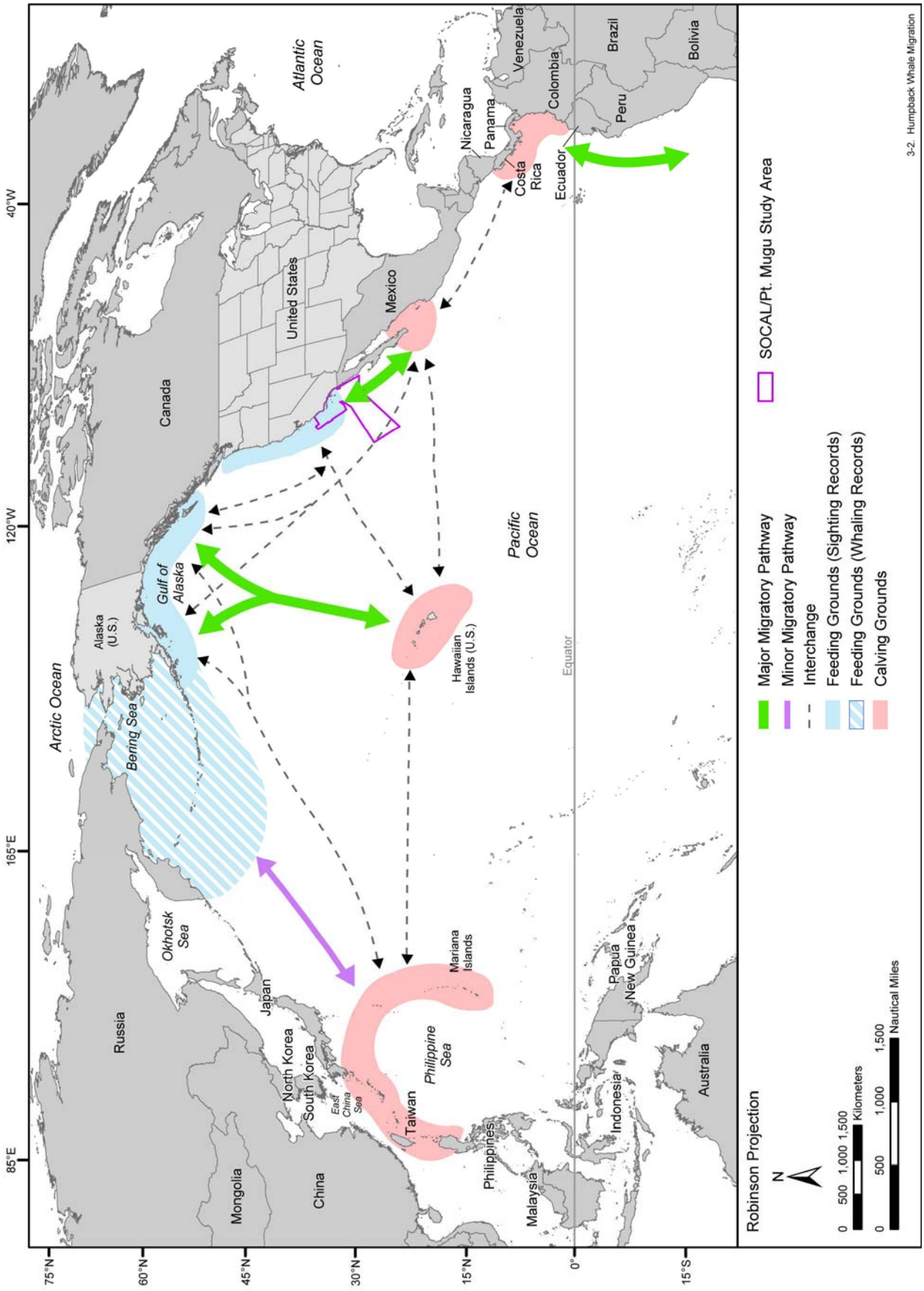

Figure 3-2. General major and minor migratory patterns of humpback whales in the North Pacific Ocean. Regions depicted with solid shading are defined by current observations of seasonal return by naturally marked individuals. Regions depicted with striped shading are defined by historical patterns of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

- Cool-water period—Occurrence patterns are assumed to be similar to the warm-water period (**Figure B-3**). Humpback whales migrate southward through southern California during November/December and return, migrating northward, starting in March (Barlow, J., NMFS-SWFSC pers. comm., 7 April 2008).

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). Current research in the Gulf of Maine suggests that feeding associations are influenced by maternal lineages (Weinrich et al. 2006). 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 yr of age (Clapham 1996). Gestation is approximately 1 yr. Calves are weaned before 1 yr of age. Calving intervals are usually 2 to 3 yr, 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). Calves, in particular, spend much of their time at the surface due to their reduced dive capacity (Szabo and Duffus 2008). 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 winter 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). Maximum source levels, measured by Au et al. (2006) with a vertical five hydrophone array, varied between individual males and ranged between 151 and 173 dB re 1 μPa-m. High frequency harmonics of songs extended to 24 kHz (Au et al. 2006), though the fundamental frequency of song ranged between 100 Hz and 4 kHz (Payne and McVay 1971; Payne et al. 1983). There is geographical variation in humpback whale

song with different populations singing different songs and all members of a population using the same basic song. The song evolves over the course of a breeding season but remains nearly unchanged from the end of one season to the start of the next (Payne et al. 1983). Darling et al. (2006) hypothesized that the song serves to organize males on the breeding grounds; the song unites males on the breeding ground with collective changes but seems also to characterize the range in male relationships. That is, interactions between males can be interactive to agonistic. Thus, song would seem to provide a real-time measure of individual associations (Darling et al. 2006).

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. Zoidis et al. (2008) presented the first evidence of sound production by humpback calves: their results suggest that both male and female calves vocalize and that the majority of their sounds are pulsed (71%); however, both frequency- and amplitude-modulated calls were recorded. Calf calls were simple in structure with an average frequency below 300 Hz, of relatively narrow bandwidth (mean = 2 kHz), and of short duration (Zoidis et al. 2008). 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 and a mean of 155 dB re 1 μPa-m. Au et al. (2001) recorded high-frequency harmonics (out to 13.5 kHz) and source level (between 171 and 189 dB re 1 μPa-m) of humpback whale songs. Songs have also been recorded on feeding grounds (Mattila et al. 1987; Clark and Clapham 2004). The main energy lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz. “Feeding” calls, unlike song and social sounds, are highly stereotyped series of narrow-band trumpeting calls. They are 20 Hz to 2 kHz, less than 1 s in duration, and have source levels of 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. Source level measurements by Au et al. (2006) indicate that humpback whales produce harmonics at 24 kHz which suggests that their hearing range may be of a similar range. Mercado et al. (2008) examined long-range propogation of sounds in coastal waters to assess humpback ability to use frequency degradation to assess range to other singing whales: their data corroborate the idea that humpbacks can assess frequency content in other individuals’ songs to judge distance.

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

Description—Adult sei whales are up to 18 m in length; however, 12 to 17 m is a more typical length for adults. Sei whales are mostly dark gray or brown with a lighter belly. There is a single prominent ridge on the rostrum and a slightly arched head with a downturned tip. The dorsal fin is prominent and very falcate (Jefferson et al. 2008). 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. There is no designated critical habitat for this species in the North Pacific. The IWC designates the entire North Pacific Ocean as one sei whale stock unit (Donovan 1991), although some evidence exists for multiple stocks (NMFS 1998b). The minimum population estimate for the Eastern North Pacific stock of the sei whale is 27 individuals (Carretta et al. 2007), and the best estimate of abundance for sei whales in Washington State, Oregon, and California waters out to 300 nm (556 km) is 43 individuals (Forney 2007).

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) provided a recent review; also see the Bryde’s whale species account below for further explanation.

Habitat Associations—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; Skov et al. 2008). 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); however, recent surveys in the waters of Guam and the Northern Mariana Islands indicate the presence of sei whales south of 15°N (DoN 2007). 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 1998b) and are seen at least as far south as 15°N (DoN 2007). 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 1998b). As noted by Reeves et al. (1999), reports in the literature from any time before the mid-1970s are suspect because of the frequent failure to distinguish sei from Bryde's whales, particularly in tropical to warm-temperate waters where Bryde's whales are generally more common than sei whales. Rice (1977) reported sighting sei whales during December to March off Point Piedras Blancas, California, south to the vicinity of the Islas Revillagigedo. During May to October, Rice (1977) noted that sei whales frequently ranged south to the area immediately west of the Channel Islands, with a sighting as far south as Baja California.

- Information Specific to the SOCAL/Pt. Mugu Study Area—Barlow (1994a) noted that only one confirmed sighting and five possible sightings (identified as sei or Bryde's whales) were made in California waters during extensive ship and aerial surveys between 1991 and 1993. Only one sei whale sighting was recorded off the California coast during the 2005 surveys (Forney 2007).

  - Warm-water period—Sei whale occurrence is expected to be rare throughout the Study Area during the warm-water period (**Figure B-4**). Several sightings have been recorded in nearshore waters of the Study Area during this time of year (**Figure B-4**). The number of sightings in **Figure B-4** does not reflect an increased abundance of this species during the warm-water period even though more sightings are recorded during this time of year. The sightings are likely a reflection of the increased survey effort during the summer.

  - Cool-water period—There is a secondary occurrence of the sei whale throughout the Study Area during this time of year to account for individuals migrating southward (**Figure B-4**).

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 2 yr: a gestation period of about 10 to 12 mo and a lactation period of 6 to 9 mo (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 seconds [s], separated by 0.4 to 1.0 s) of 10 to 20 short (4 milliseconds [ms]) 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 s, 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 in the Northern Hemisphere reaching 24 m in length. Fin whales have a very sleek body with several pale, V-shaped chevrons on the back just behind the head. The dorsal fin is prominent, usually falcate, and rises out of the back at a very shallow angle (Jefferson et al. 2008). 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 2006a).

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 2,760 individuals (Carretta et al. 2007). The fin whale was the most abundant large whale sighted during recent surveys off the U.S. west coast, and its distribution was widespread throughout the area (Barlow and Forney 2007; Forney 2007).

Habitat Associations—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). In the western North Atlantic, Waring and Finn (1995) found a significant relationship in the distributions of fin whales and sand lance in the fall. In the lower Bay of Fundy, fin whales occur in shallow areas with high topographic variation that are likely well mixed or contain frontal boundaries between mixed and stratified waters and which tend to concentrate krill and herring (Woodley and Gaskin 1996; Ingram et al. 2007). Fin whales have also been known to preferentially feed in areas within fine-scale eddies with highly-concentrated prey; these eddies form around islands during tidal retreat (Johnston et al. 2005a). Doniol-Valcroze et al. (2007) found high correlations between fin whales and thermal fronts in the Gulf of St. Lawrence. Clark and Gagnon (2004) determined that vocalizing fin whales show strong preferences for shelf breaks, seamounts, or other areas where food resources are known to occur, even during summer months. Littaye et al. (2004) determined that fin whale distribution in the Mediterranean Sea was linked to frontal areas and upwelling within large zooplankton patches. Fin whales in the North Pacific spend the summer feeding along the cold eastern boundary currents (Perry et al. 1999).

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 32°N off the coast of southern California (Mizroch et al. 2005). They have been observed during the summer in the central Bering Sea (Moore et al. 2000). During the winter (November through April), fin whales are sparsely distributed from 60°N south to the northern edge of the tropics, where it is assumed that mating and calving take place (Mizroch et al. 2005). However, some fin whales have been sighted as far north as 60°N all winter (Mizroch et al. 2005). Recoveries of marked whales demonstrate long migrations from low-latitude winter grounds to high-latitude summer grounds and extensive longitudinal movements both in-season and between years within and between the main summer concentration areas

(Mizroch et al. 2005). There is also some evidence of a resident population of fin whales in the Gulf of California, Mexico (Tershy et al. 1993b). 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 SOCAL/Pt. Mugu Study Area

- Warm-water period—The area of primary occurrence includes nearshore and offshore waters extending north from near the California/Mexico border (**Figure B-5**). This region includes the part of the "California Ground" (35°N-40°N, 130°W-120°W), which is an area of known concentration of fin whales (Mizroch et al. 2005), and is supported by the habitat model (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) and sightings (**Figure B-5**). There is a secondary buffer which extends south of the primary region; smaller numbers of fin whales are sighted in the area of secondary occurrence (**Figure B-5**). Occurrence of fin whales is rare in San Diego Bay and throughout the rest of the Study Area to account for the possibility of migrating whales.

- Cool-water period—Occurrence patterns during this time of year are expected to be similar to the warm-water period (**Figure B-5)**.

Behavior and Life History—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 yr of age (Boyd et al. 1999). Peak calving is in October through January (Hain et al. 1992) after a gestation period of approximately 11 mo. Weaning may occur at 6 mo (Boyd et al. 1999). The calving interval for fin whales ranges between two and three years (Agler et al. 1993).

Fin whales feed by "lunging" and "gulping" (Pivorunas 1979; Orton and Brodie 1987; Lambertsen et al. 1995; Goldbogen et al. 2007). 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).

Fin whale dives are typically 5 to 15 min long and separated by sequences of four to five blows at 10- to 20-s intervals (CETAP 1982; Stone et al. 1992; Lafortuna et al. 2003). Kopelman and Sadove (1995) found significant differences in blow intervals, dive times, and blows per hour between surface-feeding and non-surface-feeding fin whales. Croll et al. (2001) determined that fin whales 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 s 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). In the Southern Ocean, the average fin whale call source level was 189±4 dB re 1 μPa-m over 15–28 Hz (Širović et al. 2007). Croll et al. (2002) suggested that the 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. Adults in the Northern Hemisphere reach 23 to 27 m in length; females are larger than males. The rostrum of a blue whale is broad and U-shaped, with a single prominent ridge down the center. This species is blue-gray with light (or sometimes dark) mottling; the patterns of mottling are used to identify individual blue whales (Jefferson et al. 2008). 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).

Status—Blue whales are classified as endangered under the ESA. The blue whale was severely depleted by commercial whaling in the twentieth century (NMFS 1998a). 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 may occur (NMFS 1998b). There is a minimum population estimate of 1,005 individuals for the Eastern North Pacific blue whale stock (Carretta et al. 2007). 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 although 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 1994b; Calambokidis et al. 2007; Carretta et al. 2007).

Habitat Associations—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). Recent tagging studies off the U.S. west coast indicate that blue whales prefer areas of strong upwelling along the slope edge (Irvine and Mate 2007). In fact, one of the three high-use areas identified in this study was the west end of the Channel Islands where there is strong seasonal upwelling and elevated productivity (Irvine and Mate 2007). Blue whales off the coast of southern California appear to feed exclusively on dense euphausiid schools between 100 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 Rica Dome (Wade and Friedrichsen 1979; Reilly and Thayer 1990). The productivity of the Costa Rica Dome may allow blue whales to feed during their winter calving/breeding season instead of fasting (Mate et al. 1999).

The range of the blue whale is known to encompass much of the North Pacific Ocean, from Kamchatka (Russia) to southern Japan in the west and from the Gulf of Alaska south to at least Costa Rica in the east (NMFS 1998a). 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. Blue whales feed off California during the summer and fall (June through

November) (Calambokidis et al. 2003a). 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); large aggregations are common in the Santa Barbara Channel, south of the Channel Islands, and near San Nicolas Island (Oleson et al. 2007). 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 farther north (COSEWIC 2002). A blue whale photographed south of Prince William Sound in the Gulf of Alaska was 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., 7 April 2008).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—This period corresponds to the blue whale early breeding/late feeding season. Blue whale abundance off southern California peaks during July through September (Larkman and Veit 1998). This seasonal peak is further supported by recent acoustic detections (Oleson et al. 2007). Blue whales are commonly seen around the Coronado Islands and off San Diego during May and June (Barlow, J., NMFS-SWFSC pers. comm., 7 April 2008). The area of primary occurrence follows the habitat model (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) and captures available sightings; the swath of primary occurrence extends offshore and northward of near 32°N (**Figure B-6**). An area of secondary occurrence buffers the primary region and includes the migratory corridor of the blue whale. Blue whales are rare in waters farther offshore and in San Diego Bay.

- Cool-water period—This period corresponds to the late breeding/early feeding season for blue whales. The area of secondary occurrence for this species is a continuous band along the coast which takes into account migrating individuals (**Figure B-6**). Blue whales have a rare occurrence farther offshore in the Study Area and in San Diego Bay during this time of year.

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 yr of age (Yochem and Leatherwood 1985). There is usually a 2-yr 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. (2003b) 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. In the Southern Ocean, the average blue whale call source level was 189±3 dB re 1 μPa-m over 25 to 29 Hz (Širović et al. 2007). 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 s (Thomson and Richardson 1995) repeated every 1 to 2 min (Mellinger and Clark 2003). Their frequency range is 12 to 400 Hz, with dominant energy in the infrasonic range at 12 to 25 Hz (Ketten 1998b; Mellinger and Clark 2003). These long, patterned, infrasonic call series are sometimes referred to as "songs." The short-duration sounds are transient,

FM 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 s 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 1998b; 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 up to 18.3 m in length (Jefferson et al. 2008). The head is squarish and large, comprising about one-third of the total body length. The lower jaw is narrow and underslung (Jefferson et al. 2008). 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. The surface of the body behind the head tends to be wrinkled (Rice 1989).

Status—Sperm whales are listed as endangered under the ESA. There is no designated critical habitat for this species in the North Pacific. 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. For example, sperm whale abundance in the ETP has been estimated to be about 21,200 to 22,700 whales (Wade and Gerrodette 1993). 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 1,719 individuals in the California/Oregon/Washington stock of the sperm whale (Carretta et al. 2007). 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). A recent survey resulted in an abundance estimate of 3,140 sperm whales in California, Oregon, and Washington State waters out to 300 nm (556 km) (Forney 2007).

Habitat Associations—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 farther offshore (Hain et al. 1985; Kenney and Winn 1987; Waring and Finn 1995; Gannier 2000; Gregr and Trites 2001). However, in some areas, such as off New England, on the southwestern and eastern Scotian Shelf, or the northern Gulf of California, adult males are reported to 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. 2006). 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 demonstrates 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 ETP, sperm whale habitat use is significantly related to SST and depth of the thermocline (Polacheck 1987); sperm whale distribution in the Mediterranean has also been linked to SST fronts (Gannier and Praca 2007). 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°C (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 SOCAL/Pt. Mugu Study Area

- Warm-water period—Based on known habitat associations, the primary area of occurrence for the sperm whale is seaward of the 1,000-m isobath throughout the Study Area (**Figure B-7**). There is an area of secondary occurrence between the 200 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.

- Cool-water period—Occurrence patterns are expected to be the same as during the warm-water period (**Figure B-7**).

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 mo, lactation is approximately 2 yr, and the typical inter-birth interval is 4 to 7 yr. 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; Palka and Johnson 2007). They are capable of diving to depths of over 2,000 m with durations of over 60 min (Watkins et al. 1993). Sperm whales are known to make inactive shallow dives ("drift dives") of variable durations (0.7 to 31.5 min) and depths (8.6 to 16.5 m); sperm whales may sleep during these vertical drift dives (Miller et al. 2008). 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; Teloni et al. 2008). In contrast, females spend prolonged periods of time at the surface (1 to 5 hr daily) without foraging (Whitehead and Weilgart 1991; Amano and Yoshioka 2003). Males in high latitudes tend to forage over a wide depth range (17 to 1,860 m); their foraging behavior consists of shallow and deep dives which allow them to exploit a diverse array of prey types (Teloni et al. 2008). The average swimming speed is estimated to be 0.7 m/s (Watkins et al. 2002). Dive descents averaged 11 min at a rate of 1.52 m/s, and ascents averaged 11.8 min at a rate of 1.4 m/s (Watkins et al. 2002).

Acoustics and Hearing—Sperm whales are highly vocal and produce short-duration (generally less than 3 s), broadband clicks at varying repetition rates. 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 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. Zimmer et al. (2005b) employed a three-dimensional beam pattern array to confirm the bent-horn hypothesis for the production of regular clicks; early recordings were unable to confirm the directivity of these pulsed sounds which led to the assumption that sperm whales did not echolocate like smaller odontocetes (Watkins 1980). Data from tagged whales in the Ligurian Sea show that sperm whale clicks are composed of three components with differing characteristics, all generated by the phonic lips (below the blowhole) and very directional, thus confirming that these clicks are used in echolocation for foraging (Zimmer et al. 2005b). The clicks of neonate sperm whales are very different from usual (regular) 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. 2005c). These may be echolocation clicks used for 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). Both male and female adult sperm whales produce codas; coda type and production has been shown to be related to behavioral context and group membership (e.g., Frantzis and Alexiadou 2008). Adult sperm whale clicks with modified repetition rates can sound like distinct calls that include clangs, creaks, chirrups, squeals, and codas and function in group recognition and for social behavior (Weilgart and Whitehead 1997; Weir et al. 2007). Even though squeals, for example, might look spectrographically tonal and might sound like pure tones to the human ear, these vocalizations are pulsed with repetition rates ranging between 713 and 1,385 clicks/s and peak energy below 4 kHz (Weir et al. 2007).

Norris and Harvey (1972) were the first to predict that the interpluse interval within their clicks could be used to reliably identify body size of sperm whales; their clicks are multi-pulsed in structure. More recently, Rhinelander and Dawson (2004) for sperm whales near Kaikoura, New Zealand and Teloni et al. (2007) for sperm whales recorded in the Ligurian Sea have presented data in support of this hypothesis. The interpulse intervals relate to the two-way time travel of clicks within the heads of these whales.

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).

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

Description—Guadalupe fur seals are sexually dimorphic. Maximum length and weight for males is 1.9 m and 170 kg (Reeves et al. 1992; Jefferson et al. 2008). Adult females attain lengths of 1.4 m and weigh 40 to 50 kg (Reeves et al. 1992; Jefferson et al. 2008). Both sexes are dark grayish brown or dusky black. Older males also have tan to yellowish hairs on the back of their necks, while females are generally paler on the chest and underside of their necks. There is some variable coloration on the face and neck of females and subadults (Reeves et al. 1992; Jefferson et al. 2008).

Status—This species is listed as threatened under the ESA. Guadalupe fur seals were hunted nearly to extinction during the 1800s. All individuals alive today are recent descendants from one breeding colony at Guadalupe Island, Mexico and are considered a single stock (Carretta et al. 2007). The minimum population estimate for Mexico is 3,028 individuals (Carretta et al. 2007). There is no minimum population estimate for Guadalupe fur seals occurring in U.S. waters.

Habitat Associations—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 that provide them shelter and isolation from other species (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 entering the water, and suitable breeding habitat (Fleischer 1978).

Distribution—Before intensive hunting decreased their numbers, 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 the San Benito Islands off Baja California (Maravilla-Chavez and Lowry 1999), and a pup was 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). Sightings of Guadalupe fur seals in the Channel Islands are almost always during the summer (Stewart and Yochem 2000). Few individuals are seen ashore during the winter in Baja California (Stewart and Yochem 2000). Guadalupe fur seals may migrate at least 600 km from the rookery sites based on pelagic observations of individuals in the SCB (Seagars 1984). The movements of Guadalupe fur seals at sea are generally 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., 7 April 2008). Etnier (2002) reported 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 sites on the northern Washington Coast dating 300 to 500 yr before present.

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- Warm-water period—Guadalupe fur seals only breed on Guadalupe Island and Benito del Este; both islands are located outside the SOCAL/Pt. Mugu Study Area (**Figures 3-3** and **B-8**). Primary occurrence extends 20 km from the center of the islands to account for the main haulout and foraging areas. An area of secondary occurrence extends an additional 80 km outside the area of primary occurrence which takes into account areas that could be used for both transiting between the islands and foraging. Secondary occurrence also extends north to Point Conception and includes the Channel Islands (few Guadalupe fur seals inhabit San Miguel, San Clemente, and Santa Barbara islands). A 20 nm (37 km) wide strip (seaward of the shelf break) of secondary occurrence extends north of Point Conception (**Figure B-8**). Only the area of secondary occurrence for the Guadalupe fur seal extends into the Study Area (**Figure B-8**). Occurrence throughout the rest of the Study Area is expected to be rare.

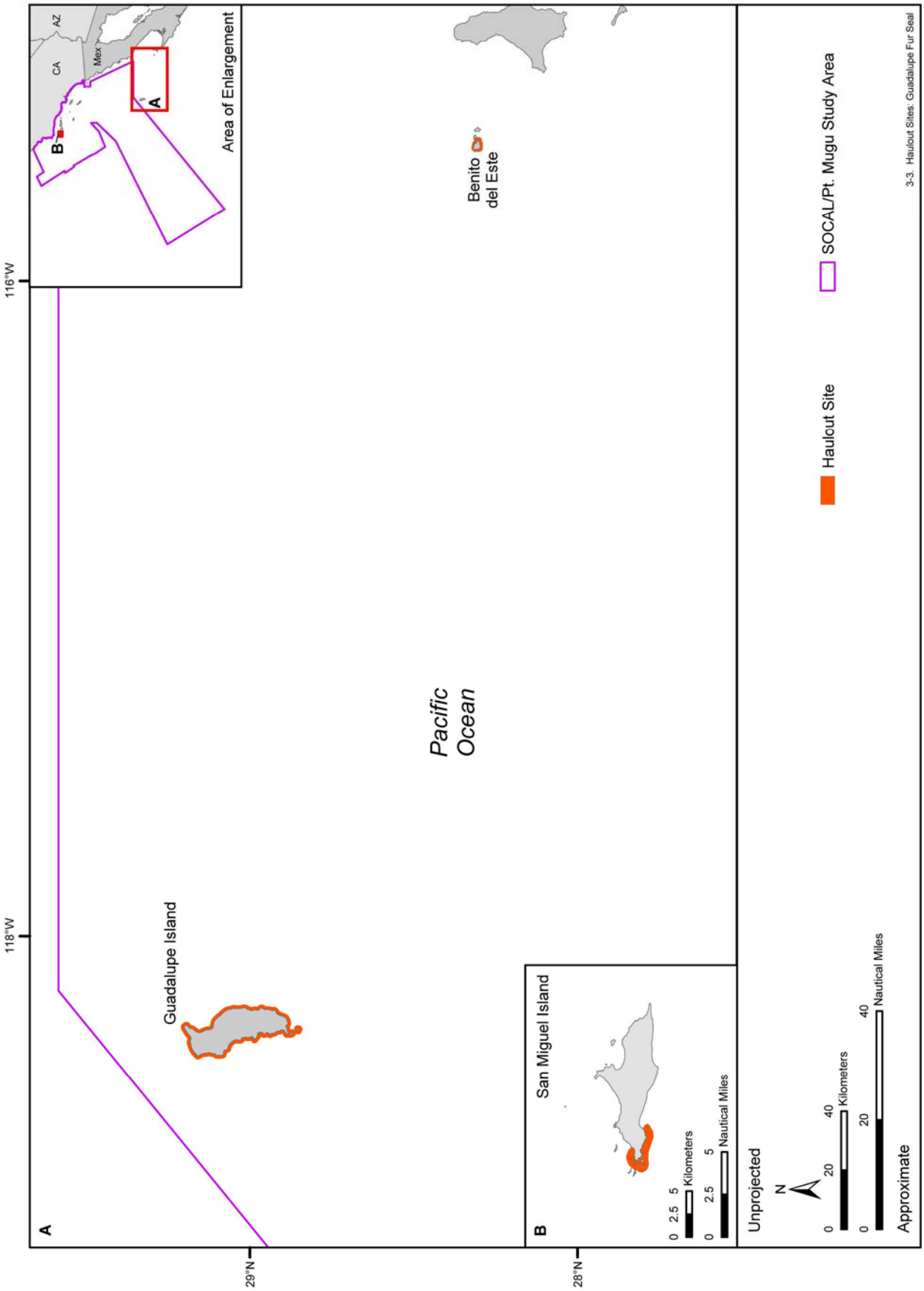

Figure 3-3. Guadalupe fur seal haulout locations in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NOS (2001).

- Cool-water period—Occurrence patterns are expected to be the same as during the warm-water period (**Figure B-8**).

Behavior and Life History—Group size and composition of Guadalupe fur seals change seasonally. Adult males, juveniles, and non-breeding 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 the middle of June through July, three to six days after hauling out. Seven to ten days after giving birth, females mate and begin a series of trips (average of 7 d) to sea to feed (Carranza 1994). Between these feeding bouts, they return to shore to nurse their pups for 5 to 6 d at a time (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 mo (Seagars 1984; Arnould 2002). The age of 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). In the San Benito Islands, and possibly at Guadalupe Island and the offshore waters of California, Guadalupe fur seals specialize on cephalopods (Hanni et al. 1997; Aurioles-Gamboa and Camacho-Ríos 2007). 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 and making an average round trip of 2,375 km (Ronald and Gots 2003).

Foraging dives average 30 m in depth and are of short duration (Arnould 2002; Ronald and Gots 2003; Aurioles-Gamboa and Camacho-Ríos 2007). Lander et al. (2000) tracked a rehabilitated female whose dives were less than 20.2 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 use bawls (Peterson et al. 1968; Belcher and Lee 2002). Many of these sounds consist of multiple harmonics with frequencies less than 7 kHz and dominant frequencies below 1 kHz (Peterson et al. 1968). Male Guadalupe fur seals are quite vocal during the breeding season and make four different call types, especially when male-male interactions ensue (Croxall and Gentry 1987). The full threat call is roughly 2 s in duration and is aurally tonal (to humans) with a fundamental frequency below 1 kHz (Croxall and Gentry 1987). The other three call types include the boundary bluff, the bark, and the growl – all call types seem correlated to some form of territorial behavior. Females produce a pup attraction call and female attraction calls, each seemingly pulsed with the fundamental frequency below ~2 kHz (Croxall and Gentry 1987).

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

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

Description—The Steller, or northern, sea lion is the largest otariid species and is significantly sexually dimorphic. The average male is 2.82 m long and weighs 566 kg. Females are much smaller with an average length of 2.28 m and an average weight of 263 kg (Fiscus 1961; 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. However, animals may appear a different color (grayish to dark brown) when they are wet (Jefferson et al. 2008). Adult males have especially thick pelage on their shoulders, chest, and neck and a sagittal crest (Fiscus 1961).

Status—There are two federally-designated DPSs of Steller sea lions based on genetics and population trends (Loughlin 1997; NMFS 1997). The western U.S. DPS (western stock) includes animals at and west of 144°W (Cape Suckling, Alaska) while the eastern U.S. DPS (eastern stock) includes all the animals east of 144°W (Loughlin 1997; NMFS 1997; Angliss and Outlaw 2008). The western stock is listed as endangered under the ESA, and the eastern stock is listed as threatened (NMFS 1997). The minimum population estimate for the western stock is 38,988 individuals (Angliss and Outlaw 2008). The minimum population estimate for the eastern stock is 44,584 individuals (Angliss and Outlaw 2008). Steller sea lions occurring in the SOCAL/Pt. Mugu Study Area are presumably from the eastern stock.

Designated critical habitat for the western stock in Alaska includes a 37-km (20-nm) buffer around all major haulouts and rookeries; a terrestrial (landward of the baseline) and air buffer zone around each major haulout and rookery; and three offshore foraging areas (one in the Gulf of Alaska and two in the Aleutian archipelago). Critical habitat for the eastern stock includes terrestrial, air, and aquatic buffer zones (3,000 m) associated with haulouts and rookeries in southeastern Alaska, Oregon, and California (**Figure 3-4**) (NMFS 1993; NMFS 2008a).

Habitat Associations—Terrestrial habitat for Steller sea lions is located on exposed, rocky shorelines and, less commonly, on sandy, gravel, or sheltered shorelines (Ban and Trites 2007). Rookery habitat generally consists of rocky shorelines on remote offshore islands and reefs with enough space above the high water mark for pups to survive rough weather conditions (Pitcher et al. 2007). Rookery habitat is located in areas of high prey availability so that lactating females have adequate resources within their foraging range (Pitcher et al. 2007). Foraging habitat is primarily shallow, nearshore, and continental shelf waters; some Steller sea lions even feed in freshwater rivers (Jameson and Kenyon 1977; Reeves et al. 1992; Robson 2002). Steller sea lions are also known to feed in deep waters past the shelf break (NMFS 2008a). Steller sea lions in the Bering Sea regularly haul out on pack ice near the ice front during winter. Pack ice also offers close proximity to prey and protection from terrestrial predators (Riedman 1990). Habitat selection may vary seasonally due to prey availability and life history constraints (NMFS 2008a).

Distribution—Steller sea lions range throughout most of the North Pacific Ocean from southern California through the Gulf of Alaska and the Aleutian Islands, into the Bering Sea and Pribilof Islands, and west to the Kuril Islands and Okhotsk Sea, Japan (Kenyon and Rice 1961). Major haulouts and rookeries are centered in the Aleutian Islands, at islands and mainland sites in the Gulf of Alaska, and in southeast Alaska (**Figure 3-4**) (Loughlin et al. 1984; Pitcher et al. 2007). Primary haulout and rookery sites are also located in Oregon and California (**Figure 3-4**) (Loughlin et al. 1992; NMFS 1993; Hastings and Sydeman 2002). Primary haulout and rookery sites in California are north of the SCB on the Farallon Islands, Año Nuevo Island, St. George Reef, and Sugarloaf Island (Loughlin et al. 1992; Hastings and Sydeman 2002). Several haulout sites are located in the northern portion of the SOCAL/Pt. Mugu Study Area (**Figure 3-5**). Historically, Steller sea lions were more numerous in the waters off California than were California sea lions (Bonnot 1928); in the last 80 years, California sea lions have become hugely abundant off the U.S. west coast (Lowry and Maravilla-Chavez 2005), while Steller sea lions are less abundant and shifting their breeding range northward (Pitcher et al. 2007). Former rookeries in the Channel and Farallon Islands have become either haulout sites only or have been taken over largely by California sea lions (Stewart et al. 1993; Hastings and Sydeman 2002; Pitcher et al. 2007). As Steller sea lion distribution shifts northward, new rookeries are being established in southeastern Alaska (Pitcher et al. 2007).

- <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

  <u>Warm-water period</u>—Steller sea lions used to breed on San Miguel Island, but none have been reported there since 1982 (Stewart et al. 1993). Steller sea lions were once abundant in the SCB, but numbers have dramatically declined in the last several decades. Steller sea lions have a primary occurrence in the Study Area between the shoreline and the 500-m isobath north of Point Conception which includes haulout sites (**Figures B-9 and 3-5**). There is a secondary occurrence buffer between the 500- and 1,000-m isobaths north of Point

Conception. Occurrence farther offshore of the secondary area and in waters south of Point Conception is expected to be rare.

- Cool-water period—Occurrence patterns are expected to be the same as during the warm-water period (**Figure B-9**).

Behavior and Life History—In general, Steller sea lions do not migrate but often disperse widely during the nonbreeding season (Baba et al. 2000; Loughlin 2002). They are gregarious animals. 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). Older (and usually larger) males aggressively defend prime territories while nonbreeding males remain at peripheral sites or haulouts (Pitcher and Calkins 1981). Females arrive soon after the males and give birth to a single pup within a few days (Pitcher and Calkins 1981). Most births occur from mid-May through mid-July, and 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). Females remain on the rookery beach with their pup for approximately 2 mo, leaving periodically to forage offshore. Most pups are weaned within a year (Pitcher and Calkins 1981), but females may be seen suckling a juvenile alongside a new pup. Females reach sexual maturity between 4 to 5 yr of age; most males become sexually mature by the age of eight (Pitcher and Calkins 1981) but are not able to defend a territory successfully until they are a few years older.

Steller sea lions are opportunistic predators, feeding primarily on fishes and cephalopods. Their diet varies geographically and seasonally (Merrick et al. 1997; Gende and Sigler 2006; Womble and Sigler 2006), with individuals from the eastern stock feeding on a more diverse diet (Trites et al. 2007). In Alaska, Steller sea lion diet includes herring, walleye pollock, sand lance, salmon, flounder, rockfish, and cephalopods (squids and octopuses) (Gende and Sigler 2006; Womble and Sigler 2006; Trites et al. 2007). Off the U.S. west coast, 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 (Fadely et al. 2005). 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 deep to locate prey (Merrick and Loughlin 1997; Loughlin 2002). In the summer, trip length is about 17 km and dives are shallower (Loughlin 2002). Females usually go to sea to feed and return to nurse their pups in 24- to 48-hr cycles (Riedman 1990). Steller sea lions tend to make shallow dives (less than 250 m). Adult females are known to dive 100 to 250 m in summer, but maximum depth in the winter may be greater than 250 m (Loughlin 2002). Young Steller sea lions make shallow (70 to 140 m) and short dives (1 to 2 min) and do not travel as far as adults due to developmental constraints (Merrick and Loughlin 1997; Rehberg et al. 2001; Pitcher et al. 2005).

Acoustics and Hearing—In-air territorial male Steller sea lion sounds are usually low frequency roars, while females vocalize less and at a higher frequency (Schusterman et al. 1970; Loughlin et al. 1987). Campbell et al. (2002) determined that females have distinctive acoustic signatures. These calls range in frequency from 30 to 3,000 Hz with peak frequencies from 150 to 1,000 Hz; typical duration is 1,000 to 1,500 ms (Campbell et al. 2002). Pups produce bleating sounds.

Underwater sounds are like the in-air signals (Loughlin et al. 1987). 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 to sexual dimorphism in hearing (Kastelein et al. 2005).

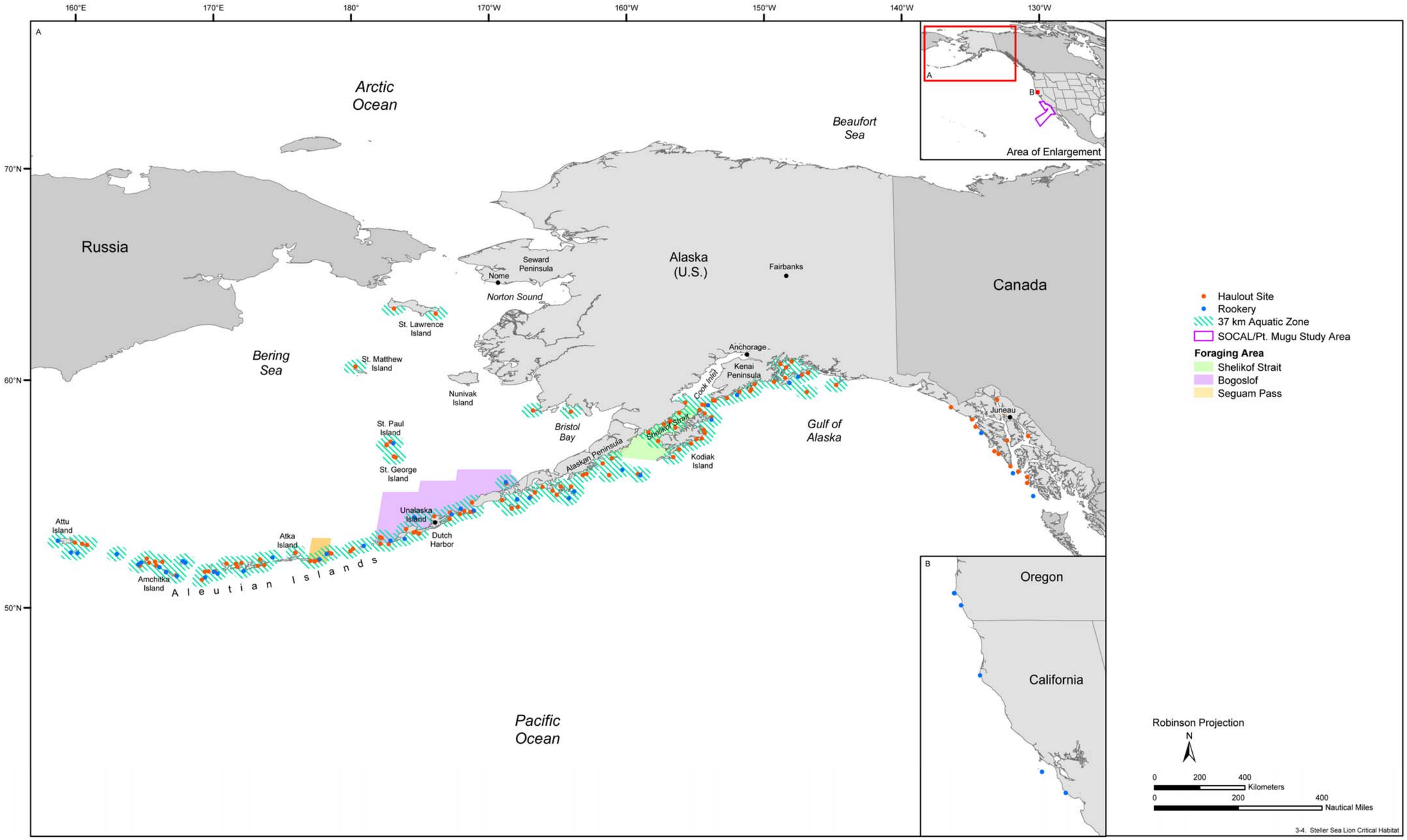

Figure 3-4. Major rookeries, haulout sites, and associated terrestrial and aquatic zones designated as critical habitat for the Steller sea lion. Critical habitat for the western DPS (west of 144°W) includes a 37-km aquatic zone extending seaward from the baseline. Critical habitat for the eastern DPS (east of 144°W) includes a 0.9-km aquatic zone (3,000 ft) extending seaward from the baseline (not visible in this figure). Source data: NMFS (1993).

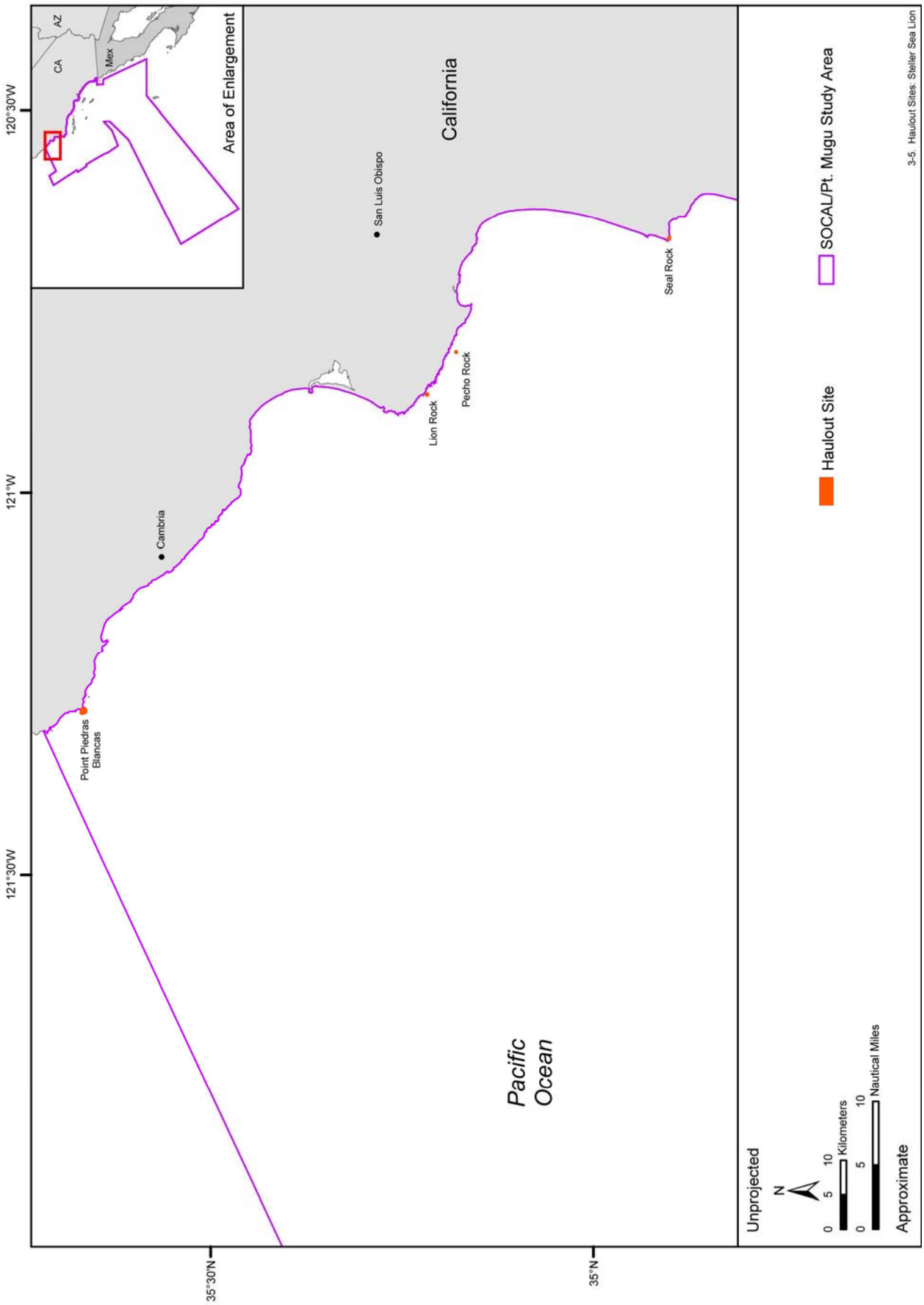

Figure 3-5. Steller sea lion haulout sites in the SOCAL/Pt. Mugu Study Area. Source data: NOS (2006).

- **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 45 kg; females are smaller, measuring maximum mean lengths of 1.4 m and maximum mean weights of 32.5 kg (Jefferson et al. 2008). 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: one southern sea otter subspecies, *Enhydra lutris nereis*, which primarily occupies waters off central California, and two northern sea otter subspecies — *Enhydra lutris lutris* found in the western North Pacific from the Kamchatka Peninsula through the Kuril Islands and *Enhydra lutris kenyoni* distributed in the Commander Islands; the Aleutian Islands; throughout central and southeastern coastal Alaskan waters; and off British Columbia, Washington State, and Oregon (Wilson et al. 1991; Cronin et al. 1996; USFWS 2003).

The USFWS recognizes five stocks in U.S. waters under the MMPA guidelines (USFWS 2005); 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 and is designated as depleted under the MMPA.

In 1914, the total California population was estimated to be approximately 50 individuals (Kenyon 1975), but recovery has occurred since they were protected. The number of sea otters counted during California spring surveys steadily increased from 1985 until 1995 when 2,377 otters were counted (USFWS 2003). A declining trend was noted in subsequent years; the depressed population growth rate was largely due to elevated mortality with infectious disease being the single most important known cause of mortality (Estes et al. 2003a; Kreuder et al. 2003). The current population trend based on three-year running averages indicates a 5% increase since 2001 (USFWS 2008). Based on the recent mainland California survey (between Point San Pedro and Rincon Point) during May 2008, the minimum size of the southern sea otter population is 2,760 individuals.[1] When factoring in the recent 2008 survey estimates, the overall trend suggests that the rate of population recovery is slowing down.[1]

In August 1987, USFWS began translocating southern sea otters to San Nicolas Island in the SCB as part of the recovery action for these animals (Riedman and Estes 1990; USFWS 2003). The last sea otter was released at San Nicolas Island in July 1990 (USFWS 2003). Of the 140 sea otters released, the fate of 70 is known. At least 13 sea otters are thought to have remained at San Nicolas Island after their release (USFWS 2003). At least three individuals from San Nicolas Island were identified in the San Diego area (Rathbun and Benz 1991). The highest count of otters at San Nicolas Island in 2007 was approximately 37 independent sea otters and 4 dependent pups (Carswell, L., USFWS, pers comm., 10 July 2008). No official numbers for 2008 are available yet.

The San Nicolas Island population is listed as “Experimental Population, Non-Essential” under the ESA; however, under P.L. 99-625, sea otters within the translocation zone (San Nicolas Island) receive the standard protections of the ESA for threatened species. Note that with respect to defense-related activities, sea otters within the translocation zone are treated as a species that is proposed to be listed [50 CFR §17.84(d)(4)(iv)].

Habitat Associations—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 2003; 2005). Sea otters in California prefer rocky shoreline with kelp beds although this is not an essential habitat requirement (Riedman and Estes 1990; USFWS 2003), and they more often

associate with giant kelp (*Macrocystis pyrifera*) as opposed to bull kelp (*Nereocystis leutkeana*). 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).

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 2003; 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 2003). Females tend to be in areas protected from weather and strong seas, while males tend to occupy more exposed areas (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).

Sea otters in California haul out on the shore at numerous sites throughout their range (Riedman and Estes 1990). Preferred haulout sites are characterized by low-relief, algal-covered rocks that are exposed at low tide although sand or cobble beaches are occasionally also used as haulout sites (Riedman and Estes 1990). Sea otters and harbor seals often haul out close to one another (Riedman and Estes 1990).

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, 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 southern sea otter historically ranged from northern California/Oregon to approximately Punta Abreojos, Baja California (Kenyon 1975). The present normal range is between Half Moon Bay and Point Conception along the coast of central and southern California (USFWS 2003). Individuals frequently wander southward beyond Point Conception (Leatherwood et al. 1978; Gallo-Reynoso and Rathbun 1997; USFWS 2003). Sea otters have been reported at San Clemente Island (Leatherwood et al. 1978). Gallo-Reynoso and Rathbun (1997) compiled reports of sea otters in Baja California, Mexico from 1965 through 1994.

As mentioned previously, sea otters were translocated to San Nicolas Island between 1987 and 1990; many have remained there since their release, and several from the island have been found in the San Diego area (Rathbun and Benz 1991; USFWS 2003).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—The area of primary occurrence is a coastal band that covers the current range of the sea otter north of Point Conception (**Figure B-10**). Primary occurrence also extends from the shoreline to the 200-m isobath around San Nicolas Island which accounts for the potential foraging range of sea otters around the island. An area of secondary occurrence buffers the primary region and extends south of Point Conception and includes the Channel Islands (**Figure B-10**). This takes into account known sightings and the possibility of encountering sea otters foraging farther offshore. Rare occurrence of the sea otter extends farther offshore and in San Diego Bay.

- Cold-water period—Occurrence during this period is anticipated to be similar to the warm-water period (**Figure B-10**).

Behavior and Life History—Sea otters may be sighted alone or in groups, often called "rafts" (Riedman and Estes 1990). Sea otters spend 40 to 49% of the day resting motionless on the water surface (Ralls and Siniff 1990; Yeates et al. 2007). 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.

Pupping occurs throughout the year, although most births occur from late February to early April (USFWS 2003; 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 at 3 yr of age while males become sexually mature at 5 yr (USFWS 2003). Gestation in the sea otter involves two phases: a delayed implantation phase of 2 to 3 mo and an implanted phase of 4 to 5 mo (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 in Riedman and Estes 1990; Estes and Bodkin 2002). Sea otters feed on or near the bottom in shallow waters. The southern sea otter feeds almost entirely on sub-tidal and inter-tidal invertebrates, occasionally taking cephalopods, fishes, and even seabirds (Riedman and Estes 1990). 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. 2003b; Tinker et al. 2008). 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.

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). Yeates et al. (2007) recently reported mean foraging dive durations for wild sea otters as 60.5±39.1 s; mean dive duration may exceed 125 s (Ralls et al. 1995).

Acoustics and Hearing—Sea otters produce a variety of airborne sounds (underwater sounds have not been studied or recorded) 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.

3.1.2.2 Non-Threatened and Non-Endangered Marine Mammal Species of the Southern California/Point Mugu Study Area

There are 37 marine mammal species that are not listed as endangered or threatened under the ESA: three baleen whale species, 27 toothed whale species, and seven pinniped species.

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

Description—The common minke whale (hereafter referred to as minke whale) is the smallest balaenopterid species in the North Pacific Ocean, with adult lengths ranging between 6.5 and 8.8 m (Jefferson et al. 2008). The head is sharply pointed, and the single median head ridge is prominent. The dorsal fin is tall (for a rorqual), falcate, and is located about two-thirds of the way back from the snout tip (Jefferson et al. 2008). 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. The minimum population estimate for the California/Oregon/Washington stock of the minke whale is 544 individuals (Carretta et al. 2007). Horwood (1990) noted that densities of minke whales throughout the North Pacific are low.

Habitat Associations—The minke whale generally 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. 2004). Occurrences in deeper water are also well-known based on whaling catches, global surveys, and acoustics (Slijper et al. 1964; Horwood 1990; Mitchell 1991; Clark and Gagnon 2004).

Shifts in prey distribution and abundance affect minke whale distribution and abundance (K. MacLeod et al. 2004). Minke whales are known to preferentially feed in highly-concentrated prey areas within fine-scale eddies; these eddies form around islands during tidal retreat (Johnston et al. 2005a). Ingram et al. (2007) reported minke whales feeding in areas with headland wakes in the Bay of Fundy (functioning similarly to create areas of upwelling and fronts that can aggregate prey). Dorsey et al. (1990) noted minke whales feeding in locations of strong tidal currents in inshore waters of Puget Sound. Hoelzel et al. (1989) reported that 80% of feeding observations in the San Juan Islands were over submarine slopes of moderate incline at a depth of about 20 to 100 m. Off the California coast, minke whales forage from kelp beds and out to the continental shelf (Dorsey et al. 1990). In other locales, they enter fjords, inland waters, and bays in search of food (Stern, J., Northeast Pacific Minke Whale Project, pers. comm., 7 April 2008).

Distribution—Minke whales are distributed in polar, temperate, and tropical waters; they are less common in some tropical areas such as the ETP (Jefferson et al. 2008). 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).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—During the warm-water period, the primary occurrence of the minke whale is a generalized coastal band that extends farther offshore south of the Channel Islands to capture sightings off Baja (**Figure B-11**). A band of secondary occurrence extends offshore of the primary region and includes the possible migratory corridor. Due to limited sighting data, the area of secondary occurrence is largely based on data from acoustic surveys that indicate that minke whales also occur farther offshore on the westernmost fringe of the Study Area (Barlow et al. 2004). Occurrence throughout the rest of the Study Area is expected to be rare.

  - Cool-water period—During the cool-water period, the area of primary occurrence is a generalized coastal band that extends farther offshore south of the Channel Islands (**Figure**

B-11). This takes into account sightings data and is largely based on the presumed migration of minke whales south during this time of year (Jefferson, T.A., NMFS-SWFSC, pers. comm., 23 to 25 January 2008). The area of secondary occurrence extends farther offshore to account for the possible migratory area. During this time of year, minke whales may be using both nearshore and offshore waters as they migrate to wintering areas. Occurrence is rare in San Diego Bay.

Behavior and Life History—Minke whales are sighted alone or in small groups of two to three individuals, although aggregations of up to 400 sometimes occur in high-latitude areas (Perrin and Brownell 2002). Mating is thought to occur in October to March but has never been observed (Stewart and Leatherwood 1985). Minke whales reach sexual maturity at an age of 5 to 7 yr (Stewart and Leatherwood 1985; Olsen and Sunde 2002). Gestation lasts 10 mo and is followed by a 4- to 5-mo lactation period (Stewart and Leatherwood 1985).

Minke whales are lunge-feeding "gulpers" like most other rorquals (Pivorunas 1979). Minke whales tend to feed on whatever food source is most abundant in a given area. 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; Murase et al. 2007).

Diel and seasonal variation in surfacing rates are documented for this species; this is probably due to changes in feeding patterns (Stockin et al. 2001). Dive durations of 7 to 380 s are recorded in the eastern North Pacific and the eastern North Atlantic (Lydersen and Øritsland 1990; Stern 1992; Stockin et al. 2001; Øien et al. 2003). Mean time at the surface averages 3.4 s (S.D.=±0.3 s) (Lydersen and Øritsland 1990).

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 ms 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 1998b). 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 s (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.

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

Description—Bryde's whales can be easily confused with sei whales. Bryde's whales usually have three prominent ridges on the rostrum (other rorquals generally have only one). The Bryde's whale's dorsal fin is tall and falcate and generally rises abruptly out of the back. Males can reach lengths of 15 m while females are longer on average, reaching lengths of 16.5 m (Jefferson et al. 2008).

It is not clear how many species of Bryde's whales exist, but genetic analyses suggest the existence of at least two species (Rice 1998; Kato 2002). The taxonomy of the baleen whale group formerly

known as sei and Bryde's whales is currently confused and highly controversial (see Reeves et al. 2004 for a recent review). It is clear that there are at least three species in this group, the antitropically-distributed sei whale, the tropically-distributed standard form Bryde's whale (probably referable to *Balaenoptera brydei*), and the "dwarf Bryde's whale" (probably referable to *Balaenoptera edeni*), which inhabits tropical waters of the Indo-Pacific (Yoshida and Kato 1999); however, the nomenclature is not resolved due to questions about the affinities of the type specimens of *Balaenoptera brydei* and *Balaenoptera edeni*. The recently-discovered Omura's whale (*Balaenoptera omurai*) is of similar size and appearance (Wada et al. 2003), thus causing additional taxonomic confusion.

Status—The IWC recognizes three management stocks of Bryde's whales in the North Pacific: Western North Pacific, Eastern North Pacific, and East China Sea (Donovan 1991). Bryde's whales in California likely belong to a larger population inhabitating at least the eastern part of the tropical Pacific (east of 150°W and including the Gulf of California and waters off California) (Carretta et al. 2007). There is no current estimate of minimum abundance for the Eastern Tropical Pacific stock because the last estimate (11,163) is over eight years old (Wade and Gerrodette 1993; Carretta et al. 2007).

Habitat Associations—Bryde's whales are found both offshore and near the coasts in many regions. Off eastern Venezuela, Bryde's whales are often sighted in the shallow waters between Isla Margarita and Peninsula de Araya, as well as into waters where there is a steep slope, such as the Cariaco Trench (Notarbartolo di Sciara 1982). Along the Brazilian coast, distribution and seasonal movements of the Bryde's whale appear to be influenced by the behavior, distribution, and abundance of Brazilian sardine (Sardinella brasiliensis) schools that approach the coast to spawn in shallow waters (Zerbini et al. 1997). In the Gulf of Mexico, all Bryde's whale sightings have been near the shelf break in DeSoto Canyon (Mullin et al. 1994b; Davis and Fargion 1996b; Jefferson and Schiro 1997; Davis et al. 1998; Davis et al. 2000). Whaling catches also have shown that the Bryde's whale is not always a coastal species (Ohsumi 1977). The Bryde's whale appears to have a preference for water temperatures between approximately 15° and 20°C (Yoshida and Kato 1999).

Distribution—The Bryde's whale is found in tropical and subtropical waters, generally not moving poleward of 40° in either hemisphere (Jefferson et al. 2008). Long migrations are not typical of Bryde's whales, though limited shifts in distribution toward and away from the equator in winter and summer, respectively, have been observed (Cummings 1985). Bryde's whales are year-round residents of the inshore waters on the west coast of Baja California south to at least as far as the Islas Tres Marias (21°N) (Rice 1977).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—During the warm-water period, occurrence throughout the SOCAL/Pt. Mugu Study Area is expected to be rare (**Figure B-12**). Although several possible sightings (identified as sei or Bryde's whales) have been made during extensive ship and aerial surveys in California waters, only one Bryde's whale has ever been positively identified (Barlow 1994a).

- Cool-water period—Occurrence is expected to be the same as during the warm-water period (**Figure B-12**).

Behavior and Life History—This species is generally seen alone or in pairs (Tershy 1992), although they can be seen in groups of up to 10 individuals (Miyazaki and Wada 1978). The Bryde's whale does not have a well-defined breeding season in most areas. There is a 2-yr reproductive cycle which is composed of 11 to 12 mo gestation, 6 mo of lactation, and 6 mo of resting (Kato 2002). Bryde's whales are lunge-feeders, feeding on schooling fish and krill (Nemoto and Kawamura 1977; Tershy et al. 1993a; Siciliano et al. 2004; Anderson 2005). Cummings (1985) reported that Bryde's whales may dive for as long as 20 min.

Acoustics and Hearing—Bryde's whales produce low frequency tonal and swept calls similar to those of other rorquals (Oleson et al. 2003). Calls vary regionally, yet all but one of the call types have a fundamental frequency below 60 Hz; they last from 0.25 s to several seconds, and they are produced in extended sequences (Oleson et al. 2003). Heimlich et al. (2005) recently described five tone types.

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

- **Gray Whale (*Eschrichtius robustus*)**

Description—Gray whales are easily identified by their mottled grayish-brown color and the white to orangish patches of whale lice and barnacles attached to their bodies, particularly their heads and tails (Jefferson et al. 2008). Instead of a dorsal fin, there is a dorsal hump followed by a series of 8 to 14 smaller "knuckles" or bumps along the dorsal ridge of the tail stock. The flippers are paddle-shaped with pointed tips. The upper jaw is moderately arched, and the head appears triangular when viewed from the top. Adults are 11 to 15 m in length and weigh up to 35 mt (Jefferson et al. 2008); 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 (Angliss and Outlaw 2008). 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). This population is currently not considered depleted under the MMPA; however, recent deoxyribonucleic acid (DNA) analyses suggest that pre-whaling abundances of gray whales were likely three to five times the current population estimates which provide support for listing the eastern Pacific population as depleted (Alter et al. 2007). Recent problems of high calf mortality and unusually thin adults may be a result of climate changes in northern feeding grounds (Grebmeier et al. 2006) and not an indication that carrying capacity has been reached (Alter et al. 2007).

Habitat Associations—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. 2008).

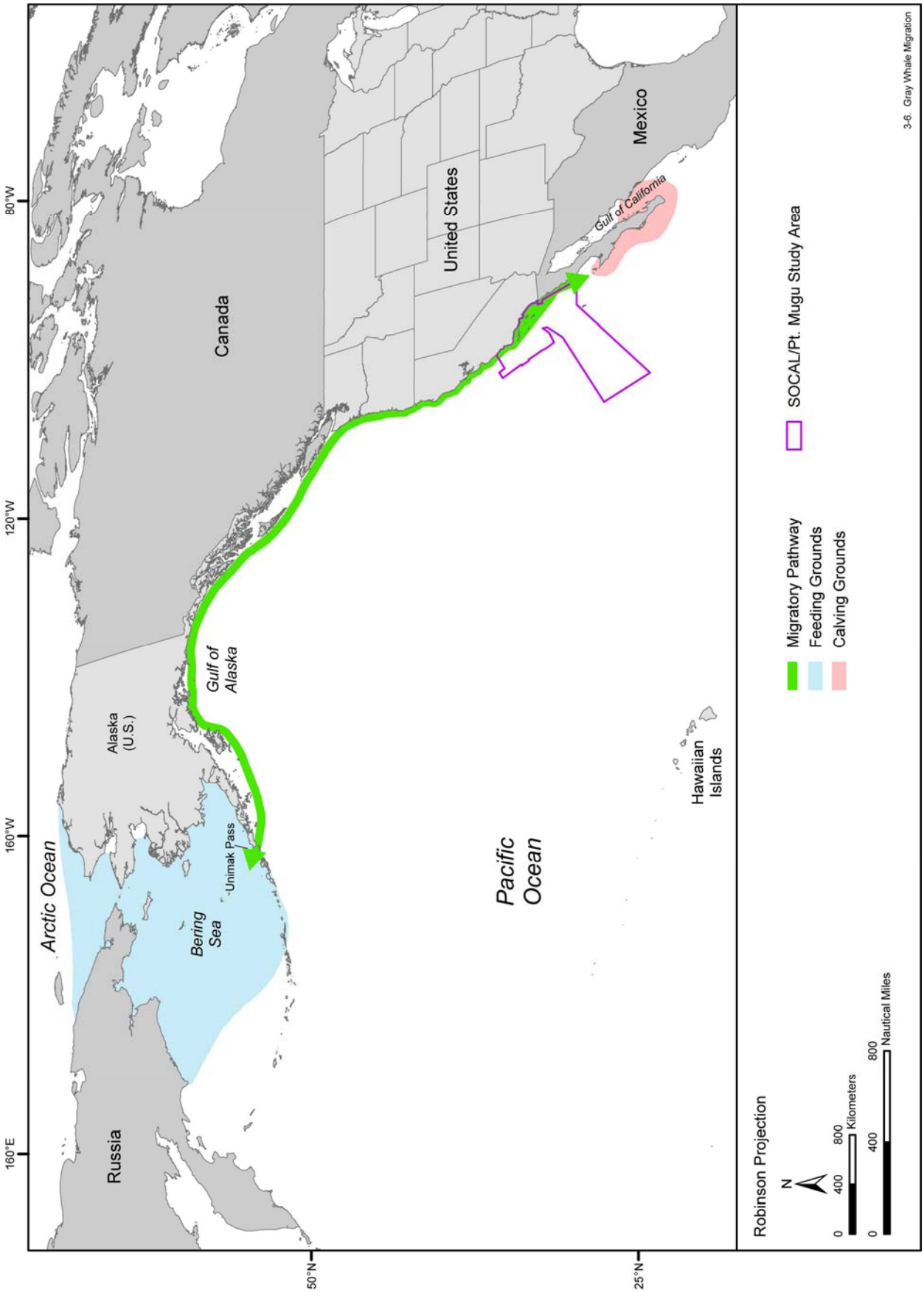

Figure 3-6. General major migratory routes of gray whales in the eastern North Pacific Ocean. Gray whales migrate along the U.S. West Coast between summer feeding grounds (April to November) in the Bering and Chukchi Seas and the Pacific Northwest and winter calving grounds (December to April) in the shallow, tropical waters off Baja California. Map adapted from: Jones et al. (1984) and Findley and Vidal (2002).

There is a pronounced seasonal north-south migration (**Figure 3-6**). 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). The northern Gulf of Alaska (near Kodiak Island) is also considered a feeding area; some gray whales occur there year-round (Moore et al. 2007). 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 kilometers per day (km/d) (Rugh et al. 2001; Jones and Swartz 2002). Although some calves are born along the coast of California (Shelden et al. 2004), 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).

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 (a few hundred individuals) of the overall eastern North Pacific population and typically arrive and depart from these feeding grounds concurrently with the migration to and from the wintering grounds (Calambokidis et al. 2002; Angliss and Outlaw 2008). Although some site fidelity is known to occur, there is generally considerable interannual variation since many individuals do not return to the same feeding site in successive years (Calambokidis et al. 2000a).

- Information Specific to the SOCAL/Pt. Mugu Study Area—The Eastern North Pacific stock of the gray whale transits through the Study Area during its northward and southward migrations between December and April. **Figure 3-6** shows a generalized migration pattern for the species. Gray whales follow three routes from within 15 to 200 km from shore (Bonnell and Dailey 1993). The nearshore route follows the shoreline between Point Conception and Point Vicente but includes a more direct line from Santa Barbara to Ventura and across Santa Monica Bay. Around Point Vicente or Point Fermin, some whales veer south towards Santa Catalina Island and return to the nearshore route near Newport Beach. Others join the inshore route that includes the northern chain of the Channel Islands along Santa Cruz Island and the Anacapas and east along the Santa Cruz Basin to Santa Barbara Island and the Osborn Bank. From here, gray whales migrate east directly to Santa Catalina Island and then to Point Loma or Punta Descanso or southeast to San Clemente Island and on to the area near Punta Banda. A significant portion of the Eastern North Pacific stock passes by San Clemente Island and its associated offshore waters (Carretta et al. 2000). The offshore route follows the undersea ridge from Santa Rosa Island to the mainland shore of Baja California and includes San Nicolas Island and Tanner and Cortes banks (Bonnell and Dailey 1993).

  Leatherwood (1974) observed a peak abundance of gray whales off the coast of San Diego in January during the southward migration and in March during the migration north. He also sighted females with calves in the area from February through May. More recent data indicate that the peak of the southbound migration past San Clemente Island is January 18 (Rugh et al. 2001).

  - Warm-water period—Although the warm-water period is outside the main migratory time of year, some late-season northbound and early southbound gray whales move through the Study Area during this period. The coastal band of secondary occurrence accounts for these individuals (**Figure B-13**). This region extends farther offshore south of Point Conception to account for the offshore migration route around the Channel Islands. The rest of the Study Area (including San Diego Bay) is an area of rare occurrence.

- Cool-water period—Gray whales are only present in the Study Area during their northward and southward migrations. This time of the year includes the main migration seasons for both north and southbound migrations. Primary occurrence during this period includes nearshore waters along the coastline; it extends farther offshore south of Point Conception to account for the offshore migration route around the Channel Islands (**Figure B-13**). A band of secondary occurrence buffers the primary region and accounts for gray whales that may migrate a bit farther offshore. Occurrence farther offshore and in San Diego Bay is considered rare.

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 or in small groups; 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 8 yr (Rice et al. 1984). The gestation period is around 13.5 mo (Rice et al. 1984). The calving season is from January through March; weaning occurs within 9 mo (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; Newell and Cowles 2006). 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).

When foraging, gray whales typically dive to 50 to 60 m for 5 to 8 min. 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) banging 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 that 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. 2008). The flippers are set forward 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. The dwarf sperm whale is similar in appearance to the pygmy sperm whale, but it has a larger, more dolphin-like dorsal fin generally set nearer the middle of the back. Pygmy and dwarf sperm whales reach body lengths of around 3.8 m and 2.7 m, respectively (Jefferson et al. 2008).

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 not available (Carretta et al. 2007); no sightings of pygmy sperm whales have been recorded during the most recent surveys (Barlow 2003a; Forney 2007). This lack of sightings does not necessarily indicate an absence of animals and is most likely due to the cryptic nature of the species (Carretta et al. 2007). 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 or documented sightings of this species there (Carretta et al. 2007).

Habitat Associations—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).

There appear to be some habitat association 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 outer continental shelf (Rice 1998; Wang et al. 2002; C.D. MacLeod et al. 2004). In particular, work on strandings and feeding habits in South Africa has indicated this (Ross 1979; Plön et al. 1998; Plön 2004). 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 studies are based on stranding records which do not provide the best evidence on habitat selection, and they often appear to ignore Ross' (1984) 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 and South African waters (Muñoz-Hincapié et al. 1998; Plön 2004). 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 species misidentifications, 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. 2008) and are known to occur off the coast of California (Hubbs 1951; Roest 1970; Caldwell and Caldwell 1989). Distribution in eastern North Pacific waters ranges from Washington State to South America (e.g., Scheffer and Slipp 1948; Hubbs 1951; Everitt et al. 1979; Muñoz-Hincapié et al. 1998)

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—Based on the known preference of *Kogia* spp. for deep waters, primary occurrence in the Study Area includes waters deeper than the 1,000-m isobath (**Figure B-14**). There is an area of secondary occurrence between the shelf break and the 1,000-m isobath (**Figure B-14**). Occurrence is rare inshore of the shelf break.

  - Cool-water period—Occurrence is expected to be the same as during the warm-water period (**Figure B-14**).

Behavior and Life History—*Kogia* species have small group sizes (mean group size is usually two individuals) (Willis and Baird 1998b; Maze-Foley and Mullin 2006). Dwarf sperm whales have been reported in groups of up to 12 individuals (Dunphy-Daly et al. 2008). 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 2004). Sexual maturity is attained at around 4 yr in both sexes of both species; however, the onset of sexual maturity in males has been reported to be as early as 2.5 and 2.6 yrs for pygmy sperm whales and dwarf sperm whales, respectively (Plön 2004). Births have been recorded between December and March for dwarf sperm whales in South Africa (Plön 2004).

Kogia feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Willis and Baird 1998b; Wang et al. 2002; Santos et al. 2006; Beatson 2007). Willis and Baird (1998b) reported that whales of the genus *Kogia* make dives of up to 25 min. Dive times ranging from 15 to 30 min (with 2 min surface intervals) have been recorded for a dwarf sperm whale in the Gulf of California (Breese and Tershy 1993). Median dive times of around 11 min are documented for *Kogia* (Barlow 1999). 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 s (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. Lengths up to 8.5 m (females) and 9.8 m (males) have been recorded; however, measurements over 7 m are considered unreliable (Jefferson et al. 2008). This species has a relatively short beak and smoothly-sloping forehead. 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. Adults often have many light scratches and circular scars on the body (Jefferson et al. 2008).

Status—The minimum population estimate for the California/Oregon/Washington stock of the Cuvier's beaked whale is 1,234 individuals (Carretta et al. 2007). 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 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 Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (e.g., Waring et al. 2001; Cañadas et al. 2002; Waring et al. 2003; MacLeod and Zuur 2005; Ward et al. 2005; Ferguson et al. 2006; MacLeod and D'Amico 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; C.D. MacLeod et al. 2004). In the ETP, 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). C.D. MacLeod et al. (2004) reported that Cuvier's beaked whales occur in deeper waters than Blainville's beaked whales in The Bahamas. 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, 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.

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).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—Based on the known preference of the Cuvier's beaked whale for deep waters, the area of primary occurrence in the Study Area includes waters deeper than the 1,000-m isobath (**Figure B-15**). The area of secondary occurrence is between the 500- and 1,000-m isobaths (**Figure B-15**). There is a rare occurrence for the Cuvier's beaked whale in waters shallower than the 500-m isobath.

- <u>Cool-water period</u>—Cuvier's beaked whale occurrence is expected to be the same as during the warm-water period (**Figure B-15**)

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). Stomach contents of Cuvier's beaked whales primarily contain cephalopods and, rarely, fish (MacLeod et al. 2003). 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; Santos et al. 2007). 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. Tyack et al. (2006) reported that based on DTAG data, Blainville's beaked whales in the Canary Islands and Cuvier's beaked whales in the Ligurian Sea forage using echolocation at depths between 222 and 1,885 m in the water column.

Rommel et al. (2006) reviewed aspects of beaked whale diving physiology and morphological/ anatomical adaptations. Dives range from those near the surface where the animals are still visible to long, deep dives. Tagging data from Cuvier's beaked whales from the Ligurian Sea has revealed: (1) dives to depths near 2 km and lasting nearly 1.5 hr; (2) slow ascent rates; and (3) a series of 'bounce' dives to 100 to 400 m between the deeper, longer dives (Cox et al. 2006; Tyack et al. 2006). Cuvier's beaked whales make a series of shallow dives after a deep foraging dive to recover from oxygen debt; average intervals between foraging dives have been recorded as 63 min for this species (Tyack et al. 2006). Tagged Cuvier's beaked whale dives with durations as long as 94 min and depths down to 1,990 m have been recorded off the Hawaiian Islands (Baird et al. 2006; Baird et al. 2007). Baird et al. (2006) reported that several aspects of diving were similar between Cuvier's and Blainville's beaked whales: 1) both dove for 48 to 68 min to depths greater than 800 m, with one long dive occurring on average every 2 hr; 2) ascent rates for long/deep dives were substantially slower than descent rates, while during shorter dives there were no consistent differences; and 3) both spent prolonged periods of time (66 to 155 min) in the upper 50 m of the water column. Both species also exhibit diel variation in diving behavior with less time spent in surface waters during the day, possibly to avoid near-surface, visually-oriented predators (e.g., large sharks, killer whales) (Baird et al. 2007).

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 because of 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 s (Manghi et al. 1999). Frantzis et al. (2002) recorded pulsed sounds with a narrow peak frequency of 13 to 17 kHz, lasting 15 to 44 s in duration. An acoustic recording tag attached to two Cuvier's beaked whales in the Ligurian Sea recorded 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); these clicks were recorded at depth with a hydrophone array. A large sample size of short, directional ultrasonic clicks from two Cuvier's beaked whales in the Ligurian Sea was recorded with non-invasive DTAGs (Johnson and Tyack 2003) at depths that averaged 475 m and a maximum of 1,267 m (Johnson et al. 2004). These clicks presented no energy lower than 20 kHz, and associated behavioral data suggest that these clicks are used during foraging by beaked whales (Johnson et al. 2004; Tyack et al. 2006). Click production ceased on ascent from a dive when the whales reached about 850 m (Johnson et al. 2004), which strongly suggests that beaked whales forage by echolocation in deep water (Tyack et al. 2006). Two types of clicks, with varied interclick intervals were documented: regular clicks showed a narrow range with 0.4 s between clicks (~175 microsecond [μs] click duration) and ended with a rapid rise in repetition rate (~250 clicks/s), which was associated with prey capture (Johnson et al. 2004). This portion of the regular click train was referred to as the 'buzz' and is comparable to click trains in dolphins and bats (Au 1993; Thomas et al. 2004).

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 also 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).

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

Description—*Mesoplodon* species have a relatively small head, large thorax and abdomen, and short tail. Blainville's beaked whales appear to reach a maximum of around 4.7 m in length (Jefferson et al. 2008). Adults are brownish or blue-gray on their dorsal side and white below. Some individuals often have a yellowish-orange sheen (diatoms films) on the head and anterior thorax. Individuals in some areas can have large numbers of oval white scars (Jefferson et al. 2008). There is sexual dimorphism in scarring, with males having high levels of scarring and females having relatively little (MacLeod 1998). *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually-dimorphic tusks which erupt only in adult males. The lower jaw of the Blainville's beaked whale is highly arched, and massive flattened tusks extend above the upper jaw in adult males (Jefferson et al. 2008).

Status—Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont (*Mesoplodon* spp.) beaked whales is 576 individuals (Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (e.g., Waring et al. 2001; Cañadas et al. 2002; Waring et al. 2003; MacLeod and Zuur 2005; Ward et al. 2005; Ferguson et al. 2006; MacLeod and D'Amico 2006; MacLeod and Mitchell 2006). Beaked whales are only occasionally reported in waters over the continental shelf (Pitman 2002). Cuvier's and Blainville's beaked whales are generally sighted in waters with a bottom depth greater than 200 m and are frequently recorded at bottom depths greater than 1,000 m (e.g., Ritter and Brederlau 1999). Most ecological information on Blainville's beaked whales comes from the northern Bahamas (C.D. MacLeod et al. 2004; MacLeod and Zuur 2005; Claridge 2006). Most time is spent along these walls where bottom depths are less than 800 m (C.D. MacLeod et al. 2004; MacLeod and Zuur 2005; Claridge 2006). Adult Blainville's beaked whales in The Bahamas are found most often over the continental slope, while subadults are found in even deeper waters (Claridge 2006). In the Society Islands, Blainville's beaked whales were observed in waters with a bottom depth of 300 to 1,400 m (Gannier 2000). Ritter and Brederlau (1999) reported sightings of this species in waters with a bottom depth less than 500 m and as shallow as 100 m off the island of La Gomera in the Canary Islands. In the ETP, the mean bottom depth for Blainville's beaked whale sightings is just over 3,500 m, and the maximum depth is 5,750 m (Ferguson 2005; Ferguson et al. 2006). As noted by MacLeod and D'Amico (2006), in many locales, occurrence patterns of beaked whales have been linked to physical features, in particular, the continental slope, canyons, escarpments, and oceanic islands.

Distribution—The ranges of most mesoplodonts are poorly known; these animals are known mostly from strandings (Mead 1989; MacLeod 2000; MacLeod et al. 2006). The Blainville's beaked whale is the most widely distributed *Mesoplodon* species. Blainville's beaked whales are thought to have a continuous distribution throughout tropical, subtropical, and warm-temperate waters of the world's oceans; they occasionally occur in cold-temperate areas (MacLeod et al. 2006). In the eastern Pacific, where there are about a half-dozen *Mesoplodon* species known, the Blainville's beaked whale

is second only to the pygmy beaked whale (*Mesoplodon peruvianus*) in abundance in tropical waters (Wade and Gerrodette 1993).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—Occurrence of *Mesoplodon* spp. in the Study Area is based on their preference for deep waters. The area of primary occurrence for the Blainville's beaked whale is in waters deeper than the 500-m isobath (**Figure B-16**). The area of secondary occurrence is between the 200- and 500-m isobaths (**Figure B-16**). There is a rare occurrence for the Blainville's beaked whale in waters shallower than the 200-m isobath.

  - Cool-water period—Occurrence of the Blainville's beaked whale is expected to be the same as during the warm-water period (**Figure B-16**).

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). Beaked whale life histories are poorly known and reproductive biology is generally undescribed. Blainville's beaked whales are found in groups ranging from one to 11 individuals (MacLeod and D'Amico 2006). As noted by MacLeod and D'Amico (2006), the Blainville's beaked whale is one of the few beaked whale species for which there is some good information on group composition, and that information is from the northeastern Bahamas. Groups there are usually comprised of females, calves, and/or juveniles. Some groups also include a mature or subadult male (Claridge 2005; MacLeod and D'Amico 2006; McSweeney et al. 2007).

Stomach content analyses of captured and stranded individuals suggest that beaked whales are deep divers that feed by suction on mesopelagic fishes, squids, and deepwater benthic invertebrates (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003; Santos et al. 2007). Mesoplodonts occupy a separate ecological niche from Cuvier's beaked whales by feeding on smaller squids which allows for the different beaked whale species to coexist (MacLeod et al. 2003; MacLeod 2005). All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (e.g., MacLeod et al. 2003; Ohizumi and Kishiro 2003). However, based on recent tagging data, Baird et al. (2006) suggested that feeding might actually occur in mid-water rather than only at or near the bottom. Tyack et al. (2006) reported that based on DTAG data, Blainville's beaked whales in the Canary Islands and Cuvier's beaked whales in the Ligurian Sea forage using echolocation at depths between 222 and 1,885 m in the water column.

Rommel et al. (2006) reviewed aspects of beaked whale diving physiology and morphological/ anatomical adaptations. Dives range from those near the surface where the animals are still visible to long, deep dives. Dive durations for *Mesoplodon* spp. are typically over 20 min (Barlow 1999; Baird et al. 2006). Tagging data from Blainville's beaked whales from the Canary Islands has revealed: (1) dives to depths near 2 km and lasting near 1.5 hr; (2) slow ascent rates; and (3) a series of 'bounce' dives of 100 to 400 m between the deeper, longer dives (Cox et al. 2006; Tyack et al. 2006). Similar to Cuvier's beaked whales, Blainville's beaked whales make a series of shallow dives after a deep foraging dive to recover from oxygen debt; average intervals between foraging dives have been recorded as 63 min for Cuvier's beaked whales and 92 min for Blainville's beaked whales (Tyack et al. 2006). Tagged Blainville's beaked whales off the Hawaiian Islands are recorded to dive as deep as 1,599 m and as long as 83 min (Baird et al. 2007). Baird et al. (2006) reported that several aspects of diving were similar between Cuvier's and Blainville's beaked whales: 1) both dove for 48 to 68 min to depths greater than 800 m, with one long dive occurring on average every 2 hr; 2) ascent rates for long/deep dives were substantially slower than descent rates, while during shorter dives there were no consistent differences; and 3) both spent prolonged periods of time (66 to 155 min) in the upper 50 m of the water column. Both species also exhibit diel variation in diving behavior with less time spent

in surface waters during the day, possibly to avoid near-surface, visually-oriented predators (e.g., large sharks, killer whales) (Baird et al. 2007).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies between 300 Hz and 129 kHz for echolocation and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of both Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006). Data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies. The DTAG was attached to two Blainville's beaked whales in the Ligurian Sea (Johnson et al. 2004). More recently, three Blainville's beaked whales were tagged with stereo DTAGs at a significantly higher sample rate (192 kHz) off the coast of El Hierro in the Canary Islands and off Andros Island in The Bahamas (Johnson 2008). The increased range of sampling on the stereo DTAG facilitated capture FM clicks from this species, which was found to be highly vocal, producing high-frequency echolocation clicks with no significant energy below 20 kHz (Johnson et al. 2004). Dive cycle and sound production were generally similar between study sites for these data. The source level of these clicks ranged from 200 to 220 dB re 1 μPa-m (Johnson et al. 2004). Madsen et al. (2005) reported interclick intervals of 300 to 400 ms. Concurrent anatomical and behavioral data (also collected with the DTAG) indicated that beaked whales use a series of regular clicks (interclick interal of 0.2 to 0.4 s, ~250 μs) during the search phase of foraging and shift to a 'buzz' click (i.e., increased repetition rate from regular clicks to ~250 clicks/s) to capture prey (Johnson et al. 2004; Johnson 2008). *Mesoplodon* begin clicking at an average depth of 400 m and cease clicking on ascent at about 720 m (Johnson et al. 2004). DTAGs also captured click echoes, which provide the first direct evidence with respect to how beaked whales use echolocation to forage; echo strength indicates a source level of 200 to 220 dB re 1 μPa-m for these beaked whale clicks (Johnson et al. 2004; Johnson 2008). It is believed that beaked whales employ a dynamic echolocation system during prey detection and capture that is somewhat different from other odontocetes that feed in more shallow water (Johnson 2008). More data are required to better understand potential similarities and differences in echolocation function across taxonomic groups of toothed whales.

As part of a combined visual and acoustic survey, Rankin and Barlow (2007) recorded both FM and AM sounds in close proximity to three Blainville's beaked whale cow/calf pairs in Hawai'i. This is one of the first reports of tonal calls from this species.

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

- **Ginkgo-toothed Whale (*Mesoplodon ginkgodens*)**

Description—The maximum known sizes for ginkgo-toothed whales are 5.3 m for both females and males (Jefferson et al. 2008). All *Mesoplodon* species have a relatively small head, large thorax and abdomen, and short tail. *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Adult male ginkgo-toothed whales appear to be dark gray over the entire body with a faint light patch on the anterior half of the rostrum and lower jaw, while females are apparently lighter in color (Mead 1989). They are not as heavily scarred as other *Mesoplodon* spp. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually-dimorphic tusks, which erupt only in adult males. In the ginkgo-toothed beaked whale, the tusks of males are wide and flattened but with a small denticle at their apex (Mead 1989).

Status—Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* stocks. The minimum

population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 576 individuals (Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; C.D. 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). 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, 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. Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank. Based on stranding records in the EPO, Palacios (1996) suggested that ginkgo-toothed whales might select relatively cool, upwelling-modified habitats, such as those found in the California and Perú currents and along the equatorial front.

Distribution—The ginkgo-toothed whale is known only from strandings (there are no confirmed sightings) in temperate and tropical waters of the Pacific and Indian oceans (Mead 1989; Palacios 1996; MacLeod et al. 2006). There are two records from the eastern North Pacific: a stranding in 1954 at Del Mar, California (Moore and Gilmore 1965) and a skull collected in December 1980 at Playa Malarrimo, outside Laguna Ojo de Liebre (Scammon's Lagoon), Baja California, Mexico (Leatherwood et al. 1988).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—Occurrence of *Mesoplodon* spp. in the Study Area is based on their preference for deep waters. The area of primary occurrence for the ginkgo-toothed beaked whale is in waters deeper than the 500-m isobath (**Figure B-16**). The area of secondary occurrence is between the 200- and 500-m isobaths (**Figure B-16**). There is a rare occurrence for the ginkgo-toothed beaked whale in waters shallower than the 200-m isobath.

- Cool-water period—Occurrence of the ginkgo-toothed beaked whale is expected to be the same as during the warm-water period (**Figure B-16**).

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). Little life history data is available for the ginkgo-toothed whale. Group sizes of *Mesoplodon* spp. are generally small, ranging from one 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; 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 content analyses of captured and stranded individuals suggest beaked whales are deep divers that feed by suction on mesopelagic fishes, squids, and deepwater benthic invertebrates (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003; Santos et al. 2007). Mesoplodonts occupy a separate ecological niche from Cuvier's beaked whales by feeding on smaller squids which allows for the different beaked whale species to coexist (MacLeod et al. 2003; MacLeod 2005). Dive durations for *Mesoplodon* spp. are typically over 20 min (Barlow 1999; Baird et al. 2006).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Constrained by data storage size and battery life to a 96 kHz sample rate,

DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies. There is no specific information available for ginkgo-toothed whale vocalizations.

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

- **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 (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" on the melon in front of and around the blowhole (Mead et al. 1982). *Mesoplodon* spp. 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 U.S. management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 576 individuals (Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; C.D. 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). 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, 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. Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank. In a rare sighting of Hubbs' beaked whales off Washington State/Oregon in July 1994, the whales appeared to be associating with a large eddy or other oceanographic feature which concentrated jumping baitfish and tunas (Jefferson, T.A., NMFS-SWFSC, pers. comm., 13 February 2008). Along the Pacific coast of 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 (Mead et al. 1982). The live sighting reported by Hubbs (1946) off La Jolla, California was a second-hand sighting made by construction workers and is not supported by any description of diagnostic characters; therefore, this sighting cannot be confirmed (Jefferson, T.A., NMFS-SWFSC, pers. comm., 8 April 2008). 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).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—Occurrence of *Mesoplodon* spp. in the Study Area is based on their preference for deep waters. The area of primary occurrence for the Hubbs' beaked whale is in waters deeper than the 500-m isobath (**Figure B-16**). The area of secondary occurrence is between the 200- and 500-m isobaths (**Figure B-16**). There is a rare occurrence for the Hubbs' beaked whale in waters shallower than the 200-m isobath.

- Cool-water period—Occurrence of the Hubbs' beaked whale is expected to be the same as during the warm-water period (**Figure B-16**).

Behavior and Life History—Life history data on Hubbs' beaked whales are extremely limited. Calving in this species most probably takes place in summer (Mead et al. 1982; Willis and Baird 1998a). 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). Dive durations for *Mesoplodon* spp. are typically over 20 min (Barlow 1999; Baird et al. 2006).

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. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies. Vocalizations recorded from two juvenile Hubbs' beaked whales consisted of low- and high-frequency click trains ranging in frequency from 300 Hz to 80 kHz and whistles with a frequency range of 2.6 to 10.7 kHz and duration of 156 to 450 ms (Lynn and Reiss 1992; Marten 2000).

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. 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).

- **Perrin's Beaked Whale *(Mesoplodon perrini*)**

Description—This is a newly-described beaked whale species (Dalebout et al. 2002). Animals initially identified as Hector's beaked whale in the eastern North Pacific Ocean (Mead 1981) were reclassified as Perrin's beaked whales (Dalebout et al. 2002). Like other *Mesoplodon* species, the Perrin's beaked whale has a relatively small head, large thorax and abdomen, and short tail. The rostrum of the Perrin's beaked whale is relatively short compared to other *Mesoplodon* species. The five specimens that have been examined indicate that they can grow to at least 4.4 m (females) and 3.9 m (males) (Jefferson et al. 2008). *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Coloration of this species is dark gray-brown above and light gray below, with scratches often covering the body (Dalebout et al. 2002). 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 teeth of the Perrin's beaked whale are flattened and triangular and positioned near the apex of the lower jaw (Dalebout et al. 2002).

Status—Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 576 individuals (Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; C.D. 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). 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, escarpments, and oceanic islands. Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank. Dalebout et al. (2002) assumed that the Perrin's beaked whale is found primarily in oceanic waters, over 1,000 m in bottom depth, based on the known habitat associations of other beaked whale species.

Distribution—The Perrin's beaked whale is known only from five stranded specimens along the California coastline (Dalebout et al. 2002). While this stranding pattern is suggestive of an eastern North Pacific Ocean distribution, there are too few records to date for this to be conclusive (Dalebout et al. 2002).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—Occurrence of *Mesoplodon* spp. in the Study Area is based on their preference for deep waters. The area of primary occurrence for the Perrin's beaked whale is in waters deeper than the 500-m isobath (**Figure B-16**). The area of secondary occurrence is between the 200- and 500-m isobaths (**Figure B-16**). There is a rare occurrence for the Perrin's beaked whale in waters shallower than the 200-m isobath.

- <u>Cool-water period</u>—Occurrence of the Perrin's beaked whale is expected to be the same as during the warm-water period (**Figure B-16**).

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). Little life history data are available for the Perrin's beaked whale. Group sizes of *Mesoplodon* spp. are generally small, ranging from one 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;

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 content analyses of captured and stranded individuals suggest beaked whales are deep divers that feed by suction on mesopelagic fishes, squids, and deepwater benthic invertebrates (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003; Santos et al. 2007). Dalebout et al. (2002) reported finding pelagic squid species, such as *Octopoteuthis deletron*, within stomach contents of stranded Perrin's beaked whales. Mesoplodonts occupy a separate ecological niche from Cuvier's beaked whales by feeding on smaller squids which allows for the different beaked whale species to coexist (MacLeod et al. 2003; MacLeod 2005). Dive durations for *Mesoplodon* spp. are typically over 20 min (Barlow 1999; Baird et al. 2006).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies between 300 Hz and 129 kHz for echolocation and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies. There is no specific information available on Perrin's beaked whale vocalizations.

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

- **Pygmy Beaked Whale (*Mesoplodon peruvianus*)**

Description—The pygmy beaked whale is the smallest known species of *Mesoplodon,* with a maximum body length of 3.7 to 3.9 m (Jefferson et al. 2008). The coloration is dark gray above and lighter below with little scarring (Reyes et al. 1991). Like other *Mesoplodon* species, the pygmy beaked whale has a relatively small head, large thorax and abdomen, and short tail. The dorsal fin of the pygmy beaked whale is small and triangular with a wide base. *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 teeth of pygmy beaked whales are relatively small for a *Mesoplodon* species; they are egg-shaped in cross-section (Reyes et al. 1991).

Status—Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 576 individuals (Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; C.D. 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). 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, escarpments, and oceanic islands. Tynan et al. (2005) reported an association of beaked whales with strong turbulence associated with rough topography along the slope near Heceta Bank. Urbán-Ramírez and Aurioles-Gamboa (1992) speculated that the pygmy beaked whale occurs in equatorial and subequatorial waters with relatively large seasonal changes in the SST, depth of the thermocline, and upwelling.

Distribution—Urbán-Ramírez and Aurioles-Gamboa (1992) proposed that the distribution area for the pygmy beaked whale is the ETP. MacLeod et al. (2006) suggested that the pygmy beaked whale occurs in the eastern Pacific from about 30°N to about 30°S.

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—Occurrence of *Mesoplodon* spp. in the Study Area is based on their preference for deep waters. The area of primary occurrence for the pygmy beaked whale is in waters deeper than the 500-m isobath (**Figure B-16**). The area of secondary occurrence is between the 200- and 500-m isobaths (**Figure B-16**). There is a rare occurrence for the pygmy beaked whale in waters shallower than the 200-m isobath.

- Cool-water period—Occurrence of the pygmy beaked whale is expected to be the same as during the warm-water period (**Figure B-16**).

Behavior and Life History—Life history data on beaked whale species are extremely limited, and there is no available information regarding reproductive parameters for the pygmy beaked whale. Seasonality of calving is not known for most beaked whale species. Group sizes of *Mesoplodon* spp. are generally small, ranging from one to 15 individuals (MacLeod and D'Amico 2006). Groups of two or three individual pygmy beaked whales have been observed (Reyes et al. 1991).

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 content analyses of captured and stranded individuals suggest beaked whales are deep divers that feed by suction on mesopelagic fishes, squids, and deepwater benthic invertebrates (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003; Santos et al. 2007). Stomach contents analyses are available for only two pygmy beaked whales; these contained no squid beaks but did have otoliths of perciform and myctophiform fish (Family Nemipteridae and Myctophidae, respectively) and probably Ophidiiformes (Reyes et al. 1991). Mesoplodonts occupy a separate ecological niche from Cuvier's beaked whales by feeding on smaller squids which allows for the different beaked whale species to coexist (MacLeod et al. 2003; MacLeod 2005). Dive durations for *Mesoplodon* spp. are typically over 20 min (Barlow 1999; Baird et al. 2006).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies. There is no specific information available on pygmy beaked whale vocalizations.

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

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

Description—The Stejneger's beaked whale reaches lengths of at least 5.7 m (Jefferson et al. 2008). This species has a typical *Mesoplodon* body shape, but the lower jaw of the adult male is highly arched with a large tusk sitting atop each arch (Mead 1989). The coloration is not very distinctive, except for some interesting white striations around the base of the tail (Walker and Hanson 1999) and a dark "hood' on the top of the head (Jefferson et al. 2008).

Status—Until better methods are developed for distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* stocks. The minimum population estimate of California/Oregon/Washington stocks of mesoplodont beaked whales is 576 individuals (Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; C.D. 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, 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).

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.

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 and the Miyagi Prefecture, Japan (Loughlin and Perez 1985; MacLeod et al. 2006).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—Occurrence of *Mesoplodon* spp. in the Study Area is based on their preference for deep waters. The area of primary occurrence for the Stejneger's beaked whale is in waters deeper than the 500-m isobath (**Figure B-16**). The area of secondary occurrence is between the 200- and 500-m isobaths (**Figure B-16**). There is a rare occurrence for the Stejneger's beaked whale in waters shallower than the 200-m isobath.

- <u>Cool-water period</u>—Occurrence of the Stejneger's beaked whale is expected to be the same as during the warm-water period (**Figure B-16**).

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. 2008). 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). 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. Mesoplodonts occupy a separate ecological niche from Cuvier's beaked

whales by feeding on smaller squids which allows for the different beaked whale species to coexist (MacLeod et al. 2003; MacLeod 2005). Stejneger's beaked whale stomach contents include squids and pelagic fish (Nishiwaki and Kamiya 1958; Walker and Hanson 1999; Yamada and Yamada 1999). Dive durations for *Mesoplodon* spp. are typically over 20 min (Barlow 1999; Baird et al. 2006).

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. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies.

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. 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).

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

Description—This species was often referred to as the "tropical bottlenose whale" in the past. This was due to the fact that whales now known to be of this species had been sighted in various locations in the tropical/subtropical Indo-Pacific but not identified to species (Pitman et al. 1999). At the time, this species was known only from a handful of skulls, and the external appearance of the species was undescribed. Until several stranded specimens were identified as Longman's beaked based on skull morphology and genetics, and the connection was made (Dalebout et al. 2003), the sighted whales were thought to be members of the *Hyperoodon* genus (either far-ranging southern bottlenose whales or possibly an undescribed tropical species). We now know these animals to be in fact, Longman's beaked whales.

The Longman's beaked whale looks very much like the southern bottlenose whale (*Hyperoodon planifrons*) in general shape and coloration but is more slender (Pitman et al. 1999; Dalebout et al. 2003). Longman's beaked whales ranging from an estimated 4 to 9 m in length have been sighted at-sea (Jefferson et al. 2008). The tall, falcate dorsal fin is set far back on the body (Pitman et al. 1999; Dalebout et al. 2003). The head has a well-rounded melon in profile, and the beak length is variable, suggesting developmental changes in beak size (Pitman et al. 1999; Dalebout et al. 2003). This species has a single pair of teeth that are set close to the tip of the lower jaw; it is suspected that, like most other beaked whales species, only adult males have erupted teeth (Dalebout et al. 2003). The body color has been described as variable but is dominated by tan to grayish-brown tones (Pitman et al. 1999). Young animals are distinctively patterned; they are darker gray-brown above with a conspicuous pale melon and white sides (Pitman et al. 1999). The light area on the head extends only as far back as the blowhole (Jefferson et al. 2008).

Status—Longman's beaked whale is considered to be a relatively rare beaked whale species (Pitman et al. 1999; Dalebout et al. 2003). Only one Pacific stock, the Hawaiian stock, is identified for this species. The minimum population estimate for this stock is 371 Longman's beaked whales (Carretta et al. 2007). Based on the 2002 surveys of the Hawaiian Islands EEZ, the best available abundance estimate of this stock is 766 individuals (Barlow 2003b; Carretta et al. 2007).

Habitat Associations—World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (e.g., Waring et al. 2001; Cañadas et al. 2002; Waring et al. 2003; MacLeod and Zuur 2005; Ward et al. 2005; Ferguson et al. 2006; MacLeod and D'Amico 2006; MacLeod and Mitchell 2006). Beaked whales are only occasionally reported in waters over the continental shelf (Pitman 2002). The Longman's beaked whale appears to have a preference for warm tropical water, with most sightings occurring in waters with a SST warmer than 26ºC (Pitman et al. 1999; Anderson et al. 2006). It is also a deepwater species. As noted by MacLeod and D'Amico (2006), in many locales, occurrence patterns of beaked whales have been linked to physical features, in particular, the continental slope, canyons, escarpments, and oceanic islands. The authors noted that more research is needed to determine how surface and deep water currents, levels of local productivity, and distribution of prey species may influence habitat usage.

Distribution—Longman's beaked whale is known from tropical waters of the Pacific and Indian oceans (Pitman et al. 1999; Dalebout et al. 2003). Ferguson and Barlow (2001) reported that all Longman's beaked whale sightings were south of 25°N. The northernmost records in the eastern North Pacific Ocean are sightings near Guadalupe Island off Baja California, during an El Niño event (Gallo-Reynoso and Figueroa-Carranza 1995).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—An area of secondary occurrence is in waters deeper than the 200-m isobaths and warmer than the 19°C isotherm (**Figure B-17**). Occurrence is expected to be rare in waters shallower than the 200-m isobath and cooler than the 18°C isotherm.

- Cool-water period—Occurrence is expected to be similar to the warm-water period (**Figure B-17**). Note that the secondary and rare occurrences during this period are based on the isotherm locations for the warm-water period as no sightings have been made in U.S. west coast waters.

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

Stomach content analyses of captured and stranded individuals suggest beaked whales are deep divers that feed by suction on mesopelagic fishes, squids, and deepwater benthic invertebrates (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003; Santos et al. 2007). All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (e.g., MacLeod et al. 2003; Ohizumi and Kishiro 2003); however, based on recent tagging data, Baird et al. (2006) suggested that feeding might actually occur in mid-water rather than only at or near the bottom. There is no information available regarding feeding behavior and preferred prey of the Longman's beaked whale.

Rommel et al. (2006) reviewed aspects of beaked whale diving physiology and morphological/ anatomical adaptations. Dives range from those near the surface where the animals are still visible to long, deep dives. A maximum dive time of 33 min has been reported for Longman's beaked whales (Anderson et al. 2006). Anderson et al. (2006) recorded a combination of short (11 to 18 min) and long (20 to 33 min) dives for Longman's beaked whales in the Indian Ocean.

Acoustics and Hearing—There is no information available for Longman's beaked whale vocalizations. MacLeod (1999) suggested that beaked whales use frequencies between 300 Hz and

129 kHz for echolocation and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies.

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

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

Description—Baird's beaked whales are the largest beaked whales; males and females can attain lengths of 10.7 m and 11.1 m, respectively (Jefferson et al. 2008). Baird's beaked whales are dark brownish-gray, usually heavily scarred, and have light scratches or splotches on the back and often on the undersides (Jefferson et al. 2008). 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 and 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 203 individuals (Carretta et al. 2007). This species is rarely sighted during surveys along the west coast of the U.S. (Barlow 2003a; Forney 2007).

Habitat Associations—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 1998a; Kasuya 2002; Tynan et al. 2005). They may be seen close to shore where deep water approaches the coast (Jefferson et al. 2008) and in shallow waters in the central Okhotsk Sea (Kasuya 2002).

Distribution—The Baird's beaked whale is found only in the North Pacific and adjacent seas (Bering Sea, Okhotsk Sea, Sea of Japan, and the Gulf of California), mainly north of 34°N in the west and 28°N in the east (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 there. 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. 2007). Baird's beaked whales are sighted less frequently and are presumed to be farther offshore during the colder water months of November through April (Carretta et al. 2007).

The continental shelf margins from the California coast to 125°W were recently identified as known "key areas" for beaked whales in a global review by MacLeod and Mitchell (2006).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—The area of primary occurrence is between the 500- and 3,000-m isobaths south of near Point Conception which includes canyons and ridges (**Figure B-18**). North of Point Conception, the primary occurrence region is between the 500-m isobath and a generalized offshore boundary; this broader area north of Point Conception is based on the

known distribution of Baird's beaked whales farther offshore in higher latitudes. Secondary occurrence includes waters between the 200- and 500-m isobaths along the entire coast of the Study Area and waters between the 3,000- and 3,500-m isobaths south of Point Conception; however, secondary occurrence around Guadalupe Island is between the 200- and 3,500-m isobaths. Baird's beaked whales have a rare occurrence in waters inshore of the 200-m isobath (including around Guadalupe Island) and in waters offshore of the primary and secondary regions.

- Cool-water period—Occurrence of Baird's beaked whale is expected to be the same as during the warm-water period (**Figure B-18**).

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). Recent sightings in southern and central California averaged 7 and 14.5 Baird's beaked whales, respectively (Barlow and Forney 2007). 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). 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 yr, with physical maturity at over 20 yr (Balcomb III 1989). Mating generally occurs in October and November; the gestation period is around 17 mo. 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; Santos et al. 2001; MacLeod et al. 2003; Santos et al. 2007); 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).

Rommel et al. (2006) reviewed aspects of beaked whale diving physiology and morphological/ anatomical adaptations. Dives range from those near the surface where the animals are still visible to long, deep dives. Prolonged dives by Baird's beaked whales for 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. Constrained by data storage size and battery life to a 96 kHz sample rate, DTAGs (Johnson and Tyack 2003) have successfully been used to non-invasively study the dive behavior and vocalization profile of Cuvier's and Blainville's beaked whales (Johnson et al. 2004; Tyack et al. 2006; Johnson 2008); data from the DTAGs support the notion that beaked whales produce pulsed sounds at ultrasonic frequencies. 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 two to three 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 echolocate (Dawson et al. 1998).

There is no direct information available on the exact hearing abilities of Baird'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. 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. 2008). 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. 2008). 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. 2008).

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

Habitat Associations—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), Honduras (Kuczaj II and Yeater 2007), 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 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). There are few records of this species in the temperate portion of the eastern North Pacific Ocean (Ferrero et al. 1994; Jefferson 2002a; Soldevilla et al. 2006).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—There is a rare occurrence of the rough-toothed dolphin throughout the Study Area during the warm-water period (**Figure B-19**). This is a tropical species that rarely ranges north of 40°N (Jefferson et al. 2008).

- Cool-water period—Occurrence of the rough-toothed dolphin is expected to be the same as during the warm-water period (**Figure B-19**).

Behavior and Life History—Small groups of 10 to 20 rough-toothed dolphins are most common; however, herds of over 100 animals have been reported (Miyazaki and Perrin 1994; Reeves et al. 1999; Jefferson et al. 2008). 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, Gulf of Mexico, and Honduras (Pitman and Stinchcomb 2002; Fulling et al. 2003; Kuczaj II and Yeater 2007). 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 yr of age; males attain sexual maturity between 5 and 10 yr (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 s) 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).

Odontocetes are generally adapted to hear high frequencies (Ketten 1997). A recent stranding event of rough-toothed dolphins in Florida facilitated the collection of two auditory evoked potentials on each of five individual dolphins (Cook et al. 2005); results showed that rough-toothed dolphins can detect sounds between 5 and 80 kHz but are likely capable of hearing much higher frequencies. Cook et al. (2005) suggest that this species has high temporal resolution, much like other dolphin species.

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

Description—Common bottlenose dolphins (hereafter referred to as 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. 2008).

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. 1998). There is a clear distinction between the nearshore and offshore form of the bottlenose dolphin in the western North Atlantic and western North Pacific, suggesting that the two forms may be eventually considered two different species (Curry and Smith 1997; Hoelzel et al. 1998; Kingston and Rosel 2004).

Status—Bottlenose dolphins 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. 2007). There is a minimum population estimate of 290 individuals for the California coastal stock and 2,295 individuals for the California/Oregon/Washington State offshore stock (Carretta et al. 2007). Lowther (2006) found distinct genetic differentiation between the offshore and coastal populations in the eastern North Pacific which supports the management of these populations as separate stocks.

Habitat Associations—*Tursiops* live in coastal areas of all continents (except Antarctica), around many oceanic islands and atolls, and over shallow offshore banks and shoals. In the eastern 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; 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).

Water temperature may directly or indirectly affect bottlenose dolphin movements (Wells and Scott 1999). Water temperature may directly affect movements by acting as a thermal barrier to dolphin movement (Barco et al. 1999). Alternatively, water temperature may indirectly affect movements by affecting prey movements (Barco et al. 1999; Wells and Scott 1999). Along the California coastline, the bottlenose dolphin's range expanded during 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 (Barco et al. 1999).

Hanson and Defran (1993) reported increased feeding by coastal bottlenose dolphins off southern California in kelp border and reef and estuary areas, which is consistent with the prey associated with these habitats. Bearzi (2003; 2006) reported that bottlenose dolphins occasionally aggregated offshore near areas of bottom relief, such as submarine canyons and escarpments, in Santa Monica Bay.

Distribution—*Tursiops* generally do not range poleward of 45°, except around the United Kingdom and northern Europe. The bottlenose dolphin has been recorded in tropical to temperate regions throughout the world (Jefferson et al. 2008).

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). 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). Since then, bottlenose dolphins have been consistently sighted in central California as far north as San Francisco (Maldini-Feinholz 1996).

Detailed long-term studies on bottlenose dolphins in the SCB have focused mostly on communities along the San Diego coastline (Defran and Weller 1999). Despite their broad coastal distribution, these dolphins generally occur no further than 1 km offshore and are most commonly found just outside of the breaking surf in waters with a bottom depth less than or equal to 10 m deep and within 0.25 km of the beach (Norris and Prescott 1961; Hansen 1990; Hanson and Defran 1993; Carretta et al. 1998; Defran and Weller 1999). Bearzi (2003) also noted a preference by bottlenose dolphins for a "coastal corridor" in Santa Monica Bay but found that the animals did not display the same rigorous boundary of 1 km from shore for the San Diego area. Photo-identification studies have documented north-south movements of individuals. Bottlenose dolphins can be observed year-round off San Diego, and peak numbers typically occur between November and February (Defran and Weller 1999).

A large population of bottlenose dolphins also occurs in offshore waters. Individuals have been documented in offshore waters as far north as about 41°N; individuals may range into Oregon and Washington waters during warm-water periods (Carretta et al. 2007). In the SCB, the offshore population centers around Santa Catalina Island (Bonnell and Dailey 1993; DeDecker et al. 1999). Offshore bottlenose dolphins have been documented to range year-round in the waters around Santa Catalina Island (Hill and Barlow 1992; Shane 1994; Carretta et al. 1995; DeDecker et al. 1999).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—The occurrence patterns for the bottlenose dolphin takes into consideration the habitat associations of the coastal and offshore stocks which occur in the Study Area. Primary occurrence extends throughout the Study Area. Primary occurrence along the coast, including the Channel Islands, accounts for the higher densities of bottlenose dolphins in this area (**Figure B-20a**). Although there is a lower density of bottlenose dolphins farther offshore, they are still frequently found there (Barlow, J., NMFS-SWFSC, pers. comm., May 2008).

    Based on accounts of Norris and Prescott (1961), a small group of approximately 25 to 35 bottlenose dolphins inhabited San Diego Bay during the late 1950s; however, it appears that they abandoned (or nearly so) the bay as the industrial/shipping presence increased. It is possible that free-ranging individuals might continue to use this area even though this is not a preferred area. Therefore, San Diego Bay is considered an area of secondary occurrence for the bottlenose dolphin (**Figure B-20b**).

  - Cool-water period—Occurrence is the same as that of the warm-water period (**Figure B-20a**).

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; Barlow and Forney 2007). 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). Off southern California, there is an increase in group size from inshore to offshore waters (Defran and Weller 1999; Bearzi 2003).

Bottlenose dolphins in waters off California often associate with Risso's dolphins, short-finned pilot whales, both common dolphin species, California sea lions, and gray whales (Norris and Prescott 1961; Shane 1994; Bearzi 2003, 2006). 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 yr, with females reaching sexual maturity as early as 7 yr (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 (Weller, D., NMFS-SWFSC, pers. comm., 9 April 2008); data are not available to determine calving peaks. There is a gestation period of 1 yr (Caldwell and Caldwell 1972). Calves of bottlenose dolphins typically remain with their mothers for 3 to 6 yr (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. 1969). Reeves et al. (2002)

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

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

- **Pantropical Spotted Dolphin (*Stenella attenuata*)**

Description—The pantropical spotted dolphin is a rather slender dolphin. This species has a dark dorsal cape, while the lower sides and belly of adults are gray. The beak is long and thin; the lips and beak tip tend to be bright white. A dark gray band encircles each eye and continues forward to the apex of the melon; there is also a dark gape-to-flipper stripe (Jefferson et al. 2008). Pantropical spotted dolphins are born spotless and develop spots as they age although the degree of spotting varies geographically (Perrin and Hohn 1994). Some populations may be virtually unspotted. Adults may reach 2.6 m in length (Jefferson et al. 2008).

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

Habitat Associations—Pantropical spotted dolphins tend to associate with bathymetric relief and oceanographic interfaces. Most sightings of this species in the Gulf of Mexico, Caribbean, and off Brazil occur over the lower continental slope (Davis et al. 1998; Mignucci-Giannoni et al. 2003; Mullin et al. 2004; Moreno et al. 2005). Mignucci-Giannoni et al. (2003) reported a sighting over the Puerto Rican Trench, one of the deepest areas in the world. Pantropical spotted dolphins may rarely be sighted in shallower waters (e.g., Peddemors 1999; Gannier 2002; Mignucci-Giannoni et al. 2003; Waring et al. 2007). Pantropical spotted dolphins in the Gulf of Mexico do not appear to prefer any one habitat and may be found within the Loop Current, inside a cold-core eddy, or along the continental slope (Baumgartner et al. 2001). Along the northeastern U.S., Waring et al. (1992) found that stenellids (members of the genus *Stenella*) were distributed along the Gulf Stream's northern wall. *Stenella* sightings also occurred within the Gulf Stream, which is consistent with the oceanic distribution of this genus and its preference for warm water (Waring et al. 1992; Mullin and Fulling 2003). In the eastern Pacific, the pantropical spotted dolphin is an inhabitant of the tropical, equatorial, and southern subtropical water masses characterized by a sharp thermocline at less than 50 m depth, surface temperatures greater than 25°C, and salinities less than 34 parts per thousand (ppt) (Au and Perryman 1985).

Distribution—The pantropical spotted dolphin is distributed in tropical and subtropical waters worldwide (Perrin and Hohn 1994). In the EPO, they are generally found from the central Gulf of California to about 10°S (Leatherwood et al. 1988). There are few records of the pantropical spotted dolphin north of the California-Mexico border. These records include a stranding in central California (Worthy et al. 1993) and another in Cold Bay, Alaska (Perrin et al. 1987). The dolphin found stranded

in Alaska was so far from its normal range that it is thought to have probably been transported there by human intervention (Jefferson, T.A., NMFS-SWFSC, pers. comm., 8 April 2008).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—The SOCAL OPAREA is along the northern extent of the pantropical spotted dolphin's range. This species generally has a rare occurrence in waters colder than the 19°C isotherm (**Figure B-21**). Secondary occurrence is in waters warmer than a generalized 19°C isotherm. Two sightings are reported in the northeastern portion of the SOCAL OPAREA in the general vicinity of the Channel Islands. These sightings were from the NMFS Platforms of Opportunity Program and are considered to be suspect since this species prefers warmer waters and identification of stenellid dolphins to species can be difficult to the inexperienced observer (Jefferson, T.A., NMFS-SWFSC, pers. comm., 23 to 25 January 2008).

- Cool-water period—Occurrence of the pantropical spotted dolphin is expected to be the same as during the warm-water period (**Figure B-21**). Due to shifts in the location of the 19°C isotherm during this time of year, the area of secondary occurrence only covers the southernmost portion of the Study Area and includes sightings data (**Figure B-21**).

Behavior and Life History—Pantropical spotted dolphin group sizes range from a few individuals to several thousands (Jefferson et al. 2008). Observations of pantropical spotted dolphins caught in tuna purse seines in the ETP show that subgroups contain mother/calf pairs, adult males, or juveniles (Pryor and Shallenberger 1991). Pantropical spotted dolphins in the ETP and Indian Ocean are often found in mixed species aggregations that include spinner dolphins (*Stenella longirostris*), tunas, and various oceanic bird species. In the ETP, where this species has been best studied, there are two (possibly three) calving peaks: one in spring, (one possibly in summer), and one in fall (Perrin and Hohn 1994). Pantropical spotted dolphins prey on epipelagic fishes, squids, and crustaceans (Perrin and Hohn 1994; Robertson and Chivers 1997; Wang et al. 2003). Results from various tracking and feeding studies suggest that pantropical spotted dolphins in the ETP and off Hawai'i feed primarily at night on epipelagic and mesopelagic species which rise towards the surface after dark (Robertson and Chivers 1997; Scott and Cattanach 1998; Baird et al. 2001). Dives during the day generally are shorter and shallower than dives at night; rates of descent and ascent are higher at night than during the day (Baird et al. 2001). Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the ETP and off Hawai'i (Baird et al. 2001).

Acoustics and Hearing—Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz (Ketten 1998b, 1998a; Oswald et al. 2004). Click source levels between 197 and 220 dB re 1 μPa-m have been recorded for pantropical spotted dolphins (Schotten et al. 2004).

There are no published hearing data for pantropical spotted dolphins (Ketten 1998). Anatomy of the ear of the pantropical spotted dolphin has been studied; Ketten (1992; 1997) found that they have a Type II cochlea, like other dephinids.

- **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 (Jefferson et al. 2008).

Status—There is a minimum population estimate of 16,737 individuals for the California/Oregon/ Washington stock of the striped dolphin (Carretta et al. 2007).

Habitat Associations—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 SOCAL/Pt. Mugu Study Area

- Warm-water period—The striped dolphin has a primary occurrence in waters deeper than the 3,000-m isobath based on known habitat associations and sightings as well as the habitat model (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) (**Figure B-22**). The area of secondary occurrence buffers the primary region and includes sightings in slightly shallower waters (**Figure B-22**). Occurrence is rare in nearshore waters.

- Cool-water period—Occurrence patterns for the striped dolphin are expected to be similar to that of the warm-water period (**Figure B-22**).

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; Barlow and Forney 2007).

Life history information is based mostly on western North Pacific specimens (Archer II and Perrin 1999). Males reach sexual maturity between 7 and 15 yr of age, at an average body length of 2.2 m. Females become sexually mature between 5 and 13 yr of age (Archer II and Perrin 1999). Off Japan, where their biology has been best studied, there are two calving peaks: one in summer and another in winter (Perrin et al. 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 (DSL) 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; Oswald et al. 2004).

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. 2008). The back is dark brownish-gray, the belly is white, and the anterior flank patch

is tan to cream in color. The lips are dark, 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. Adults in the eastern Pacific range in length from 1.6 to 2.2 m in females and 1.7 to 2.3 m in males (Jefferson et al. 2008).

Status—The single current management unit recognized by NMFS in this area is the California/Oregon/Washington stock, which has a minimum population estimate of 392,687 individuals (Carretta et al. 2007). 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). The short-beaked common dolphin was the most abundant cetacean species sighted in recent surveys out to 300 nm (556 km) off the U.S. west coast (Forney 2007).

Habitat Associations—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).

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 and from Brazil to Argentina 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 widely distributed from the coast to at least 300 nm (556 km) from shore (Forney 2007). 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).

Dohl et al. (1986) conducted aerial surveys in the SCB, but they did not distinguish short- and long-beaked species in their records (although most of their data are probably from the short-beaked common dolphin). Therefore, those conclusions must be considered suspect, although they did see an influx of common dolphins into the area from the south during the warm-water months.

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—The area of primary occurrence includes waters deeper than the 100-m isobath and encompasses the high density of sightings in the Study Area (**Figure B-23**). This area covers a slightly broader region than during the cool-water period since *Delphinus* spp. are sighted farther offshore in the SCB during the summer (Forney and Barlow 1998). Secondary occurrence extends seaward of the primary area and between the shoreline and the 100-m isobath. Occurrence in San Diego Bay is rare.

- Cool-water period—Occurrence patterns are similar to the warm-water period, but the primary area does not extend quite as far offshore since *Delphinus* spp. are sighted more often in inshore waters of the SCB during the winter (Forney and Barlow 1998) (**Figure B-23**).

Behavior and Life History—Group size ranges from around 10 to over 10,000 individuals (Jefferson et al. 2008). In southern California waters, an average group size of less than 200 short-beaked common dolphins was reported (Hill and Barlow 1992; Bearzi 2003). Common dolphins are fast-moving swimmers, active bowriders, and they often jump in the air. Calving peaks differ between stocks and have been reported in spring and autumn as well as in spring and summer (Jefferson et al. 1993). North Pacific females and males reach sexual maturity at roughly 8 and 10 yr of age, respectively (Ferrero and Walker 1995). Gestation is approximately 11 mo, and mating occurs primarily during May and June (Ferrero and Walker 1995). The peak calving season for common dolphins in the eastern North Pacific is spring and early summer (Forney 1994).

Common dolphins feed opportunistically on those species most abundant locally and change their diet according to fluctuations in the abundance and availability of prey (Young and Cockcroft 1994). Based on a small sample size from the eastern North Pacific, short-beaked common dolphins may feed more extensively on squid than the long-beaked form (Heyning and Perrin 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 1998b). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998b). Maximum source levels were approximately 180 dB 1 μPa-m (Fish and Turl 1976). Off the British Isles, Goold (2000) found a diel pattern to common dolphin vocal behavior. Although no attempt to characterize whistle parameters was conducted, whistles were recorded more during crepuscular periods. Goold's results contradict the findings of Moore and Ridgway (1995) from the SCB; whistles were documented more during morning and afternoon periods, were predominantly classed into four types, and exhibited an overall frequency range of 6.6 to 10.2 kHz with a duration between 0.164 to 0.216 s for 97% of all whistles recorded. For both Goold (2000) and Moore and Ridgway (1995), diel whistle patterns coincided with feeding behavior which supports a function for whistle use during coordinated activity. 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 s. Additional work in the Celtic Sea conducted by Ansmann et al. (2007) examined almost 2,000 whistles from this species; these FM tones were broadly classified into six categories with simple upsweeps and downsweeps most common. Whistles ranged in frequency from 3.56 to 23.15 kHz and lasted between 0.05 to 2.02 s in duration (Ansmann et al. 2007). Whistle parameters were found to vary with behavioral context, group size, and geographic region around the British Isles.

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. More recently, Aroyan (2001) examined a model simulation for *Delphinus* hearing capabilities. Directional hearing in the lower jaw tissues and between both ears was suggested with mild differences found between the model simulations and data for hearing in bottlenose dolphins (Aroyan 2001).

- **Long-beaked Common Dolphin (*Delphinus capensis*)**

Description—The long-beaked common dolphin is a moderately slender animal with a long beak and a tall, slightly falcate dorsal fin (Heyning and Perrin 1994). They are distinctively marked; they have a

V-shaped dark saddle that produces an hourglass pattern on the side of the body (Jefferson et al. 2008). As in the short-beaked species, the back is a dark, brownish gray; the belly is white; and the anterior flank patch is tan to cream in color. The lips are dark and there is a stripe running from the apex of the melon to encircle the eye. There is also a black to dark gray chin-to-flipper stripe, which may encompass the gape in this species. There are other color pattern and body shape differences between long-beaked and short-beaked common dolphins. Adults can reach lengths of up to 2.6 m although most populations are somewhat smaller (Jefferson and Van Waerebeek 2002).

Status—There is a minimum population estimate of 1,152 individuals in the California stock of the long-beaked common dolphin (Carretta et al. 2007).

Habitat Associations—Long-beaked common dolphins occupy a wide range of habitats, including shallow bays and gulfs, and waters over the continental shelf and slope. This species appears to be restricted to waters relatively close to shore (Jefferson and Van Waerebeek 2002); there is no known occurrence of this species around oceanic archipelagos that are long distances from a continent (Jefferson, T.A., NMFS-SWFSC, pers. comm., 8 April 2008). The long-beaked common dolphin seems to prefer shallower and warmer water than the short-beaked common dolphin (Perrin 2002). In the northwestern Indian Ocean, the extremely long-beaked Indo-Pacific common dolphin (*Delphinus capensis tropicalis*) is routinely found in upwelling-modified waters (Ballance and Pitman 1998).

Distribution—The long-beaked common dolphin occurs in warm-temperate and tropical coastal waters in West Africa and southern Africa in the eastern Atlantic; from Venezuela to Argentina in the western Atlantic; from central California to southern Mexico and in Peru in the eastern Pacific; around Korea, southern Japan, and Taiwan in the western Pacific; and around the rim of the Indian Ocean (Jefferson and Van Waerebeek 2002; Perrin 2002; Jefferson et al. 2008). Along the U.S. west coast, its distribution overlaps with that of the short-beaked common dolphin. Central California is the northernmost limit for stranded long-beaked common dolphins (Heyning and Perrin 1994). Long-beaked common dolphins are commonly found within about 180 km of the coast (Jefferson et al. 2008). In the eastern North Pacific, all sightings of long-beaked common dolphins have been within about 100 nm (185 km) of shore (Heyning and Perrin 1994). Along the U.S. west coast, long-beaked common dolphins are frequently sighted within around 50 nm (93 km) off the coast between Baja California and central California (Carretta et al. 2007).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—The occurrence patterns displayed in **Figure B-24** were drawn on the basis of the output of the habitat model (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) and the distribution of records. The primary occurrence of the long-beaked common dolphin is a narrow coastal band which includes the Channel Islands (**Figure B-24**). A wider band of secondary occurrence buffers the area of primary occurrence, accounting for the possibility of encountering this species farther offshore. Occurrence is considered rare farther offshore throughout the rest of the Study Area and in San Diego Bay.

- Cool-water period—Occurrence patterns during this time of year are expected to be similar to the warm-water period (**Figure B-24**).

Behavior and Life History—Group size ranges from less than a dozen to several thousand individuals (Jefferson et al. 2008). In southern and central California waters, average group sizes of around 287 and 466 long-beaked common dolphins have been reported, respectively (Barlow and Forney 2007). Common dolphins are fast-moving swimmers and active bowriders and often exhibit acrobatic leaps and breaches (Jefferson et al. 2008).

There is sparse information on the life history of this species; however, some information is provided for short-beaked common dolphins. North Pacific females and males reach sexual maturity at roughly 8 and 10 yr of age, respectively (Ferrero and Walker 1995). Gestation is approximately 11 mo and

mating occurs primarily during May and June (Ferrero and Walker 1995). The peak calving season for common dolphins in the eastern North Pacific is spring and early summer (Forney 1994).

Common dolphins feed opportunistically on those species most abundant locally and change their diet according to fluctuations in the abundance and availability of prey (Young and Cockcroft 1994). Based on a small sample size from the eastern North Pacific, the long-beaked common dolphin may feed less extensively on squid than the short-beaked form (Heyning and Perrin 1994). 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). No diving information is available for long-beaked common dolphins. A tagged short-beaked common dolphin 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 1998b). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998b). Maximum source levels were approximately 180 dB 1 μPa-m (Fish and Turl 1976). During summer and fall in 2000, common dolphins were recorded acoustically and confirmed visually in the ETP during ship-board transects (Kinzey et al. 2001); the parameters for collecting audio data from a towed array and sonobuoys matched the values previously reported for *Delphinus* vocalizations (see above).

Popov and Klishin (1998) recorded auditory brainstem responses from a short-beaked common dolphin. The audiogram was U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz. Long-beaked common dolphins probably have very similar hearing characteristics. More recently, Aroyan (2001) examined a model simulation for *Delphinus* hearing capabilities. Directional hearing in the lower jaw tissues and between both ears was suggested with mild differences found between the model simulations and data for hearing in bottlenose dolphins (Aroyan 2001).

- **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). Adults in the eastern North Pacific reach 2.5 m (males) and 2.4 m (females) in length (Jefferson et al. 2008). Two forms are recognized for the eastern North Pacific. The southern form is larger and is thought to range south of 36°N along the coasts of California and Baja California, while the northern form ranges from southern California to Alaska (Walker et al. 1986; Carretta et al. 2007). Genetic data indicate mixing of these two forms off southern California (Lux et al. 1997). These two forms are not readily distinguishable or recognizable in the field (Jefferson et al. 2008).

Status—Both the southern and northern forms are included in the California/Oregon/Washington stock of the Pacific white-sided dolphin. The minimum population estimate for this stock is 20,441 individuals (Carretta et al. 2007).

Habitat Associations—The Pacific white-sided dolphin is most common in temperate waters over the outer continental shelf and slope. Sighting records and captures in pelagic driftnets indicate that this species also occurs in oceanic waters well beyond the shelf and slope (Leatherwood et al. 1984; Ferrero and Walker 1996).

Distribution—The Pacific white-sided dolphin occurs across temperate North Pacific waters; in the eastern North Pacific, they range as far south as the mouth of the Gulf of California and northward to the Bering Sea and coastal areas of southern Alaska (Leatherwood et al. 1984; Jefferson et al. 2008). 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. 2007). Peak abundance in California waters occurs from November to April (Leatherwood et al. 1984). Forney and Barlow (1998) noted high abundances of Pacific white-sided dolphins off California during winter (February through April); however, recent analyses of acoustic and visual detections did not indicate a seasonal trend in abundance of this species (Soldevilla et al. 2006).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—A nearshore band of primary occurrence extends throughout the Study Area and captures the high density of sightings in this region (**Figure B-25**). A 50-nm (93-km) band of secondary occurrence buffers the primary region. There is a rare occurrence in San Diego Bay and in deeper waters offshore of the secondary region, which takes into consideration the fact that this species is rarely found beyond the slope.

  - Cool-water period—During this time of year, primary occurrence is along the coast, including the Channel Islands to approximately the 2,000-m isobath (**Figure B-25**). A 50-nm (93-km) band of secondary buffers the primary area and takes into consideration the smaller number of sightings offshore of the primary area during this time of year. There is a rare occurrence in San Diego Bay and in deeper waters offshore of the secondary region, which takes into consideration the fact that this species is rarely found beyond the slope.

Behavior and Life History—This is a gregarious species; group sizes range from tens to thousands of individuals (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 1997a). 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 1997b; Brownell et al. 1999; Morton 2000). Leatherwood (1975) observed Pacific white-sided dolphins and California sea lions feeding together on anchovies off southern California. 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 s (Black 1994; Heise 1997b).

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). Whitten and Thomas (2001) studied whistles from six captive Pacific white-sided dolphins at Shedd Aquarium and classified their FM tones into three categories. Peak frequencies ranged from 1.06 to 17.06 kHz with an average frequency range of 5.2 to 7.8 kHz and durations between 0.04 to 0.756 seconds (Whitten and Thomas 2001). Echolocation clicks range in frequency from 50 to 80 kHz; the peak amplitude is 170 dB re 1uPa-m (Fahner et al. 2004). During the summer and fall of 2000, Pacific white-sided dolphins were recorded acoustically and confirmed visually in the ETP during ship-board surveys (Kinzey et al. 2001).

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. Au et al. (2007) examined the ABRs of captive Pacific white-sided dolphins at Shedd Aquarium and documented seven to eight waves in response which is slightly different than that for bottlenose dolphins and belugas. This species exhibited a latency response similar to bottlenose dolphins which suggests some conservation in processing speed of signals between these species (Au et al. 2007).

- **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. 2008). 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 somewhat falcate, and the flippers are long, pointed, and recurved. Young Risso's dolphins range from light gray to dark brownish-gray and are relatively unmarked. Adults range from dark gray to nearly white and are covered with white scratches and splotches, possibly resulting from the beaks and suckers of squid or the teeth of other Risso's dolphins (Jefferson et al. 2008).

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 9,947 individuals for the California/Oregon/Washington stock of the Risso's dolphin (Carretta et al. 2007).

Habitat Associations—Several studies have noted that Risso's dolphins are found offshore, along the continental slope, and over the continental shelf (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. This is also likely true along the eastern U.S. coast between Cape Hatteras and George's Bank where individuals were distributed along the northern wall of the Gulf Stream and associated with warm-core rings (Waring et al. 1992). Leatherwood et al. (1979) and Shane (1994) reported on sightings of Risso's dolphins in shallow northeastern Pacific waters near oceanic islands. These sites are in areas where the continental shelf is narrow and deepwater is closer to the shore (Leatherwood et al. 1979; Gannier 2000, 2002). Tynan et al. (2005) reported a preference of Risso's dolphins for slope and outer shelf waters associated with Heceta Bank off Oregon.

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). Changes in both abundance and shoreward shifts of Risso's dolphin distribution have been reported during such periods; sightings of Risso's dolphins in southern California waters were rare before the 1982/1983 El Niño event but appear to have dramatically increased around Catalina Island (Shane 1994, 1995). Shane (1994; 1995) suggested that Risso's dolphins might have filled the niche vacated by pilot whales when market squid temporarily vanished in 1983/1984 just after the El Niño event.

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—Primary occurrence for the Risso's dolphin is in the northeastern portion of the Study Area (**Figure B-26**). Occurrence in this nearshore portion captures most sightings and is based on the output of the habitat model developed for the warm-water period (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) and modified by NMFS-SWFSC expert opinion. Secondary occurrence is offshore of the primary region. Rare occurrence includes waters shallower than the 100-m isobath and includes San Diego Bay.

- <u>Cool-water period</u>—An area of primary occurrence covers the nearshore waters of the northern portion of the Study Area and is based on sightings and the output of the habitat model developed for the warm-water period (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) (**Figure B-26**). This area is slightly smaller than during the warm-water season possibly due to the shift in warmer waters. Secondary occurrence extends farther offshore of the primary region due to the possibility of encountering Risso's dolphins in this area.

Occurrence in waters shallower than the 100-m isobath (including San Diego Bay) is expected to be rare.

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 4,000 (Jefferson et al. 2008). Risso's dolphins have a stratified social organization in which individuals form stable, long-term bonds that are organized into pairs or small clusters of individuals; social stratification is based on age and sex classes (Hartman et al. 2008). 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 s) 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. 2004a).

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.

- **Northern Right Whale Dolphin (*Lissodelphis borealis)***

Description—The northern right whale dolphin, plus its congener, the southern right whale dolphin (*Lissodelphis peronii*), are the only members of the Family Delphinidae without a dorsal fin. The northern species is extremely slender and is mostly black with a small white patch behind the tip of the lower jaw and a wide white patch on the chest that narrows behind the flippers and continues along the belly (Reeves 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).

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. There is a minimum population estimate of 11,754 individuals for the California/Oregon/Washington stock of the northern right whale dolphin (Carretta et al. 2007).

Habitat Associations—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 CCS) (Smith et al. 1986). Soldevilla et al. (2006) noted that northern right whale dolphins were frequently sighted in shelf and offshore waters of southern California. Leatherwood and Walker (1979) reported sighting this species frequently around prominent banks and seamounts 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° East (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. Peak abundance in the SCB is during winter (Forney and Barlow 1998). Periods of peak abundance of northern right whale dolphins in southern California correspond very closely with known periods of peak abundance of market squid, *Loligo opalescens*, a major prey item (Leatherwood and Walker 1979). Leatherwood and Walker (1979) reported that this species has been observed off Pyramid Head, San Clemente Island, and off Catalina Island, which are important squid fishing grounds in southern California. 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). Northern right whale dolphins can be found farther offshore during the summer months in southern California (Forney and Barlow 1998).

- Information Specific to the SOCAL/Pt. Mugu Study Area—Northern right whale dolphins occur in the Study Area year-round, but abundance and distribution vary seasonally. This species is most abundant off central and northern California in nearshore waters in winter (Dohl et al. 1983).

  - Warm-water period—The northern right whale dolphin is a cold-water species and is not as abundant in southern California during the warm-water period due to shifting distributions into Oregon and Washington State as water temperatures increase (Leatherwood and Walker 1979; Forney 1994; Barlow 1995; Forney et al. 1995; Forney and Barlow 1998). As noted by Leatherwood and Walker (1979), a few sightings south of Point Conception were made during the summer, but they were well off the continental shelf. Primary occurrence includes all of the Channel Islands and most sightings in the northern portion of Study Area and is supported by the habitat model output (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) (**Figure B-27**). A 50-nm (93-km) strip of secondary occurrence buffers the primary region and includes the rest of the sightings in the Study Area. Occurrence farther offshore in warmer waters of the Study Area is considered rare. Rare occurrence also includes waters shallower than the 100-m isobath inshore of the primary and secondary regions.

  - Cool-water period—The peak abundance of northern right whale dolphins in southern California occurs during the cool-water period and corresponds closely with the peak abundance of squid (Forney and Barlow 1998). Occurrence patterns are based on the output of the habitat model developed for the warm-water period (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008). Primary occurrence is throughout the continental shelf in the SCB and extends farther offshore north of the Channel Islands (**Figure B-27**). A 50-nm (93-km) buffer of secondary occurrence accounts for offshore sightings. Occurrence is rare between the shoreline and the 100-m isobath in the northern portion of the Study Area. Rare occurrence also extends farther offshore throughout the rest of the Study Area.

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; Tynan et al. 2005). Onset of sexual maturity is approximately 9.9 yr for males and 9.7 yr 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; Rankin et al. 2007). Rankin et al. (2007) recorded only

click and pulsed sounds from any of the twenty single species sightings in their surveys, which suggests that this species does not whistle. The recorded burst-pulses were stereotyped and are assumed to play a communicative function (Rankin et al. 2007). 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.

- **Melon-headed Whale (*Peponocephala electra*)**

Description—Melon-headed whales at sea closely resemble pygmy killer whales; both species have a blunt head with little or no beak. Melon-headed whales have pointed (versus rounded) flippers and a more triangular head shape than pygmy killer whales (Jefferson et al. 2008). The body is charcoal gray to black, with unpigmented lips (which often appear light gray, pink, or white) and a white urogenital patch (Perryman et al. 1994). This species also has a triangular face "mask" and indistinct cape (which dips much lower below the dorsal fin than that of pygmy killer whales). Melon-headed whales reach a maximum length of 2.78 m; males are somewhat longer than females (Jefferson et al. 2008).

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

Habitat Associations—Melon-headed whales are most often found in offshore, deep waters. For example, most sightings in the Gulf of Mexico have been well beyond the edge of the continental shelf break (Mullin et al. 1994a; Davis and Fargion 1996a; Davis et al. 2000) and out over the abyssal plain (Mullin et al. 1994a). Nearshore sightings are generally from areas where deep, oceanic waters are found near the coast (Perryman 2002). Melon-headed whales are found in deep waters close to shore (within a few kilometers) around the Society and Marquesas Islands of French Polynesia (Gannier 2000, 2002) and Lembata Island of the Indonesian archipelago (Rudolph et al. 1997), as well as in some waters of the Philippines (Leatherwood et al. 1992). Nearshore sightings have also been recorded in relatively-shallow waters (77 m) in the Northern Mariana Islands although this may be anomalous (Jefferson et al. 2006). In the ETP, this species is primarily found in upwelling-modified and equatorial waters (Au and Perryman 1985; Perryman et al. 1994).

Distribution—Melon-headed whales are found worldwide in tropical and subtropical waters. They have occasionally been reported from higher latitudes, but these sightings are often associated with incursions of warm water currents (Perryman et al. 1994).

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—The melon-headed whale is a tropical species, with the northernmost sightings near the southwestern-most corner of the SOCAL OPAREA (Wade and Gerrodette 1993). This species is expected to have a rare occurrence throughout the Study Area during this time of year (**Figure B-28**).

- <u>Cool-water period</u>—Occurrence of the melon-headed whale during the cool-water period is expected to be similar to the warm-water period (**Figure B-28**).

Behavior and Life History—Melon-headed whales are typically found in large groups ranging between 150 and 1,500 individuals (Perryman et al. 1994; Gannier 2002), although Watkins et al. (1997) described smaller groups of 10 to 14 individuals. These animals often log at the water's surface in large schools composed of subgroups. Melon-headed whales are found in mixed-species aggregations, commonly with Fraser's dolphins (*Lagenodelphis hosei*) (Miyazaki and Wada 1978; Perryman et al. 1994; Reeves et al. 1999; Gannier 2002; Mullin et al. 2004). They also occur occasionally with spinner, bottlenose, and rough-toothed dolphins, as well as short-finned pilot whales (Jefferson and Barros 1997; Gannier 2002; Perryman 2002).

Melon-headed whale life history is sparsely described due to lack of data. It is unclear whether significant seasonality in calving occurs (Jefferson and Barros 1997). Females reach sexual maturity at about 11.5 yr of age and males at 16.5 yr (Jefferson and Barros 1997). Melon-headed whales prey on squids, pelagic fishes, and occasionally crustaceans. Most fish and squid prey are mesopelagic in waters up to 1,500 m deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros 1997). There is no information on specific diving depths for melon-headed whales.

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

No empirical data on hearing ability for this species are available.

- **Pygmy Killer Whale (*Feresa attenuata)***

Description—The pygmy killer whale is often confused with the melon-headed whale and less often with the false killer whale. Flipper shape is the best distinguishing characteristic; pygmy killer whales have rounded flipper tips and continuous curve to the leading edge of the flipper (Jefferson et al. 2008). The body of the pygmy killer whale is somewhat slender (especially posterior to the dorsal fin) with a rounded head that has little or no beak (Jefferson et al. 2008). The color of this species is dark gray to black with a prominent narrow cape that dips only slightly below the dorsal fin and a white to light gray ventral band that widens around the genitals. The lips and snout tip are sometimes white. Pygmy killer whales reach lengths of up to 2.6 m; males are slightly larger than females (Jefferson et al. 2008).

Status—There are no abundance estimates for the pygmy killer whale in the NOAA SAR for this area of the Pacific.

Habitat Associations—Pygmy killer whales generally occupy tropical oceanic habitats. In the northern Gulf of Mexico, this species is found primarily in deeper waters off the continental shelf (Davis and Fargion 1996b; Davis et al. 2000) out to waters over the abyssal plain (Jefferson, T.A., NMFS-SWFSC, pers. comm., 23 to 25 January 2008). Pygmy killer whales were sighted in waters deeper than 1,500 m off Cape Hatteras (Hansen et al. 1994). In some areas, pygmy killer whales are found within a few kilometers of shore near the shelf, such as around the Marquesas Islands of French Polynesia (Gannier 2002), off Lembata Island of the Indonesian archipelago (Rudolph et al. 1997), in some waters off the Philippines (Leatherwood et al. 1992), and off the Big Island of Hawai'i.

Distribution—This species has a worldwide distribution in deep tropical to warm-temperate oceans. Pygmy killer whales typically do not range north of 40°N or south of 35°S (Jefferson et al. 2008). Most of the records outside the tropics are associated with strong, warm western boundary currents that effectively extend tropical conditions into higher latitudes (Ross and Leatherwood 1994).

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—The pygmy killer whale is a tropical species which rarely ranges north of 40°N or south of 35°S, with the most northern sightings in the eastern Pacific near the southwestern-most corner of the SOCAL OPAREA (Wade and Gerrodette 1993). This species is expected to have a rare occurrence throughout the Study Area during the warm-water period (**Figure B-29**).

- <u>Cool-water period</u>—Occurrence is expected to be similar to the warm-water period (**Figure B-29**).

Behavior and Life History—Pygmy killer whales are one of the most poorly-described delphinid species, and almost nothing is known about their reproductive biology and social organization. They occur in small to moderate herds of generally less than 50 to 60 individuals. Pygmy killer whales eat predominantly fish and squid. They are known to occasionally attack other dolphins (Perryman and Foster 1980; Ross and Leatherwood 1994). There is no information available on diving behavior of this species.

Acoustics and Hearing—The pygmy killer whale emits short duration, broadband signals similar to those of a large number of other delphinid species (Madsen et al. 2004b). Clicks produced by pygmy killer whales have centroid frequencies between 70 and 85 kHz; there are bimodal peak frequencies between 45 and 117 kHz. The estimated source levels are between 197 and 223 dB re 1 μPa-m (Madsen et al. 2004b). These clicks possess characteristics of echolocation clicks (Madsen et al. 2004b).

There are no hearing data available for this species.

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

Description—The false killer whale is a large, dark gray to black dolphin with a faint gray patch on the chest and sometimes light gray areas on the head (Jefferson et al. 2008). The false killer whale has a long, slender body, a rounded overhanging forehead, and little or no beak. 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). Individuals reach maximum lengths of 6 m (males) and 5 m (females) (Jefferson et al. 2008).

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

Habitat Associations—False killer whales are found primarily in oceanic and offshore areas although they do approach close to shore at oceanic islands (Baird 2002). False killer whales have been known to approach very close to shore in such areas as the inshore waters of Washington 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 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 SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—Occurrences of false killer whales in the Study Area are based on their preference for warm waters. Secondary occurrence includes waters warmer than the 20.5°C isotherm which only includes the southernmost waters of the Study Area (**Figure B-30**). This species is expected to have a rare occurrence in waters cooler than the 20.5°C isotherm throughout the rest of the Study Area during this time of year (**Figure B-30**). It should be noted that there are four older stranding records from San Nicolas Island (Stager and Reeder 1951), as well as a report of a probable capture of this species off the west end of Santa Catalina Island (Norris and Prescott 1961).

- Cool-water period—Occurrence of the false killer whale during the cool-water period is expected to be rare throughout the Study Area (**Figure B-30**).

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; however, one population has an apparent peak in late winter (Jefferson et al. 2008). False killer whales primarily eat deep-sea cephalopods and fish (Odell and McClune 1999), but they have been known to attack other cetaceans, including dolphins (Perryman and Foster 1980; Stacey and Baird 1991), sperm whales (Palacios and Mate 1996), and baleen whales (Hoyt 1983).

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 1998b). 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 to 225 dB re 1 μPa-m (Madsen et al. 2004a).

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 (0.9 to 1.8 m in height) (Jefferson et al. 2008). 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 (Dahlheim and Heyning 1999). Females may reach 8.5 m in length and males 9.8 m (Jefferson et al. 2008). 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 transient 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 mentioned previously, there are at least three ecotypes in the eastern North Pacific: “residents,” “transients,” and “offshores.” 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 2005b). Some researchers instead refer to these two ecotypes as “fish-eaters” (i.e., residents) and “mammal-hunters” (i.e., transients). Offshore killer whales have not been observed to intermix with residents or transients (Black et al. 1997; Wiles 2004; Krahn et al. 2007). There may also be a fourth ecotype, the “LA (=Los Angeles) pod” (Black et al. 2003). Monterey Bay is the only known region where these four ecotypes of killer whales have overlapping ranges (Black et al. 2003).

Eight killer whale stocks are currently identified by the NMFS within the Pacific U.S. EEZ: (1) the Alaska resident stock – occurring from southeastern Alaska to the Aleutian Islands and the Bering sea; (2) the Northern Resident stock – occurring from British Columbia through part of southeastern Alaska; (3) the Southern Resident stock – occurring within the inland waters of Washington State and southern British Columbia and in coastal waters from British Columbia through California; (4) the Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock – occurring mainly from Prince William Sound through the Aleutian Islands and Bering Sea; (5) the AT1 Transient stock – occurring in Alaska from Prince William Sound through the Kenai Fjords; (6) the West Coast Transient stock – occurring from southeastern Alaska through California; (7) the Offshore stock – occurring from Alaska through California; and (8) the Hawaiian stock (Angliss and Outlaw 2008).

The Southern Resident killer whale (SRKW) stock is considered a DPS and was recently listed as endangered under the ESA (NMFS 2005d); it is also designated as depleted under the MMPA. The SRKW DPS consists of three pods: J, K, and L (NMFS 2005b) which are very familiar to the general public. Critical habitat was recently designated 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 6,630 km^2 of marine habitat (NMFS 2006b; NMFS 2008b).

Only the West Coast Transient and Offshore stocks are expected to occur in the SOCAL/Pt. Mugu Study Area. The minimum population estimate for the West Coast Transient stock is 314 killer whales (Angliss and Outlaw 2008). The total number of known offshore killer whales along the U.S. west coast, Canada, and Alaska is 211 individuals; however, it is not known what proportion of time this transboundary stock spends in U.S. waters (Carretta et al. 2007). A minimum of 331 individual offshore killer whales is estimated to occur in U.S. waters off California, Oregon, and Washington State (Carretta et al. 2007).

Habitat Associations—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). Offshore killer whales usually occur 15 km or more offshore but also visit coastal waters and occasionally enter protected inshore waters (Wiles 2004). Along the coast of California, killer whales are often sighted well offshore, and they also frequently move into the kelp beds and into bays and inlets (Leatherwood et al. 1988). Offshore concentrations of killer whales in the ETP occur within the divergence zones of the North Equatorial Current and the Equatorial Counter Current (Dahlheim et al. 1982).

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 (NMFS 2008b).

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 (Braham and Dahlheim 1982); in British Columbia and Washington State inland waterways (Bigg et al. 1990); and along the outer coasts of Washington State, Oregon, and California south into Mexican waters (Green et al. 1992; Barlow 1995; Forney et al. 1995; Black et al. 1997). In contrast to the protected inland passages of the Pacific Northwest and Alaska, killer whales living in the open waters of California and Mexico are less concentrated and less predictable in their movements (Black et al. 1997; NMFS 2008b).

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 (Monterey Bay) (Black et al. 2003)[2,3] and as far north as the Queen Charlotte Islands (Wiles 2004). Recent sightings of SRKW were documented off the Farallones, Fort Bragg, and Monterey Bay between January and March 2007 (NMFS 2008b).[4] The Northern Resident killer whale (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). NRKW individuals have been found as far south as Oregon and possibly California (Morin et al. 2006). Groups of offshore killer whales are encountered as far south as Los Angeles, mostly during winter (Ford et al. 1994). Recent photo-identification resightings have connected offshore individuals recorded between Alaska, Washington State, and California; therefore, a single population of offshore killer whales may move throughout the eastern North Pacific (Krahn et al. 2007).

The LA Pod is often seen off Los Angeles and Orange County; large numbers are documented here primarily during the winter, from late December to late March (Black et al. 1997). Members of this pod have been documented from as far north as Monterey Bay, along the Pacific coast of Mexico, and inside the Gulf of California (Black et al. 1997; Guerrero-Ruiz et al. 1998). One offshore type killer whale was photographed off Los Angeles, California and resighted in the northern Queen Charlotte Islands in British Columbia (Black et al. 1997).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—Killer whales regularly occur in the Study Area year-round. Members of the LA Pod have been reported off the coast of Los Angeles and Orange County (Black et al. 1997). The offshore ecotype has also been sighted in this area, particularly during the cool-water period (Black et al. 1997). The area of primary occurrence includes both nearshore and offshore waters, taking into account the distribution of known sightings of this species (**Figure B-31**). Secondary occurrence extends farther offshore and accounts for the possibility of encountering killer whales far offshore, in an area with less survey effort.

- Cool-water period—Killer whale occurrence during this period is expected to be similar to the warm-water period (**Figure B-31**).

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). Transients travel in small matrilineal groups which typically contain less than 10 animals (e.g., Morton 1990; Ford and Ellis 1999). 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). The LA Pod is composed of at least 13 individuals, including 3 adult males (Black et al. 1997). Killer whales normally occur in small groups in warm-temperate and

tropical eastern Pacific waters; the largest recorded group size was 75 individuals, with a mean group size of 5.3 animals (Dahlheim et al. 1982).

There is no published information on killer whale reproductive behavior in or near the Study Area. 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 yr of age (Ford and Ellis 1999). Maximum life span is estimated to be 80 to 90 yr for females and 50 to 60 yr 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; Steiger et al. 2008). 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; Jones 2006). Salmon are the principal 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). Transients have diets largely consisting of marine mammals (including cetaceans, pinnipeds, and sea otters) 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; Vos et al. 2006). Based on Krahn et al. (2007), the diet of offshores may comprise more long-lived fish (e.g., rockfish, shark, tuna) instead of salmon species, the traditional prey of residents. Marine mammals may also be prey for offshores based on recent analyses of stable isotopes and organochlorine contaminants (Herman et al. 2005). Members of the LA Pod have never been observed to kill a mammal (Black et al. 1997), athough they did attack a great white shark off the Farallones in October 1997 (Pyle et al. 1999).

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 the social sounds of this species are pulsed calls, 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] are associated with travel and foraging) (Miller 2006). Pulsed calls are the most frequently-observed vocalization from killer whales and can be discrete, variable, or abberant (Ford 1989, 1991; Holt 2008). The discrete or stereotyped calls are likely used to maintain group cohesion during travel or other periods of separation (see Ford 1989, 1991; Filatova 2007; Holt 2008). Foote and Nystuen (2008) examined the call structure (for calls between 0 and 10 kHz) of the three sympatric killer whale ecotypes (offshore, transient, and resident) in the Pacific Northwest in relation to ecological variables. Even though different between ecotypes, each group seemed to produce calls or a calling strategy outside the range of their identified prey (Foote and Nystuen 2008). Residents produced calls that overlapped their prey's hearing sensitivity at the low end but which included peak energy well above the prey's range. Transient killer whale calls all overlapped the hearing range of

their primary prey (whales, porpoises, and seals); however, members of this ecotype hunt silently (Barrett-Lennard et al. 1996).

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 their dialects are highly stereotyped, repetitive, discrete calls which are group-specific and shared by all members of each group (Ford 1991, 2002b). These dialects are likely 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 (Yurk et al. 2002) and for resident killer whales in Southeast Kamchatka, Russia (Filatova 2007) and are to likely occur in other regions as well. A comparison of the variation in call parameters produced by resident, transient, and offshore killer whales indicates significant shifts in minimum frequencies and peak frequency energy between these ecotypes, which likely corresepond to their foraging strategies and distribution (Foote and Nystuen 2008). Residents need not 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 with a range of best sensitivity (±10 dB from lowest threshold) between 18 to 42 kHz; however, their hearing is most sensitive at 20 kHz, which is one of the lowest maximum-sensitivity frequencies 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 SOCAL/Pt. Mugu 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 7.2 m (males) (Jefferson et al. 2008).

Pilot whales have bulbous heads, which become more globose in adult males; there is little or no beak (Jefferson et al. 2008). The dorsal fin is distinctive with a very wide base. It is falcate and low and 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 14 to 19% of the total body length. 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. 2008).

Status—Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters, where two forms have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). There is a minimum population estimate for the California/Oregon/Washington stock of the short-finned pilot whale of 123 individuals (Carretta et al. 2007).

Short-finned pilot whales have been taken in various fisheries in southern California. Prior to the El Niño event in 1982 through 1983, pilot whales were the most frequently-documented species of cetacean taken in fisheries in this area, especially in purse seine fishing for squid (also called round haul fishing) off Santa Catalina Island (Heyning et al. 1994). DeMaster et al. (1985) estimated that about 30 pilot whales were taken in the purse seine fishery and an additional 30 were taken in oceanic gillnets in 1980 alone (see also Hanan et al. 1993). Squid fishermen also sometimes shot pilot whales (DeMaster et al. 1985). The estimated annual mortality during the early 1980s was about

3 to 15% of the California population estimate, and, therefore, would have been unsustainable and may have led to the decline of this species in southern California (DeMaster et al. 1985).

Habitat Associations—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).

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. 2008). The long-finned pilot whale 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 at least in the western North Pacific (Bernard and Reilly 1999).

Sightings of short-finned pilot whales north of Point Conception are uncommon (Forney 1994). The full geographic range of the California/Oregon/Washington stock is not known; however, it may be continuous with animals found off Baja California (Carretta et al. 2007).

From at least the 1950s until the early 1980s, short-finned pilot whales were fairly abundant in nearshore waters off southern California, with an apparent resident population around Santa Catalina Island (Norris and Prescott 1961; Dohl et al. 1981; Evans et al. 1984; Shane 1984, 1994). This is the same area where spawning market squid (*Loligo opalescens*), the most likely prey of the short-finned pilot whale, occurs (Dohl et al. 1981; Shane 1984; Bonnell and Dailey 1993; Shane 1995). Short-finned pilot whale distribution off southern California changed dramatically after the 1982/1983 El Niño event, when squid did not spawn as usual in the area, and pilot whales virtually disappeared from the area for 9 yr (Shane 1994, 1995). Since then, survey data indicate that pilot whales have returned to California waters (Carretta et al. 1995; Barlow and Gerrodette 1996; Forney 2007). The short-finned pilot whale might have been competitively excluded by the Risso's dolphin, which is also a squid-eating species, after the 1982/1983 El Niño event (Shane 1994).

- Information Specific to the SOCAL/Pt. Mugu Study Area—From at least the 1950s until the early 1980s, short-finned pilot whales were fairly abundant in nearshore waters of southern California, with an apparent resident population around Santa Catalina Island (Norris and Prescott 1961; Dohl et al. 1981; Evans et al. 1984; Shane 1984, 1994). Distribution off southern California changed dramatically after the 1982/1983 El Niño event. Pilot whales have not been sighted as often in recent years (Barlow 1995).

  - Warm-water period—There is a secondary occurrence of the short-finned pilot whale south of Point Conception (boundary generally follows the 17°C isotherm) during this time of year (**Figure B-32**). Occurrence farther north and in San Diego Bay is considered to be rare.

  - Cool-water period—Occurrence of the short-finned pilot whale in the Study Area during the cool-water period is expected to be similar to the warm-water period (**Figure B-32**); however, there is a region of primary occurrence in a 10-nm (19-km) ring around Santa Catalina Island during this time of year. Occurrence here is based on increased winter (January through March) abundance of the former resident population (Shane 1984, 1994) and the possibility for this population to return based on recent data which suggest that this species is becoming more common in the area (Jefferson, T.A., NMFS-SWFSC, pers. comm., 23 to 25 January 2008).

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 in association 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 yr for females and 17 yr for males (Bernard and Reilly 1999). The gestation period for short-finned pilot whales is 15 to 16 mo, with a mean calving interval of around 4 to 6 yr (Bernard and Reilly 1999). In the Northern Hemisphere, calving peaks occur in the fall and winter in most populations (Jefferson et al. 2008).

Pilot whales are deep divers. They can stay submerged for well over 20 min; 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 whales are known to produce three general categories of sounds: clicks, whistles, and burst-pulsed signals, although information on this species' vocal behavior is known only from a few fragmented sources from disparate geographic regions. 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 1998b). Weller et al. (1996) documented an agonistic interaction between short-finned pilot whales and sperm whales in the northern Gulf of Mexico and observed infrequent whistles and occasional burst-pulsed sounds during this encounter. Two forms of short-finned pilot whale are found along the Pacific coast of Japan (Nakahara and Amano 2001; Nakahara et al. 2003); these northern and southern groups are geographically, genetically, and morphologically distinct, and both forms produce clicks, whistles, and burst-pulse signals. The northern group of whales produced calls with a longer duration and wider frequency range when compared with the southern form (Nakahara et al. 2003). Intra-group variation was documented for the southern form (Nakahara and Amano 2001); although whether this variation occurred at the individual or subgroup level has yet to be determined. Mussi et al. (2003) found inter-individual variation in the calls of long-finned pilot whales off Italy which suggests that signature calls might be evident in the short-finned variety. As part of a larger study to examine the acoustic identification of species in the ETP, Oswald et al. (2003) determined that short-finned pilot whale whistles (from 10 recording sessions and a sample of 153 whistles) presented characters distinctive to this species (66% correct classification) apart from other sympatric delphinids. Whistle frequency ranged from about 1.3 kHz to 10.3 kHz with an average duration of 0.4 seconds (Oswald et al. 2003). Short-finned pilot whales were acoustically detected in Hawaiian deep waters (Norris et al. 2005); very few vocal signals were recorded from these dolphins, which suggests (coupled with their low-level of activity) that these individuals were resting. This species is also observed around the Canary Islands; recent studies with DTAGs suggest that short-finned pilot whales forage at depth both at night and during the day around the islands and produce broadband clicks and buzzes consistent with biosonar-mediated foraging (Aguilar de Soto et al. 2005).

There are no published hearing data available for this species; however, vocal responses by long-finned pilot whales to both low- and high-frequency anthropogenic sounds, as well as the calls of killer whales, have been reported (e.g., Schevill 1964; Taruski 1979; Bowles et al. 1994; Rendell and Gordon 1999), which provides indirect evidence for the general hearing capabilities for this genus. That is, their hearing should reflect the frequency ranges of the sounds they produce.

- **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. 2008). 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 (Jefferson et al. 2008).

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, (5) Oregon/Washington coast, (6) Northern California/Southern Oregon, (7) San Francisco-Russian River, (8) Monterey Bay, and (9) Morro Bay (Carretta et al. 2007). The Morro Bay stock occurs in the SOCAL/Pt. Mugu Study Area and ranges from Point Conception to just south of Monterey Bay. There is a minimum population estimate of 1,206 individuals in the Morro Bay stock of the harbor porpoise (Carretta et al. 2007). Forney (1999) reported that the abundance of the harbor porpoise in nearshore waters off California appears to have declined and might actually reflect movement out of the area in relation to changing oceanographic conditions.

Habitat Associations—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). Tynan et al. (2005) noted that harbor porpoises in the northern California Current System extended their distributions farther offshore (out to the 200-m isobath) in association with high chlorophyll concentrations in a few regions.

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 west to Kamchatka and Japan. This species is found only as a stray south of Point Conception (Leatherwood et al. 1988). This species has more restricted movements along the Pacific coast than along the Atlantic coast of the U.S. (Carretta et al. 2007).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—In the eastern North Pacific Ocean, harbor porpoises primarily occur from Alaska south to Point Conception; this species prefers coastal and inland waters. Therefore, the area of primary occurrence extends north of Point Conception and includes waters inshore of the 100-m isobath (**Figure B-33**). A secondary area of occurrence buffers the primary region and includes waters between the 100- and 300-m isobaths. Strays have been reported farther south during this time of year (see Norris and Prescott 1961). Based on these reports, there is a rare occurrence throughout the rest of the Study Area during this time of the year.

  - Cool-water period—The harbor porpoise's occurrence pattern for the cool-water period is expected to be similar to that of the warm-water period (**Figure B-33**).

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, but they do occasionally aggregate in large groups of 50 to several hundred individuals during feeding or migration (Jefferson et al. 2008).

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 yr of age and give birth to one calf each year (Read and Hohn 1995). Calves are born in late spring (Read 1990a; Read and Hohn 1995). Many females are pregnant and lactating simultaneously (Read 1990b; Read and Hohn 1995). Relative to other cetaceans, harbor porpoises seem to allocate a larger percentage of their total body mass to blubber (McLellan et al. 2002), which helps them meet the energetic demands of living in a cold-water environment.

Harbor porpoises feed on a 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 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 of the water column (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 s (Westgate et al. 1995). Westgate and Read (1998) noted that dive records of tagged porpoises did not reflect the vertical migration of their prey; porpoises made deep dives during both day and night.

Acoustics and Hearing—Harbor porpoise vocalizations include clicks and pulses (Ketten 1998b), 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 1998b). 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 of approximately 2.2 m (females) and 2.4 m (males) (Jefferson et al. 2008). 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 2002b).

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 2002b). 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 2002b). 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 43,425 individuals for the California/Oregon/Washington stock of the Dall's porpoise (Carretta et al. 2007). The stock structure of the eastern North Pacific Dall's porpoise is not known; however, based on patterns of stock differentiation in the western North Pacific, it is expected that separate stocks will emerge when data become available (Perrin and Brownell 1994).

Habitat Associations—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), outer continental shelf, slope, and oceanic waters (Jefferson 1988; Ferrero et al. 2002).

Distribution—Dall's porpoise is endemic to the North Pacific. It is found from northern Baja California, Mexico, north to the Bering Sea and south to Japan (Jefferson et al. 2008). 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. Soldevilla et al. (2006) reported more frequent sightings of Dall's porpoises off southern California during winter and spring. Dall's porpoises probably also range south into Mexican waters during exceptional cold-water 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).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—Occurrence patterns during this period are based on the habitat model (Forney, K., NMFS-SWFSC, pers. comm., 8 April 2008) and the distribution of sightings. Dall's porpoises are found most consistently north of Point Conception due to the northward shift in the center of abundance during this period. Therefore, the primary area of occurrence extends north of Point Conception in waters deeper than the 100-m isobath (**Figure B-34**). A secondary area of occurrence buffers the primary region north of the California/Mexico border and includes many sightings in the SCB. A small region of secondary occurrence includes shallow waters between the 50- and 100-m isobaths inshore of the primary region north of Point Conception. Occurrence between the shoreline and the 50-m isobath is considered rare (**Figure B-34**). South of Point Conception, there is a rare occurrence in waters shallower than the 100-m isobath and in waters offshore of the secondary area which includes warmer waters.

  - Cool-water period—The primary area of occurrence is cut on a generalized line that extends north from approximately the California/Mexico border due to upwelling along the upper Baja California coast (**Figure B-34**). This primary occurrence area follows the 15.5°C isotherm and includes colder waters in the Study Area. A small region of secondary occurrence extends farther offshore of the primary region and also includes shallow waters inshore of the primary area between the 50- and 100-m isobaths (**Figure B-34**). There is an area of rare occurrence between the shoreline and the 50-m isobath inshore of the secondary area and farther south throughout the rest of the Study Area.

Behavior and Life History—Groups of Dall's porpoises are generally small (most often less than 10 individuals), 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 2002b). 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 2002b). Dall's porpoises have even been observed to "snout ride" on bow waves pushed forward by the heads of large whales (Jefferson 2002b).

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 possibly smaller peak in March (Jefferson 1989). Gestation lasts about 10 to 12 mo (Jefferson 2002); the lactation period is unknown, but it is thought to be very short, perhaps 2 to 4 mo (Jefferson 1990). Females reach sexual maturity from 4 to 7 yr of age, while males are considered sexually mature at 3.5 to 8 yr (Houck and Jefferson 1999).

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). 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 porpoises (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, or common, seal is a small to medium-sized phocid. 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. 2008). 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). There is geographic variation in coloration, life history parameters, and cranial morphology (Jefferson et al. 2008).

Status—Three stocks of harbor seals are recognized along the U.S. west coast. Two occur north of the Study Area in Washington State and Oregon while the third occurs in California. The minimum population size of the California stock of the harbor seal is 31,600 individuals (Carretta et al. 2007). There does not appear to be much interchange between the stocks (Carretta et al. 2007).

Habitat Associations—The harbor seal is a nearshore species that spends most of its time in the water. Harbor seals haul out on land year-round and for longer periods of time and in greater numbers during the molting, pupping, and breeding season (late spring to early summer) (Stewart and Yochem 1994). Terrestrial habitat consists of sheltered beaches and offshore islands and reefs with little disturbance and easy access to prey; harbor seals often use the same haulout sites from year to year (Stewart and Yochem 2000; Bjørge and Tolley 2002; Nordstrom 2002; Montgomery et al. 2007). Haulout substrate varies but includes intertidal and subtidal rock outcrops, sandbars, sandy beaches, and even 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). Harbor seals generally haul out on sandy, cobble, and gravel beaches in the SCB (Stewart and Yochem 1994). They haul out and breed on all the southern Channel Islands (Stewart and Yochem 1994, 2000).

Aquatic habitat consists of coastal waters. Harbor seals are rarely found more than 20 km from shore and frequently occupy bays, estuaries, and inlets (Baird 2001). They have a preference for submarine canyons (Bearzi et al. 2008). Harbor seals utilize habitat at depths ranging from 10 to 446 m and within 50 km of haulout sites (Stewart and Yochem 1994; Lowry et al. 2001).

Distribution—The harbor seal is one of the most widespread pinniped species with a nearly continuous distribution in both the Atlantic and Pacific oceans. Its distribution stretches from the east Baltic Sea west across the Atlantic and Pacific oceans to southern Japan (Stanley et al. 1996). In the SCB, harbor seals are distributed along haulout sites on mainland beaches and all of the Channel Islands (**Figure 3-7**) (Lowry and Carretta 2003). A census conducted during the 2002 molting period documented most seals in the Channel Islands at haulout sites on Santa Cruz Island (Lowry and Carretta 2003). The Channel Islands with the fewest hauled out individuals are San Clemente and

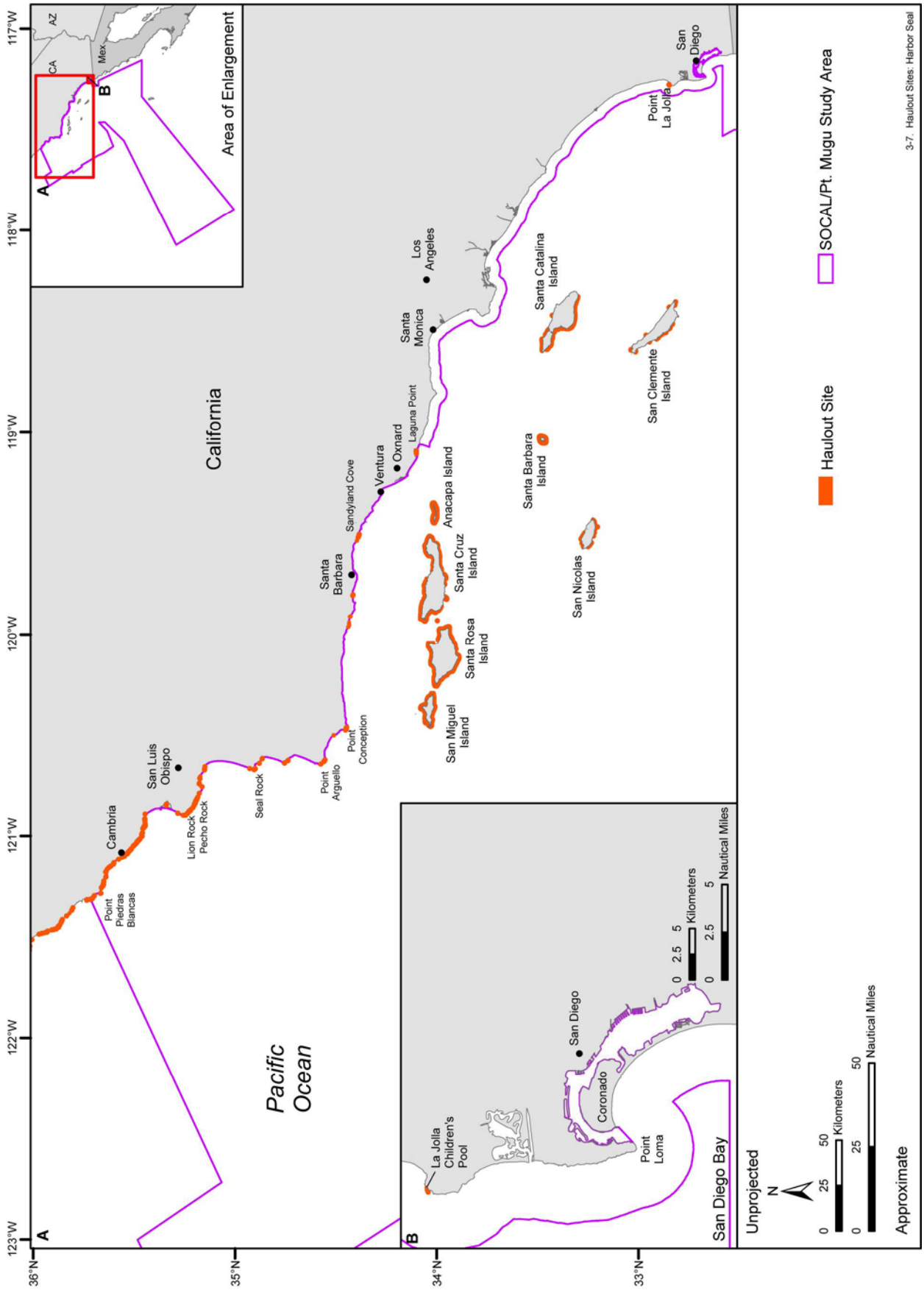

Figure 3-7. Harbor seal haulout sites in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NOS (2001), CDFG (2005), and NOS (2006).

Santa Barbara islands (Stewart and Yochem 1994, 2000). Harbor seals are capable of making long-distance movements in excess of 200 km, though this is not common and may be particular to younger age classes (Lowry et al. 2001; Greig 2002; Oates 2005). Many harbor seals disperse along the coast and at sea during the fall and winter to forage; most of these probably remain near the Channel Islands but some may leave the SCB seasonally (Bonnell and Dailey 1993; Stewart and Yochem 1994, 2000).

- Information Specific to the SOCAL/Pt. Mugu Study Area—Harbor seals regularly occur in the Study Area year-round; this species primarily occurs within 20 km from shore (Baird 2001). Harbor seals may also be found 20 to 40 km offshore, including the 40-nm (74-km) zone between San Diego and Point Mugu. They regularly occupy the San Diego Bay area and likely forage in kelp beds along the San Diego coastline (Stewart, B.S., Hubbs-Sea World Research Institute, pers. comm., 14-26 January and 20 April 2005). A small, protected beach in La Jolla, California, known as "Children's Pool," is also a regular haulout site for harbor seals (Yochem and Stewart 1998). Main breeding sites are located on San Nicolas, San Miguel, Santa Rosa, and Santa Cruz islands. Minor breedings areas are located on Santa Barbara, San Clemente, Santa Catalina, and Anacapa islands (Lowry, M., NMFS-SWFSC, pers. comm., May 2008). 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).

  - Warm-water period—Many harbor seals disperse along the coast and at sea during the warm-water period but do not likely leave the SCB (Bonnell and Dailey 1993). Primary occurrence extends 20 km from shore along the entire coast of the Study Area except between Point Mugu and just north of La Jolla where there are no haulout sites (**Figure B-35a**). Primary occurrence also extends 20 km around the Channel Islands and includes San Diego Bay (**Figure B-35b**). A buffer of secondary occurrence extends 20 to 40 km outside of the primary area and 40 km from the shoreline from Point Mugu to just north of La Jolla to account for movements farther offshore. Occurrence throughout the rest of the Study Area is rare.

  - Cool-water period—Harbor seal abundance in the Study Area is expected to be highest in late May and early June during the peak of molting season (Bonnell and Dailey 1993). Occurrence patterns are expected to be similar to the warm-water period (**Figures B-35a** and **B-35b**).

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). Although gregarious on land, harbor seals have 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 site fidelity by individuals to specific haulout sites within seasons. Human and predator disturbance affects where harbor seals choose to haul out (Nordstrom 2002; Harris et al. 2003; Montgomery et al. 2007).

The timing of harbor seal pupping along the U.S. west coast varies with latitude; pups are born earlier farther south and later farther north (Temte et al. 1991; Jeffries et al. 2000; Greig 2002). On the Channel Islands, pups are born from late February to early April with a peak in March (Bonnell et al. 1978; Stewart and Yochem 1994, 2000). The pupping season lasts at least 2 mo (Bonnell et al. 1978; Stewart and Yochem 1994; 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 24 d (Thompson et al.

1994). Mating takes place in the water shortly after the pups are weaned. Implantation occurs approximately 2 to 2.5 mo after mating and gestation lasts from 8 to 8.5 mo (Greig 2002). On the Channel Islands, harbor seals haul out in high numbers in late May and early June during the peak of molting season (Stewart and Yochem 1994). Sexual maturity is reached at 4 to 5 yr of age, and adult females typically produce a single pup each year (Riedman 1990).

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). Their diet consists of fish and invertebrates and varies depending on life stage (Bigg 1981; Stewart and Yochem 2000; Oates 2005). Just-weaned juveniles tend to feed on small crustaceans, small fishes, and cephalopods. Prey species of juveniles include northern anchovy, Pacific hake, Dover sole, and bay shrimp (Oates 2005). Prey species common to both juveniles and adults include rockfishes, spotted cusk-eel, red octopus, and market squid (Stewart and Yochem 2000; Oates 2005). Rockfish, spotted cusk-eel, octopus, plainfin midshipman, and shiner surfperch are the most common prey species for harbor seals in the Channel Islands (Stewart and Yochem 1994). 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). Calls from captive harbor seals also showed individual differences at 2 weeks (wk) of age, as well as differences between male and female pups (Khan et al. 2006). Adult males 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). Hemilä et al. (2006) examined middle and inner ear anatomy to confirm that phocids are more specialized for aquatic hearing; harbor seals showed a high-frequency hearing limit in air of 22 kHz but an in-water limit of 100 kHz. Research by Bodson et al. (2007) indicates that harbor seals are low-frequency specialists with respect to localizing underwater pure tones.

- **Hooded Seal (*Cystophora cristata*)**

Description—Hooded seals are large, sexually-dimorphic phocids with average adult males reaching 2.6 m in length and 192 to 352 kg in weight (Jefferson et al. 2008). Females are smaller, measuring approximately 2 m in length and weighing 145 to 300 kg (Jefferson et al. 2008). Hooded seal pups are blue-black dorsally and silver-gray ventrally (having shed their lanugo coat prior to birth); pups and very young juveniles are referred to commonly as “blue-backs”. Adults are silver to gray in color with an overlay pattern of black mottling (Reeves and Ling 1981). The face is black to behind the eyes; the flippers are also dark (Reeves and Ling 1981). The most unique feature of this species is

the prominent two-part nasal ornament of sexually mature males that gives the species its common name. When relaxed, this nasal appendage hangs as a loose, wrinkled sac over the front of the nose; however, when the nares are closed and the sac inflated, it becomes a large, tight bi-lobed "hood" that covers the front of the face and top of the head. Adult males also have a very elastic nasal septum that they can extrude through one of their nostrils as a membranous pink balloon (Jefferson et al. 2008).

Status—The world's hooded seal population consists of three separate stocks, each of which are identified with a specific breeding region: the Northwest Atlantic (whelping sites in Newfoundland/Labrador, the Gulf of St. Lawrence, and the Davis Strait), the Greenland Sea ("West Ice"), and the White Sea ("East Ice") (NMFS 2007). It is not known to which stock the vagrant hooded seals observed in the eastern North Pacific belong. The minimum population estimate for the entire Northwest stock of hooded seals is 592,100. There are insufficient data to calculate an estimate for U.S. waters (NMFS 2007).

Habitat Associations—Hooded seals are known to inhabit the edge of the heavy pack ice for breeding and molting (spring to summer) and display a general preference for deep waters near the shelf break (Campbell 1987; Folkow et al. 1996; Bowen and Siniff 1999). From late winter to spring they remain over the continental shelf, following distinct movement patterns that keep them in close association with drifting pack ice (Campbell 1987; Folkow et al. 1996; Stenson et al. 1996; Kovacs 2002; NMFS 2007). During the non-breeding season (fall to winter), hooded seals may make far-ranging journeys in deep oceanic waters, often remaining in areas of steep bathymetric relief, before returning to the pack ice (Folkow et al. 1996; Folkow and Blix 1999; Reeves et al. 2002; ICES 2006).

Distribution—Hooded seals are found in the Atlantic region of the Arctic Ocean and in high latitudes of the North Atlantic Ocean; they inhabit the seasonally-shifting pack ice zone of the North Atlantic from the Gulf of St. Lawrence, Newfoundland, and Labrador in the west to the western Barents Sea in the east (Campbell 1987). The hooded seal is a highly migratory species that can make extensive movements and shows a great tendency toward wandering. There are several extralimital sightings of this species in the Pacific Ocean, including three known occurrences (two confirmed sightings and one anecdotal record) of hooded seals in the western Beaufort Sea, an individual sighted repeatedly in southeast Alaska, and a female recorded near San Diego, California (Burns and Gavin 1980; Dudley 1992; Fay 1995). The range of hooded seals may be considerably influenced by changes in ice cover and climate due to their dependency on the pack ice (Campbell 1987; Johnston et al. 2005b).

➢ Information Specific to the SOCAL/Pt. Mugu Study Area

- Warm-water period—Rare occurrence extends throughout the Study Area during the warm-water period (**Figure B-36**). Only extralimital individuals are expected to occur in this region. There is one record of a female hooded seal found at the Silver Strand State Beach in San Diego, California in July 1990; this is the only record of a hooded seal in the Pacific Ocean (Dudley 1992).

- Cool-water period—Occurrence is expected to be similar to the warm-water period (**Figure B-36**).

Behavior and Life History—The hooded seal is solitary except during the breeding and molting seasons when it will aggregate on the pack ice with other seals (Kovacs 2002). Pupping and breeding occur in late March and early April, with most births occurring at the end of March (Campbell 1987; Riedman 1990). The lactation period is just 4 d long, during which time the single pup will suckle almost continuously and double its body weight. After 4 d, the pup is weaned and often abandoned to make its own way to the edge of the pack ice (Bowen et al. 1985; Bowen and Siniff 1999). The female enters estrous and mates approximately a week after weaning her pup; delayed implantation allows the female to pup at the same time each year (Kovacs 2002). After the breeding season, individuals disperse to forage in the open ocean until the molting season in June and August (Folkow and Blix

1999). Less is known about the behavior of this species during the fall and winter when they venture away from the ice to forage, though sighting and stranding data indicate that they move on large spatial and temporal scales (Spangler and Sadove 1995; Folkow et al. 1996; Folkow and Blix 1999; McAlpine et al. 1999; Mignucci-Giannoni and Haddow 2002; Coltman et al. 2007).

Hooded seals feed primarily on squid and deepwater fishes such as Greenland halibut, redfish, polar cod, herring, and blue whiting; data indicate that there may be a seasonal component to prey choice or availability (Reeves and Ling 1981; Campbell 1987; Folkow and Blix 1999; Kovacs 2002; Haug et al. 2007). Hooded seal pups initially feed on krill and other invertebrates until they have sufficient skills to capture fish (Kovacs 2002). Adult hooded seals spend much of their time submerged and can dive to depths of over 1,000 m, remaining underwater for periods of up to almost an hour (Folkow and Blix 1999; Stenfors et al. 2001).

Acoustics and Hearing—Hooded seals emit eight different call types although it is suspected that their repertoire is more varied (Ballard and Kovacs 1995). Both males and females produce calls that are primarily aerial and have most of their energy at 0.1 to 1.2 kHz (Terhune and Ronald 1973). Only males are thought to produce underwater calls (Terhune and Ronald 1973; Ballard and Kovacs 1995). Males produce low-frequency sounds in air that coincide with dominance displays using the nasal ornament (as mentioned previously). Vester et al. (2001) recorded ultrasonic clicks produced by hooded seals, with a frequency range of 66 to 120 kHz, dominant energy at 93 kHz ($\pm$22 kHz), and average source levels of 143+ dB re 1 µPa-m in conjunction with live fish hunting.

There are no data on the hearing capabilities of this species. The generic underwater hearing range for phocids is a peak sensitivity ranging between 10 and 30 kHz, with a high-frequency limit of about 60 kHz (Wartzok and Ketten 1999). Low frequency limits underwater are not well established for phocids. Phocid peak hearing sensitivities in air are shifted to slightly lower frequencies (3 to 10 kHz) (Wartzok and Ketten 1999).

- **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 nearly three times larger than adult females (Deutsch et al. 1994). The northern elephant seal reaches a standard length (SL) 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 (making it appear reddish or pinkish) from fighting with other males (Jefferson et al. 2008). 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 (Jefferson et al. 2008).

Status—The northern elephant seal population has recovered dramatically after being reduced to perhaps no more than a few animals in the 1890s (Bartholomew and Hubbs 1960; Stewart et al. 1994). There is movement and some genetic interchange between rookeries, but most elephant seals return to their natal rookeries to breed (Huber et al. 1991). There are two demographically-distinct populations of northern elephant seals; there is a population that breeds in Baja California, Mexico, and a population that breeds on islands off California in the U.S. The minimum population estimate for the California breeding stock is 74,913 individuals (Carretta et al. 2007). The population in California is continuing to increase, but the Mexican stock appears to be stable or slowly decreasing (Stewart et al. 1994; Carretta et al. 2007).

Habitat Associations—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°N 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). Northern elephant seals utilize the benthic environment and oceanographic features such as eddies as foraging habitat (Bradshaw et al. 2004; Simmons et al. 2007). Some individuals may also forage in coastal waters or move into subtropical or tropical waters, particularly those from the Mexico breeding stock (Stewart and DeLong 1995; Aurioles et al. 2006; Simmons et al. 2007).

The effects of El Niño events on the habitat use of some pinniped species in the North Pacific can be severe. Stewart and Yochem (1991) studied the effects of the strong 1982/1983 ENSO event on northern elephant seals breeding in the Channel Islands. They found that females arrived 5 to 8 d 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; however, Crocker et al. (2006) found that the effects of a second major ENSO event in 1997/1998 reduced available prey and caused a decrease in foraging success throughout the North Pacific Ocean.

Distribution—The northern elephant seal is endemic to the North Pacific Ocean and occurs almost exclusively in the eastern and central North Pacific. However, vagrant individuals sometimes range to the western North Pacific. The most far-ranging individual appeared on Nijima Island off the Pacific coast of Japan in 1989 (Kiyota et al. 1992).

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; **Figure 3-8**). The major rookeries in Mexico are Cedros Island, Benito del Este, Medio and Este, and Guadalupe Island; a minor rookery is located at the Coronado Islands (Lowry, M., NMFS-SWFSC, pers. comm., May 2008). In California, elephant seals breed in the southern Channel Islands (Stewart and Yochem 2000). There are large rookeries on San Miguel and San Nicolas islands and smaller rookeries on Santa Barbara and San Clemente islands (Stewart and Yochem 1986; Stewart et al. 1993; Stewart et al. 1994; Lowry 2002). Elephant seals haul out on these islands to breed from late December to February and to molt from April to July. There are also rookeries and haulout sites on Piedras Blancas, Cape San Martin, Año Nuevo Island and Peninsula, the Farallon Islands, and Point Reyes (Stewart et al. 1994). A relatively new rookery is located at Point Conception (Lowry, M., NMFS-SWFSC, pers. comm., May 2008). 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.

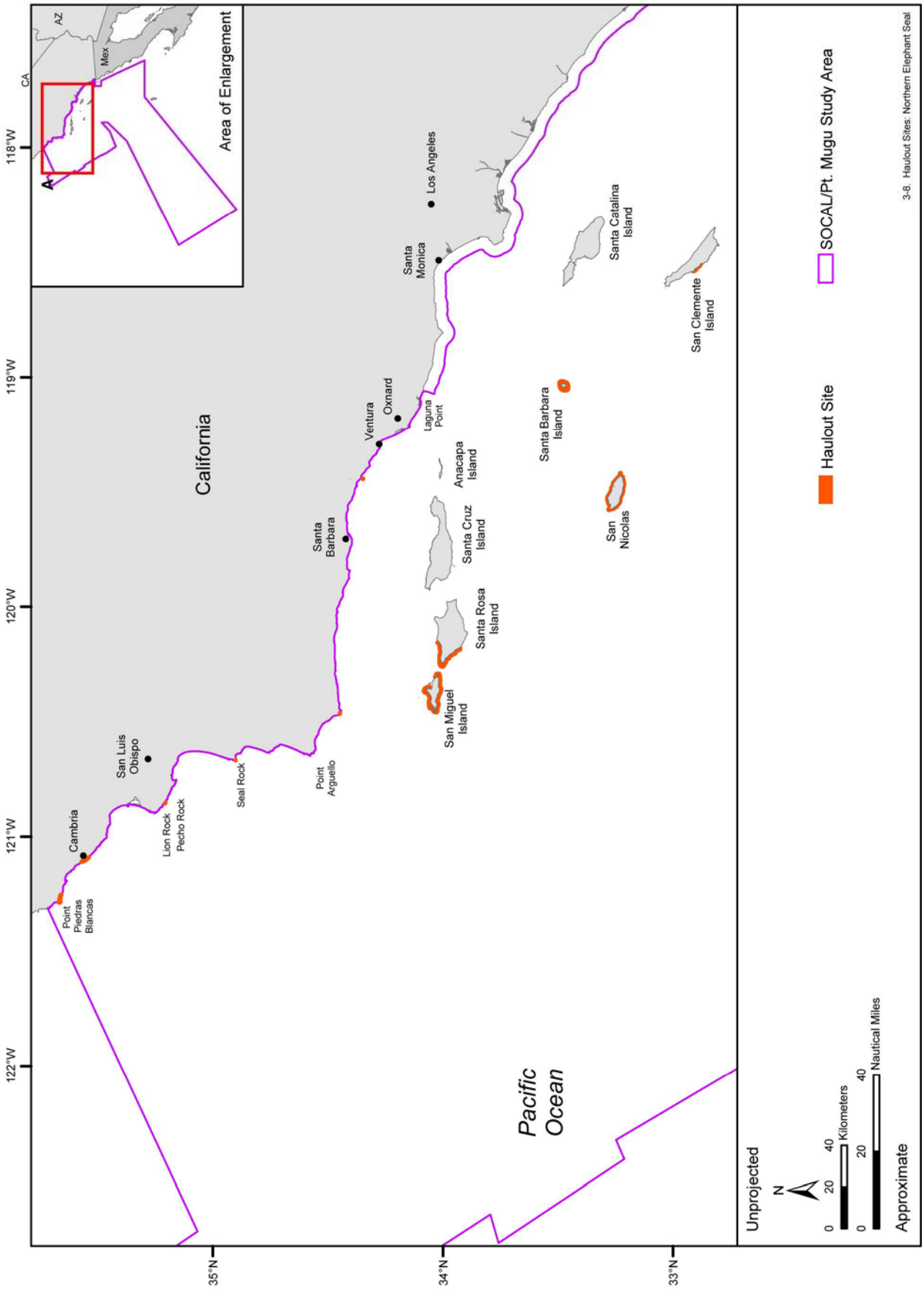

Figure 3-8. Northern elephant seal haulout sites in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NOS (2001, 2006), and Stewart, B.S., Hubbs-Sea World Research Institute, pers. comm., 14-26 January and 20 April 2005.

The foraging range of northern elephant seals extends thousands of kilometers offshore from the breeding range into the central North Pacific (Stewart and Delong 1993; Hassrick et al. 2007). Adult males and females segregate while foraging and migrating (Stewart and DeLong 1995; Stewart 1997; Hassrick et al. 2007). Adult females mostly range west to about 173°W, between the latitudes of 40°N and 45°N, whereas adult males range farther 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 (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).

- Information Specific to the SOCAL/Pt. Mugu Study Area—The northern elephant seal is expected to occur year-round in the offshore region of the Study Area and throughout the Channel Islands, primarily on San Miguel and San Nicolas islands (**Figure 3-8**); however, smaller colonies also breed and haul out on San Clemente and Santa Barbara islands (Bonnell and Dailey 1993; Koski et al. 1998; DoN 2002). Several thousand northern elephant seals also breed on Santa Rosa Island (Stewart, B.S., Hubbs-Sea World Research Institute, pers. comm., 14-26 January and 20 April 2005). Rookeries and haulouts are also scattered along the coast of the Study Area north of the Channel Islands to Piedras Blancas (**Figure 3-8**). Northern elephant seals are known to migrate thousands of kilometers from their breeding areas, and females, in particular, usually travel west of these sites (Stewart and Huber 1993; Stewart and DeLong 1995; Le Boeuf et al. 2000). Therefore, it is likely that the far offshore areas of low survey effort in the Study Area would be considered high-usage habitat given sufficient survey effort in those areas.

  - Warm-water period—Lowest numbers of northern elephant seals occur in the Study Area during the summer when most seals are at sea outside the Study Area, but adults return to land to molt during this time (Koski et al. 1998; Carretta et al. 2007). Primary occurrence includes offshore waters of the Study Area as well as coastal waters around rookeries and haulout sites (**Figure B-37**). There is a secondary occurrence between the coast and the primary occurrence region north of Point Conception. South of Point Conception, secondary occurrence is a narrow band between the rare and primary occurrence areas. South of the California/Mexico border, secondary occurrence extends from the shoreline to the primary occurrence boundary which accounts for possible haulout sites along the Mexico coastline. Occurrence in San Diego Bay and along the coast between Point Conception and the California/Mexico border is considered rare.

  - Cool-water period—Peak numbers of northern elephant seals in the waters of the Study Area correspond to the winter offshore movements from their breeding colonies, the return of females to haulout sites to molt, and the initial forays of pups into coastal waters (Koski et al. 1998). Peak numbers on land occur during the winter when northern elephant seals congregate on breeding islands and during the spring when females and juveniles haul out to molt (Bonnell and Dailey 1993). Occurrence patterns are expected to be similar to the warm-water period (**Figure B-37**).

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 mo at sea and undertake two annual migrations between haulout and feeding areas (Stewart and DeLong 1995). They haul out on land to give birth and breed, and after spending time at sea to feed (post-breeding migration), they generally return to the same areas to molt (Stewart and Yochem 1984; Stewart and DeLong 1995; Le Boeuf et al. 2000). 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 d before returning to land to molt (Le Boeuf et al. 2000). After remaining on land for about a month to molt, the females spend 8 mo at sea (the length of the gestation period) before returning to the rookery to give birth (Le Boeuf et al. 2000). Elephant seals do not necessarily return to the same beach to breed and molt. For example, Huber et al. (1991) found that female northern elephant seals often molt on one island and breed on another, though there is year-to-year fidelity to these sites.

After the breeding season, adult males spend about 4 mo at sea before returning to shore in summer to molt (Le Boeuf et al. 2000). They spend about 1 mo ashore to molt and then return to sea for another 4 mo before returning to the rookery for the breeding season (Le Boeuf et al. 2000).

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 d, breed, and depart (Le Boeuf and Peterson 1969; Stewart and Huber 1993). Gestation lasts 8 mo following a 2- to 3-mo period of embryonic diapause so that females give birth approximately 11 mo after mating (Stewart and Huber 1993). During the breeding season, elephant seals congregate in large numbers on their breeding rookeries (Le Boeuf 1974). 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 (Le Boeuf 1974; Stewart and DeLong 1994; Stewart and Yochem 2000). Other animals, especially other bulls seeking to challenge the alpha male or sneak copulations, often surround the harems (Le Boeuf 1974).

Males reach sexual maturity at about 6 or 7 yr but do not reach “social maturity” until 9 or 10 yr (Stewart and Huber 1993). 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 (Riedman 1990; Le Boeuf et al. 2000; Hassrick et al. 2007).

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. 2007).

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; Le Boeuf et al. 1989; DeLong and Stewart 1991). Elephant seals may spend as much as 90% of their time submerged (DeLong and Stewart 1991; Bennett et al. 2001); this year-round pattern of continuous, long, deep dives explains why northern elephant seals are rarely seen at sea and why their oceanic whereabouts and migrations have long been unknown (Stewart and DeLong 1995). The average diving cycle consists of a 23 min dive followed by a 2 to 4 min surface interval (Le Boeuf et al. 1986; Le Boeuf et al. 1989; DeLong and Stewart 1991). The longest known dive is 77 min (Stewart and Huber 1993). Dives average between 350 and 550 m in depth 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 (Le Boeuf et al. 2000; Aurioles et al. 2006). Data show that young females increase dive time and depth as they age and that they generally dive deeply at night and shallower during the day, probably as they follow migrating prey in the water column (Aurioles et al. 2006). 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 make vertical migrations and are part of the DSL (Antonelis et al. 1994). Elephant seals from the Mexico breeding stock probably feed farther south and over a broader longitudinal scale than those from the California breeding stock (Aurioles et al. 2006).

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-m (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). Hemilä et al. (2006) examined middle and inner ear anatomy to confirm that phocids are more specialized for aquatic hearing; elephant seals showed a high-frequency hearing limit in air of 24 kHz but an inwater limit of 80 to 100 kHz. Elephant seals are relatively good at detecting tonal signals over masking noise (Southall et al. 2000).

- **Ringed Seal (*Pusa hispida*)**

Description—The ringed seal is one of the smallest phocids. Adults reach 1.65 m in length and weigh up to 110 kg. Ringed seals resemble harbor seals but are much plumper. The ringed seal's coloration is its most distinctive feature. The pelage is gray with lighter colored rings scattered across the dorsal surface of the animal; the rings appear at approximately one year of age after the animal's first molt (Jefferson et al. 2008).

Status—There are five subspecies of the ringed seal: three in marine waters and two in freshwater lakes (Amano et al. 2002). There is some evidence for genetic differentiation in the isolated subspecies but not for the subspecies occurring in the Arctic basin (Palo et al. 2001; Amano et al. 2002). The Alaska ringed seal stock is the only stock recognized in U.S. waters. There are no current estimates of abundance for this stock nor are there sufficient data available for a minimum population estimate (Angliss and Outlaw 2008).

Habitat Associations—Ringed seals are pagophilic, occurring in areas of high ice concentration most of the year (Kingsley 1990). They prefer areas of stable ice such as fast ice and the interior of the pack ice and often occur in waters with very high (>90%) surface coverage (Kingsley 1990; Teilmann et al. 1999; Simpkins et al. 2003). Ringed seals will haul out at holes or narrow cracks in fast ice or in the middle of very large floes (>48 m) but not on the edge of wide leads or ice floes (Kingsley 1990; Simpkins et al. 2003). Subadults winter in shear zones and areas of unconsolidated ice not suitable for breeding and are subject to intense predation by polar bears (*Ursus maritimus*) (Kingsley 1990). During the spring and summer (March to May), habitat selection varies; females and older males select very stable, interior pack ice while subadult males occur in the less stable, outer fast ice (Krafft et al. 2007). By late spring when the snow cover melts, ringed seals haul out in the open at their breathing holes or at newly-formed cracks to molt and bask (Kingsley and Stirling 1991). During the fall and winter, ringed seals may occur offshore or inshore. Offshore individuals prefer habitat with 40 to 80% ice coverage in areas of high productivity while inshore individuals select habitat near glacier fronts (Freitas et al. 2008).

Distribution—The ringed seal has a circumpolar distribution throughout the Arctic Ocean, Hudson Bay, and the Baltic, Bering, and Okhotsk seas (Jefferson et al. 2008). Ringed seals are able to cover long distances in relatively short times, with extralimital occurrences documented as far south as Portugal in the North Atlantic Ocean and southern California in the eastern North Pacific Ocean (Dudley 1992; van Bree 1996; Ridoux et al. 1998; Lucas and McAlpine 2002). These extralimital strays are not necessarily lost to the population since at least one individual is known to have returned to the vicinity of known normal ringed seal distribution (Ridoux et al. 1998).

- Information Specific to the SOCAL/Pt. Mugu Study Area

  - Warm-water period—There is a rare occurrence of the ringed seal throughout the Study Area during the warm-water period (**Figure B-38**); only extralimital individuals are expected to occur here. A ringed seal was found on a beach in La Jolla, California in 1976 (Dudley 1992).

  - Cool-water period—Occurrence is expected to be similar to the warm-water period (**Figure B-38**).

Behavior and Life History—Adult ringed seals are solitary, except for loose feeding aggregations in the water in summer (Kingsley 1990). During the breeding season, ringed seals do not aggregate but occur in isolated small groups of a single female, her pup, and an adult male (Smith and Hammill 1981; Krafft et al. 2007). The presence of older males associated with females on the inner fast ice during the breeding season coupled with the presence of younger adult and subadult males in the outer fast ice suggests that competitive exclusion takes place and that ringed seals are probably territorial (Smith and Hammill 1981; Krafft et al. 2007).

The ringed seal establishes breathing holes in the unbroken ice as it forms during the fall. They maintain these holes throughout the winter by constantly scratching away the ice with the claws on their foreflippers (Smith and Stirling 1975). In early spring, ringed seals occupy lairs in the overlying snow, which are used as pupping and resting sites (Smith and Stirling 1975). Ringed seals scratch these lairs (known as subnivean lairs) out of the snow above the breathing hole in the ice to shelter themselves from predators and severe weather conditions (Smith and Stirling 1975). Hammill and Smith (1991) suggested that the lair evolved primarily in response to predation (particularly of the pups) by polar bears, and the thermal protection that they provide is a secondary, but predator-related, benefit. Females give birth and leave their pups in the lairs between nursings. Pups are born in late March through early May and they are nursed for 4 to 6 wk (Frost and Lowry 1981). Mating occurs after pups are weaned, usually in late April and May; delayed implantation takes place (Kingsley 1990). From mid-May through July, ringed seals haul out to bask in the sun. They molt from late March until the ice breaks up, which usually occurs in July.

Ringed seals feed on a variety of zooplankton and fish (Weslawski et al. 1994; Wathne et al. 2000). In nearshore waters, ringed seals feed on polar cod (*Boreogadus saida*) and on small crustaceans (*Mysis* spp.). In deeper, offshore waters they feed on zooplankton (e.g., *Themisto libellula* and *Thysanoessa inermis*) and fish (Weslawski et al. 1994; Holst et al. 2001). Stomach content analysis studies show that cod occurs more often in older seals. There is also evidence of dichotomous prey choice between males and females, with males preferring fish and females preferring zooplankton (Lowry et al. 1980; Dehn et al. 2007). Food consumption rates vary seasonally; the general pattern is for seals to feed intensively from late summer to early spring. During the breeding and molting seasons, ringed seals feed less intensively and spend proportionately more time hauled out (Riedman 1990; Born et al. 2002).

Median dive duration is less than 10 min for adult ringed seals (Lydersen 1991; Teilmann et al. 1999; Gjertz et al. 2000). Ringed seals occasionally dive up to 50 min or longer and at depths of more than 250 m, although most dives are shallower than 100 m (Lydersen 1991; Teilmann et al. 1999; Gjertz et al. 2000). Pups are precocious, entering the water soon and often after birth and diving to depths of 89 m for up to 12 min (Smith and Hammill 1981; Lydersen and Hammill 1993).

Acoustics and Hearing—Ringed seals produce clicks with a fundamental frequency of 4 kHz and varying harmonics up to 16 kHz (Schevill et al. 1963). Stirling (1973) described barks, high-pitched yelps, and low- and high-pitched growls. Ringed seals appear to be most vocal during the breeding season (Stirling et al. 1983). Ringed seals are sensitive to underwater sounds in the 8 to 60 kHz band (Terhune and Ronald 1975, 1976). The hearing ability of ringed seals has not been tested below 1 kHz (Terhune and Ronald 1975).

- **Ribbon Seal (*Histriophoca fasciata*)**

Description—Ribbon seals are phocids that are easily identified by their color pattern. Adults males have dark, black or brown-black pelage with pale bands encircling the neck, foreflippers, and pelvis (Jefferson et al. 2008). Adult females have lighter coats and less distinct banding than males. Pups are born with a thick, white coat (lanugo coat) that is replaced by a dark, bluish-gray pelage after four to five weeks. The banding pattern emerges after two years (Jefferson et al. 2008). Adults reach a maximum length of around 1.8 m and weigh 90 to 148 kg (Jefferson et al.).

Status—Ribbon seals occurring in U.S. waters are managed as one stock (Angliss and Outlaw 2008). Little is known about their status, but there are probably three populations of ribbon seals: two in the Okhotsk Sea and one in the Bering Sea (Fedoseev 2002; Jefferson et al. 2008) There are currently no reliable estimates of population size (Angliss and Outlaw 2008).

Habitat Associations—Ribbon seals rarely haul out on fast ice or land; they prefer firm pack ice far offshore and along regions with an abrupt continental shelf for breeding, molting, and nursing (Fay 1974; Fedoseev 2002). These areas are characterized by small ice floes (less than 20 m wide) separated by water or slush ice and are subject to rapid dispersal or compaction by winds and ocean currents (Burns 1970). Ribbon seals cannot make breathing holes in thick ice (10 to 15 cm) and avoid areas of solid ice fields (Fedoseev 2002). Prey resources are also highly concentrated near the ice floes and ribbon seals associate with ice habitat in the vicinity of high benthic biomass (Fedoseev 2002; Simpkins et al. 2003). Recent data suggest that after the breeding and molting season, ribbon seals occur in oceanic, pelagic habitats both on and off the continental shelf (Boveng et al. 2007).

Distribution—Ribbon seals inhabit the North Pacific and Arctic oceans, ranging from south of the central Aleutians; west to the Kamchatka Peninsula and the Sea of Okhotsk; and north into the Bering Sea, the Chukchi Sea, and parts of the western Beaufort Sea (Angliss and Outlaw 2008). Vagrants have been sighted in Cordova, Alaska, and Morro Bay, California (Roest 1964; Rice 1998).

Ribbons seals are closely associated with ice for much of the year. They give birth, suckle pups, mate, and molt along the ice edge from January to July (Frost and Lowry 1980; Reeves et al. 2002). As the ice recedes (usually from May to July), the seals move north with it, continuing to haul out on the edge of the pack ice. When the sea ice melts (July through November), ribbon seals become pelagic and probably spend most of their time foraging in the Bering and Chukchi seas (Frost and Lowry 1980). The complete distribution and range of ribbon seals at sea are not known (Burns 1970).

➢ <u>Information Specific to the SOCAL/Pt. Mugu Study Area</u>

- <u>Warm-water period</u>—Occurrence of the ribbon seal is expected to be rare throughout the Study Area (**Figure B-39**); only extralimital individuals would occur in this region. An individual was captured alive near Morro Bay, California, in November 1962 (Roest 1964), and another was reported in San Pedro, California in 1987 (Dudley 1992).

- <u>Cool-water period</u>—Occurrence is expected to be similar to the warm-water period (**Figure B-39**).

Behavior and Life History—Ribbon seals are solitary animals, forming small groups only during the breeding season (Ronald and Gots 2003). Pupping occurs in April and May (Riedman 1990). The lactation period is about four weeks. Pups remain on the ice until they shed their natal pelage at

around 3 to 4 wk after birth (Burns 1970). Mating probably occurs in April and May near the time when pups are weaned (Kelly 1988). Delayed implantation takes place and gestation lasts approximately 8.5 mo; females give birth about 11 mo after mating (Kelly 1988; Riedman 1990). Males are sexually mature at 3 to 5 yr of age. Although females reach sexual maturity between 2 and 4 yr of age, many do not give birth until around the age of 4 or 5 (Reeves et al. 1992).

Prey composition and size vary among ribbon seal age classes. This is probably due to differences in foraging technique and diving ability (Deguchi et al. 2004). Pups less than 1 yr old feed on small euphausiids but eat mostly shrimp between 1 and 2 yr of age (Fedoseev 2002). In contrast, adult diets consist primarily of cephalopods and fish (Fedoseev 2002; Deguchi et al. 2004). They also eat eelpout, mysids, crabs, saffron cod, herring, capelin, and a variety of other fish and cephalopods (Reeves et al. 1992; Dehn et al. 2007). Ribbon seals usually forage in the deep intermediate-bottom layer of the continental slope (Deguchi et al. 2004). The ribbon seal is well adapted for diving and is known to dive to depths of 600 m (Fedoseev 2002).

Acoustics and Hearing—Ribbon seal vocalizations are downward frequency sweeps and puffing sounds. These frequency sweeps are in the range of 0.1 to 7.1 kHz and have a source level of 160 dB re 1 μPa-m (Watkins and Ray 1977). There are no published data on the hearing abilities of the ribbon seal.

- **Northern Fur Seal (*Callorhinus ursinus*)**

Description—Northern fur seals are extremely sexually dimorphic; males may be more than four times larger than females (Gentry 2002; Jefferson et al. 2008). Males can grow up to 2.1 m in length and weigh 270 kg, while females can reach 1.5 m and 50 kg or more (Jefferson et al. 2008). Northern fur seals have thick, cream-colored pelage overlaid by long, coarse guard hairs that make them appear darker. Females and subadults are generally silver to charcoal gray with a lighter underside and some variable light coloration on the face. Adult males may be gray to black or reddish-brown in color. Adult males have thicker pelage around their head, neck, chest, and shoulders and a sagittal crest. Pups are generally black with a light belly. Northern fur seals have relatively small heads and short, pointed snouts with long ear flaps (Jefferson et al. 2008).

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. 2007). The San Miguel Island northern fur seal stock is not considered to be depleted under the MMPA, unlike the Eastern Pacific stock (Carretta et al. 2007). The current minimum population estimate for the San Miguel Island stock is 5,096 individuals (Carretta et al. 2007). Abundance at San Miguel Island has increased steadily over the past four decades, with the exception of two severe declines associated with ENSO events in 1993 and 1998 (DeLong and Antonelis 1991; Melin and DeLong 2000; Testa 2005).

Habitat Associations—The northern fur seal is an oceanic species, spending up to 8 mo at sea each year; pups may spend as many as 22 mo at sea before returning to land (Ream et al. 2005; Carretta et al. 2007). At sea, they are usually sighted 70 to 130 km from land in upwelling regions along the continental shelf and slope, seamounts, submarine canyons, and sea valleys (Kajimura 1984). Pup habitat use has been shown to consist of deep waters beyond the continental shelf (Baker 2007). Females forage in upwelling regions in the vicinity of Point Conception during the summer months (Antonelis et al. 1990). The upwelling system also produces fog and wind conditions that cool the island during the summer months when northern fur seals pup and breed (DeLong 1982). 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. 2007). The largest rookery is in the Pribilof Islands in the Bering Sea. 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 Island and the Farallon Islands in California (Pyle et al. 2001; Robson 2002).

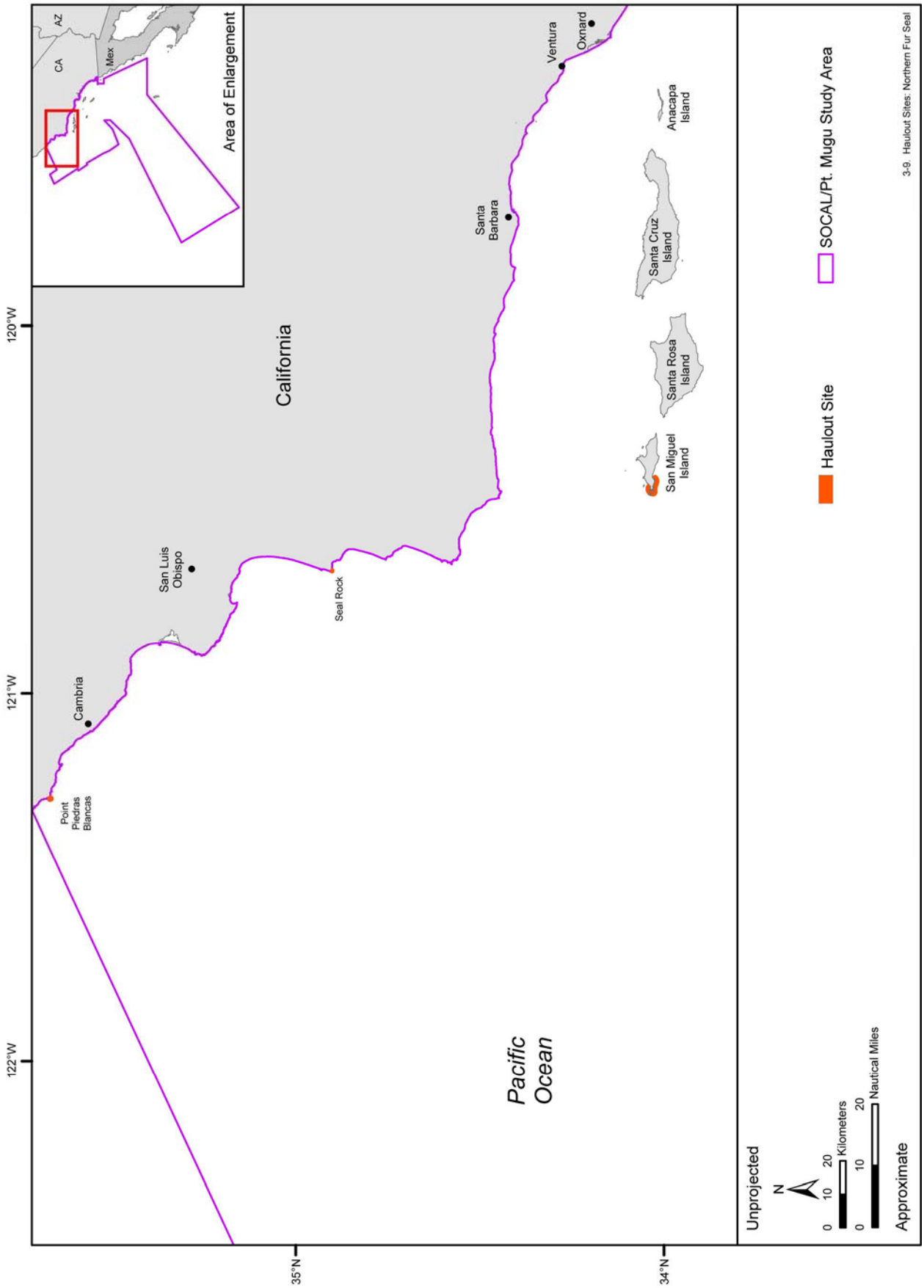

Figure 3-9. Northern fur seal haulout sites in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NOS (2001, 2006).

The population of northern fur seals on San Miguel Island originated from the Pribilof Islands population during the late 1950s or early 1960s (DeLong 1982). Northern fur seal colonies are located at Adams Cove on San Miguel Island and on Castle Rock, an offshore island 1.1 km northwest of San Miguel Island (Le Boeuf and Bonnell 1980; Robson 2002; **Figure 3-9**). There have been a few occurrences of individuals hauling out at San Nicolas Island during the summer (Stewart and Yochem 2000).

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). The northward migration begins in March, and most of the eastern Pacific stock has left the offshore areas of the contiguous U.S. by June (Antonelis and Fiscus 1980). Although both stocks are found in the SCB during the fall and winter, the San Miguel Island stock remains in or near the area throughout the year (Koski et al. 1998). Adult females and juveniles from the San Miguel stock are found in offshore waters of northern California, Oregon, and Washington State 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., 7 April 2008). The total number of northern fur seals at San Miguel Island fluctuates seasonally. There are fewer animals (mostly juveniles and subadult males) at San Miguel during late November to May as most individuals feed offshore (Stewart and Yochem 2000). The numbers rise again in late May at the start of the breeding season (Bonnell et al. 1978).

- Information Specific to the SOCAL/Pt. Mugu Study Area—Northern fur seals occur in the Study Area year-round. They are a cold-water species and are usually sighted offshore (70 to 130 km from land) and along the continental shelf and slope, where they typically forage (Kajimura 1984). The largest numbers for this species will likely be in areas greater than 500 m deep on account of foraging at the slope and will include San Miguel Island, the southernmost haulout site for this species (Kajimura 1984; Robson 2002). Northern fur seals are occasionally found within depths of 200 to 500 m where opportunistic feeding may occur (Lowry, M., NMFS-SWFSC, pers. comm., 7 April 2008).

  - Warm-water period—Peak abundance on San Miguel Island coincides with the breeding season (late May through October). Occurrence at sea during the summer and fall is likely to be in an area west of San Miguel Island, over the Rodriguez Seamount and northward from 24 to 67 km offshore to an area near Point Sal (Bonnell et al. 1978; Bonnell et al. 1983). The buffer limits are temperature-based due to the expected occurrence of northern fur seals in cool waters north of the 18°C isotherm. An area of primary occurrence includes waters colder than the 18°C isotherm and includes San Miguel Island (**Figure B-40**). North of Point Conception, primary occurrence extends seaward of the 100-m isobath while secondary occurrence includes waters inshore of the 100-m isobath. South of Point Conception, the secondary occurrence boundary is near the 18.5°C isotherm and includes all the Channel Islands (**Figure B-40**). Occurrence farther offshore and in San Diego Bay is considered rare.

  - Cool-water period—Numbers decline somewhat during the early winter and spring, when some northern fur seals move offshore to feed, but rise again at the start of breeding season in late May (Bonnell et al. 1978). However, occurrence patterns are expected to be similar to the warm-water period (**Figure B-40**).

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, the 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. 1978). Pups are born between June and August on the Pribilof Islands (York 1987). Females enter estrous and mate four to seven days after parturition (Kiyota et al. 2008). Northern fur seals exhibit strong site fidelity for mating and birthing; males defend only one territorial location in their reproductive lifetime and females bear their young within eight to ten meters 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 d and feeding at sea for around 4 d (DeLong 1982). Pups are weaned at around 4 mo (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 together (Antonelis and Fiscus 1980; Kajimura 1984). Northern fur seals are opportunistic feeders (Kajimura 1984). The principal prey species off California include northern anchovy, Pacific whiting, market squid, California lanternfish, Pacific saury, jack mackerel, rockfishes, sablefish, and oceanic squids (*Onychoteuthis* spp.) (Antonelis and Perez 1984; Kajimura 1984; Stewart and Yochem 2000).

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). Pups are relatively altricial; they do not enter the water until they are 40 to 50 days old and make short, shallow dives despite the fact that they may cover large distances after weaning (Baker and Donohue 2000; Baker 2007).

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 decibels (dB) better than in air (Babushina et al. 1991).

- **California Sea Lion (*Zalophus californianus*)**

Description—California sea lions are middle-sized otariids. They are extremely sexually dimorphic; males may reach a maximum length of 2.4 m and weigh 390 kg while females may reach 2.0 m in length and weigh 110 kg (Ono 1991; Jefferson et al. 2008). Adult males have a significant sagittal crest but lack the thick, coarse “mane” pelage around the neck, shoulders, and chest found in other sea lion species (Heath 2002; Jefferson et al. 2008). The coat color varies from sandy brown to dark brown; males are darker than females and juveniles and pups are born with dark pelage that fades to yellowish-tan after a few months (Heath 2002; Jefferson et al. 2008).

Status—The California sea lion is the most abundant pinniped along the California coast. The minimum population size of the U.S. stock of the California sea lion is 141,842 individuals (Carretta et al. 2007). This number was determined from counts during the July 2005 census of all age and sex classes that were ashore at the Channel Islands in southern California and at haulout sites between Point Conception and the Oregon/California border. This is a minimum population estimate because it does not include sea lions that were at sea or hauled out at locations that were not censused (Carretta et al. 2007).

Habitat Associations—California sea lions prefer to breed on sandy, remote beaches (Le Boeuf 2002) but also haul out and pup on rocky beaches. Breeding areas are restricted to productive upwelling zones where prey is easily available to lactating females (Heath 2002). The Channel Islands provide undisturbed habitat, much of which is cooled by prevailing winds that minimize heat stress to the animals (Bonnell and Ford 1987). California sea lions frequent bays, harbors, and river mouths (Jefferson et al. 2008) and often haul out on man-made structures such as piers, jetties, offshore buoys, and oil platforms (Riedman 1990). They generally stay nearshore over the continental shelf (Keiper et al. 2005) but are occasionally sighted several hundred kilometers offshore (Rintoul et al. 2006; Jefferson et al. 2008).

Distribution—The range of the California sea lion extends from British Columbia to Mexico with occasional occurrences noted in Alaskan waters (Maniscalco et al. 2004; Lowry and Forney 2005). Distribution is somewhat sexually-segregated and varies by season. Males occur north of California during the fall and winter whereas females tend to stay farther south year-round (Maniscalco et al. 2004).

California sea lions congregate near rookery islands and specific open-water areas during the summer. The primary rookeries off the coast of the U.S. are located in the Channel Islands on San Nicolas, San Miguel, Santa Barbara, and San Clemente islands (Le Boeuf and Bonnell 1980; Bonnell and Dailey 1993; Lowry and Forney 2005; Lowry and Maravilla-Chavez 2005; **Figure 3-10**). There are also rookeries and haulouts along the coast of the Baja California Peninsula and far offshore at Guadalupe Island, Mexico. Most individuals stay within 50 km of the rookery islands during the breeding season (Bonnell et al. 1978). Individuals breeding on the Channel Islands typically feed over the continental shelf and remain within 54 km of 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).

In the non-breeding season, adult and subadult males migrate northward along the coast of California to Vancouver Island and return south the following spring (Bonnell et al. 1978; Lowry and Forney 2005). Females and juveniles disperse somewhat but tend to stay in the SCB area (Ono 1991; Lowry and Forney 2005). California sea lions from the west coast of the Baja California Peninsula also migrate to southern California during the fall and winter (Bonnell et al. 1978; Lowry and Forney 2005). There is a general distribution shift northwest in fall and southeast during winter and spring, probably in response to changes in prey availability (Bonnell and Ford 1987). California sea lions are the most-frequently sighted pinnipeds offshore of southern California during the spring, and peak abundance in the SCB is during the May through August breeding season (Bonnell et al. 1978; Keiper et al. 2005).

- Information Specific to the SOCAL/Pt. Mugu Study Area—California sea lions occur in the Study Area year-round. Historically, California sea lions have hauled out at several mainland locations in the SCB; however, Seagars et al. (1985) concluded that no California sea lions have pupped or mated on the mainland coast of southern California and that occupation of mainland haulout sites appears to be sporadic. California sea lions are currently distributed throughout the Channel Islands seaward to the continental shelf region.

  - Warm-water period—Peak abundance on land generally occurs in late June during the summer breeding season (Stewart and Yochem 1984). The height of the breeding season on San Nicolas Island is in early July; numbers of adult females and juveniles peak in mid to late June while most males return to sea in late July and migrate away from the Channel Island rookeries to forage and haul out in other areas (mostly to the north) (Lowry, M., NMFS-SWFSC, pers. comm., May 2008). Most rookery sites in the Channel Islands are used as haulout areas during the non-breeding season (Stewart and Yochem 1984). An area of primary occurrence extends from the shore to just beyond the shelf break north of Point Conception (**Figure B-41a**). Primary occurrence extends farther offshore south of Point Conception to cover the Channel Islands and most of the SCB and include NMFS sightings. A 30-km buffer of primary occurrence surrounds Guadalupe Island, a major haulout site (Bonnell and Dailey 1993; Ronald and Gots 2003; Lowry and Forney 2005; **Figure B-41a**).

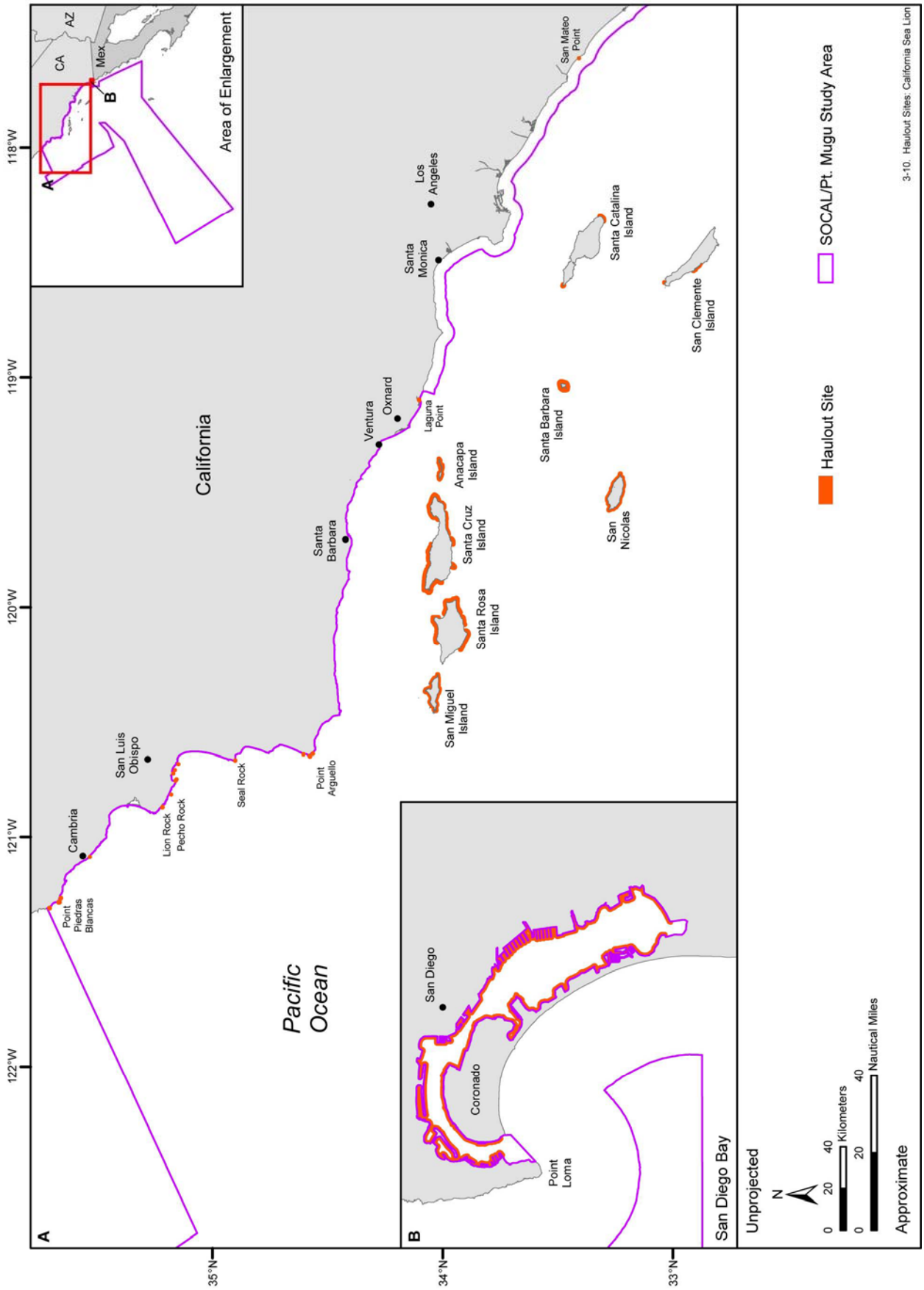

Figure 3-10. California sea lion haulout sites in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NOS (2001, 2006), Stewart, B.S., Hubbs-Sea World Research Institute, pers. comm., 14-26 January and 20 April 2005, and Lowry, M., NMFS-SWFSC, pers. comm., May 2008.

Primary occurrence also occurs in the northern portion of San Diego Bay where California sea lions often haul out on piers and buoys, particularly near the sportfishing bait areas and the U.S. Coast Guard docks (Riedman 1990; Lowry, M., NMFS-SWFSC, pers. comm., 3 March 2008; **Figure B-41b**). There is an area of secondary occurrence between the shelf break and near the 2,000-m isobath north of Point Conception. South of Point Conception, the secondary occurrence buffers the primary region around the Channel Islands and includes other sightings data. Secondary occurrence also extends 70 km around the primary region of Guadalupe Island. The southern portion of San Diego Bay is also a secondary area of occurrence (**Figure B-41b**). Occurrence farther offshore in the Study Area is considered rare.

- Cool-water period—Occurrences of California sea lions during the cool-water period are expected to be similar to the warm-water period but with fewer animals (**Figures B-41a** and **B-41b**). Primary occurrence extends farther offshore than during the warm-water period to account for sightings (**Figures B-41a** and **B-41b**).

Behavior and Life History—California sea lions are highly gregarious and often haul out in large numbers. Prior to mating, many females form groups of 2 to 20 individuals (Heath 2002). At sea, they are usually solitary but tend to form large groups near food-rich areas (Antonelis and Fiscus 1980). Male California sea lions are territorial breeders. They establish territories in May and fast throughout the breeding season, maintaining their territory through vocal and physical defense (Heath 2002). Females mate in June and July shortly after giving birth. They have delayed implantation, and gestation generally lasts from October through June or July (Williams et al. 2007). They nurse their pups for 8 d and then alternate between feeding trips at sea for 3 d and nursing periods of about 2 d (Antonelis et al. 1990; Ono 1991). Pups are weaned at between 6 mo and a year or even longer (Riedman 1990). Sexual maturity occurs at around 4 to 5 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. In Santa Monica Bay, California sea lions are known to follow and feed near common and bottlenose dolphins, possibly taking advantage of the superior food-locating abilities of the dolphins (Bearzi 2006). Near rookeries in southern California, they primarily feed on Pacific whiting, northern anchovy, mackerel, squid, sardines, and rockfish (Antonelis et al. 1990; Lowry et al. 1991; Lowry and Carretta 1999; Lowry and Forney 2005). Further north, prey species include Pacific whiting, squid, anchovy, steelhead, lamprey, and salmon (Everitt et al. 1981; Roffe and Mate 1984; Lowry et al. 1991; Lowry and Forney 2005). Most dives are within 80 m of the surface and less than 3 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). Pups are capable of making long distance movements very shortly after birth (less than 4 wk), though probably with parental support (Young et al. 2007).

In the water, California sea lions often “raft” at the surface alone or in groups and frequently raise their flippers out of the water, primarily as a means of thermoregulation (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 influence 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, slow growing reptiles found throughout the world's tropical, subtropical, and temperate seas (Lutz and Musick 1997; CCC[1]). There are seven living species of sea turtles from two distinct families, Dermochelyidae (leatherback sea turtle; one species) and Cheloniidae (hard-shelled sea turtles; six species); six of which are found in U.S. waters. These two families can be distinguished from one another on the basis of their carapace (upper shell) and other morphological features. Sea turtles are an important marine resource that provide economic (consumptive and non-consumptive) and ecological (existence and intrinsic) 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.

Modifications to the body and limbs from the basic turtle design make sea turtles highly adapted to the marine environment. Sea turtles possess powerful, modified forelimbs (or flippers) that enable them to swim continuously for extended periods of time (Wyneken 1997). They have compact and streamlined bodies that help 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 migrating. Sea turtles often migrate thousands of kilometers between their nesting beaches, mating areas, nursery habitats, and feeding grounds, which would not be possible without the aforementioned suite of adaptations (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, for example, 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 specialized for life at sea, sea turtles begin their lives on land. Aside from this brief terrestrial period, sea turtles are rarely encountered out of the water. Sexually mature females return to land in order to nest and 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). Basking allows sea turtles to thermoregulate, elude predators, avoid harmful mating encounters, and possibly accelerate the development of their eggs (Spotila et al. 1997). On occasion, sea turtles 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). Sea turtles nest every 2 to 3 yr, with the possible exception of Kemp's ridley turtles (*Lepidochelys kempii*) which may nest in consecutive years (Ehrhart 1995). During the nesting season, sea turtles lay several clutches containing 50 to 200 eggs (Witzell 1983; Dodd 1988; Hirth 1997). Internesting intervals range from 9 to 28 d depending on the species (Hirth 1980; Miller 1997). Most sea turtles re-nest in close proximity to the original nesting beach during subsequent nesting attempts. The leatherback turtle is a notable divergence from this pattern. Leatherbacks nest primarily on high-energy beaches with little reef or rock offshore where stochastic erosion can reduce the probability of nest survival. To compensate, leatherbacks scatter their nests over larger geographic areas and lay, on average, twice as many clutches as other species (Eckert and Sarti-M. 1997). 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 (Proffitt et al. 1986; Miller 1997).

Most nesting and hatchling emergence events occur at night as daytime beach temperatures could be lethal (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 crawl in the direction of the brightest light, which on most beaches is towards the ocean/sky horizon (Ernst et al. 1994). Artificial beachfront lighting that appears brighter than the seaward horizon may disorient hatchlings, reducing their chance for reaching the ocean (Witherington and Bjorndal 1991). Newly emerged hatchlings are also easy prey for a variety of scavengers including seabirds, crabs, and mammals (Ehrhart 1995; Miller 1997). It is estimated that only 1 out of every 1,000 hatchlings survives long enough to reproduce (Frazer 1986).

Hatchlings spend the first few years of their lives in offshore waters, drifting in convergence zones or *Sargassum* mats where they find food (mostly pelagic invertebrates) and refuge in flotsam (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 this "early juvenile nursery habitat" before migrating to neritic feeding grounds that comprise the "later juvenile developmental habitat" (Musick and Limpus 1997; Frazier 2001). Juvenile sea turtles in this later juvenile developmental habitat 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 feeds on pelagic soft-bodied invertebrates at both the surface and at depth (S.A. Eckert et al. 1989). 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).

Sea turtles undergo complex seasonal movements influenced by changes in ocean currents, turbidity, salinity, food availability, and perhaps most importantly, 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) and may even become cold-stunned in extremely cold waters when rapid temperature drops occur. One strategy to avoid cold water temperatures is for animals to migrate to warmer waters; this has been observed for turtles in the northeastern U.S. (Musick and Limpus 1997). Alternatively, some individual green and loggerhead turtles escape cold conditions by resting on the seabed or burying themselves in the bottom sediment and brumating or hibernating (Ogren and McVea 1982; Hochscheid et al. 2005). The preferred temperature ranges of sea turtles vary across age classes and species as well as seasons. The leatherback turtle has a wider range of preferred water temperatures than other species due to its ability to thermoregulate (Spotila et al. 1997; Southwood et al. 2005; Wallace et al. 2005).

Knowledge of sea turtle sensory biology is limited to a few studies for each sense (vision, olfaction, and hearing). Sea turtles have a spherical lens which is ideal for underwater vision as the refractive index of their cornea is nearly identical to that of sea water (Bartol and Musick 2003; Levenson et al. 2004). Sea turtles have the visual acuity to detect relatively small objects within the marine environment. They are also able to see in color, primarily in the shorter wavelengths (450 to 620 nanometers [nm]), with peak sensitivity for loggerhead and green turtles occurring at 580 nm (yellow) (Bartol and Musick 2003; Levenson et al. 2004). Leatherback spectral sensitivity is primarily at shorter wavelengths with a peak in sensitivity between 400 and 500 nm (violet and blue) (Crognale et al. In press). On land, sea turtle vision is highly myopic (nearsighted). Visual cues on land are restricted to diffuse images, and brightness levels (Bartol and Musick 2003).

Several behavioral studies have illustrated that sea turtles are able to smell underwater, an unusual ability for an air-breathing vertebrate. Manton et al (1972a) observed loggerheads moving the floor of the mouth up and down with the nostrils flared open in response to the introduction of a chemical cue. The throat movements appear to be a means to pump water through the nasal cavities so the turtle can smell underwater (Manton et al. 1972a). Upon a chemical release, flipper movements increased and approaches towards the cue were quite violent (Manton et al. 1972a). Constantino and Salmon (2003) also found that turtles have responses to chemical stimuli and will orient themselves into currents towards

the stimuli when the food is not directly visible; however, when food is visible, sea turtles ignore the chemical stimuli and head towards the food object. This would illustrate that chemical cues are important for detecting prey at distance, but then visual cues would take over. Studies have also shown that sea turtles have the capacity to recognize one water mass from another by olfaction. It has been suggested that this may contribute to the species finding waters off their natal beaches (Owens et al 1986; Manton et al. 1972a, 1972b; Grassman et al. 1984).

Sea turtle reception of sound occurs through bone conduction, with the skull and shell acting as receiving structures (Lenhardt et al. 1983). A few preliminary investigations using adult green, loggerhead, and Kemp's ridley turtles suggest that sea turtles are most sensitive to low-frequency sounds (Ridgway et al. 1969; Lenhardt et al. 1983; Bartol 1999; Moein Bartol and Ketten 2006). Typically, sea turtles hear frequencies from 30 to 2,000 Hz and have a range of maximum sensitivity between 100 to 800 Hz (Ridgway et al. 1969; Lenhardt 1994). Green turtle hearing sensitivity peaks at 300 to 400 Hz (Ridgway et al. 1969), loggerhead turtle hearing sensitivity peaks at 400 to 500 Hz (Lenhardt 2002), and Kemp's ridleys are most sensitive to sounds between 100 and 200 Hz (Moein Bartol and Ketten 2006). Hearing below 80 Hz is less sensitive but still potentially usable to the animal (Lenhardt 1994). A recent study of juvenile green turtle hearing showed that the species was able to detect levels below 50 Hz underwater (Eckert, S.A., WIDECAST, pers. comm. 7 April 2008). 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).

Climatic fluctuations have produced a growing concern about the effects of climate change on various marine species, including sea turtles. Responses of sea turtles to climate change are difficult to interpret due to the confounding effects of natural responses and human influences. Global warming will likely increase the foraging range of leatherback turtles farther into temperate and boreal waters as isotherms shift (M.C. James et al. 2006; McMahon and Hays 2006). Large-scale climatic events may affect turtles by loss of nesting beaches as sea levels rise (Vagg and Hepworth 2006). Nesting biology of sea turtles is strongly affected by temperature both in timing and in the sex-ratio of hatchlings. The effects of climate change may upset the natural ratio of male to female hatchlings, as higher temperatures during incubation tend to produce more females (e.g., Hays et al. 2003; Hawkes et al. 2007). Earlier nesting and longer nesting seasons are also being correlated with warmer SSTs (e.g., Weishampel et al. 2004; Hawkes et al. 2007). In the Pacific Ocean, productivity and prey abundance are associated with cooler ocean temperatures. Rising SSTs could lower prey abundance which could lead to lowered breeding capacity (Chaloupka et al. 2008). In fact, scientists have documented an inverse relationship between SST and the number of loggerhead and leatherback nests in the Pacific Ocean (Saba et al. 2007; Chaloupka et al. 2008).

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). Other important resources include NMFS and USFWS authored sea turtle recovery plans (http://www.nmfs.noaa.gov/pr/recovery/#turtles), NMFS compiled Proceedings of the Annual Symposia on Sea Turtle Biology and Conservation (http://www.nmfs.noaa.gov/pr/species/turtles/symposia.htm), Bjorndal (1995), Lutz and Musick (1997), Bolten and Witherington (2003), Lutz et al. (2003), and Gulko and Eckert (2004).

3.2.2 Sea Turtles of the Southern California/Point Mugu Study Area

Four species of sea turtles are regular inhabitants of the SOCAL/Pt. Mugu Study Area: leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), loggerhead (*Caretta caretta*), and olive ridley (*Lepidochelys olivacea*) turtles (**Table 3-2**). These species occur as a regular or normal part of the fauna in the Study Area, regardless of abundance estimates. A fifth species, the hawksbill turtle (*Eretmochelys imbricata*), is regarded as a rare visitor to the SOCAL/Pt. Mugu Study Area, occurring in the area only sporadically (Eckert 1993). All five species are protected under the ESA. Leatherback and hawksbill turtles are listed as endangered throughout their geographic ranges, while the loggerhead turtle is listed as threatened throughout its range. As a species, green and olive ridley turtles are also listed as

threatened, although specific nesting populations of both species are currently listed as endangered. It is highly probable that green and olive ridley turtle assemblages found in the SOCAL/Pt. Mugu Study Area are mixes of offspring from both threatened and endangered nesting populations in the Pacific Ocean. A risk-averse strategy would assume all green turtles encountered in the Study Area come from the Eastern Pacific nesting population and all olive ridley turtles encountered in the Study Area come from the Mexican Pacific nesting population (i.e., that all green and olive ridley turtles encountered in the Study Area are endangered). Critical habitat has not been designated for any species of sea turtle in the U.S. Pacific; however, NMFS is currently reviewing petitions to reclassify the Northern Pacific loggerhead as a distinct population segment with critical habitat designations, as well as to designate critical habitat for leatherback in the Northern Pacific (CBD and TIRN 2007; CBD and TIRN 2007; NMFS 2007).

In the eastern North Pacific Ocean, sea turtles are not particularly common north of Mexico. Sea turtles are much less abundant off southern California 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 southern California (and farther north) is strongly affected by seasonal changes in water temperature. In general, sea turtle sightings off the southern California 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 to southern California 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) south to Baja California due to strong upwelling and the southward flow of the California current (**Figure 2-10**). Due to less than optimal water temperatures in the region, sea turtles are not known to nest on southern California beaches (NMFS and USFWS 1998d; 1998e; 1998f; 1998c; 1998b; 1998a). Cool water temperatures off southern California may also inhibit reproductive activity by reducing the quality and availability of food resources in the area (Fuentes et al. 2000). Regular nesting by leatherbacks and olive ridley turtles occurs along the Pacific coast of Baja California Sur, which is the northernmost known nesting site in the EPO (Fritts et al. 1982; Sarti-M. et al. 1996; López-Castro et al. 2000).

San Diego Bay is the only bay on the U.S. west coast where sea turtles congregate for extended periods of time. Green turtles routinely occupy the southern part of the bay, spending most of their time in a long, narrow channel that contains water discharged from the Duke Energy power plant (formerly the San Diego Gas and Electric Company). In 1960, the San Diego Gas and Energy Company began discharging warm water into the channel, creating an artificially tropical microhabitat in an otherwise cool, temperate bay (Stinson 1984; Dutton and McDonald 1990b, 1990a). The NMFS-SWFSC Sea Turtle Research Program regularly monitors green turtles in San Diego Bay through biological sampling, sonic tracking, and satellite telemetry.[2] No other sea turtle species are known to reside in the bay (Dutton and McDonald 1990b).

The distribution of all available sea turtle occurrence records in the SOCAL/Pt. Mugu Study Area and vicinity by season (warm-water period: 15 June through 15 December; cool-water period: 16 December through 14 June) is presented in **Appendix C**, **Figures C-1a** and **C-1b**. The distributions of available sea turtle records by season for individual species are presented in **Figures C-2** through **C-6**. Sea turtle occurrence records include sightings from NMFS aerial and shipboard surveys (red symbols) as well as sightings from other sources (non-NMFS surveys and opportunistic encounters), strandings, and incidental fisheries bycatch records (green symbols). It should be noted that the number of sea turtle records in a given season or portion of the Study Area is often a function of the source or type of data, level of effort, and sighting conditions. Also depicted on all maps in **Appendix C** are tracklines from NMFS aerial and shipboard surveys for which occurrence data were collected for this assessment.

Table 3-2. Sea turtle species with known or potential occurrence in the SOCAL/Pt. Mugu Study Area. Taxonomy follows Pritchard (1997).

	Scientific Name	Status	Occurrence[1]
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[2,3]	Regular
Loggerhead turtle	*Caretta caretta*	Threatened	Regular
Olive ridley turtle	*Lepidochelys olivacea*	Threatened[2]	Regular
Hawksbill turtle	*Eretmochelys imbricata*	Endangered	Rare

[1] A species' occurrence in the Study Area can be described as one of the following: Regular—occurs as a regular or normal part of the fauna in the Study Area, regardless of how abundance estimates; Rare—occurs in the Study Area sporadically; or Extralimital—does not normally occur in the Study Area and occurrences there are considered beyond the species' normal range.

[2] 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 green and olive ridley turtles found in the SOCAL/Pt. Mugu Study Area are endangered.

[3] The NMFS and USFWS identify the regionally important population of green turtles nesting along the Pacific coasts of Mexico, Central America, 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, not all greens found in the SOCAL/Pt. Mugu Study Area are likely to be East Pacific greens.

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 (green, loggerhead, olive ridley, and hawksbill) are often difficult to distinguish to species, particularly when they are young (i.e., small size classes), during aerial surveys, and/or when the observers do not have a high level of experience (Kenney 2005). Species identification is less reliable when individuals from the general public (e.g., commercial and recreational fishermen, beachgoers) sight sea turtles. The reliability of species recognition may also be in question when sea turtles strand or nest, especially if qualified individuals are not present to make an accurate identification (Lund 1985).

A listing and description of data sources used to determine each species' occurrence in the SOCAL/Pt. Mugu 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 "unknown (no survey effort)" (hatched) are habitats that have not been adequately surveyed. Protected species biologists with the NMFS-SWFSC ultimately devised these qualitative terms.

Each sea turtle species known to occur or potentially occurring in the SOCAL/Pt. Mugu Study Area is listed below with its description, status, habitat preferences, distribution (including location and seasonal occurrence in the SOCAL/Pt. Mugu Study Area), behavior, and life history. Species appearance within the text follows the taxonomic order as presented in **Table 3-2**.

Figures C-1a and **C-1b** are combined maps of all sea turtles (including unidentified sea turtles) since all sea turtles are listed as threatened and endangered.

- Information Specific to SOCAL/Pt. Mugu Study Area—The SOCAL/Pt. Mugu Study Area is designated as an area of primary occurrence of threatened and endangered sea turtles during both seasons, mostly due to the distribution of leatherbacks in the area between September and January (overlapping the cool- and warm-water periods) (**Figure C-1a**). Recent satellite tracks of leatherback movements have shown that leatherbacks move through the area as they migrate between foraging areas and their nesting grounds in the western Pacific Ocean (Eckert, S.A., WIDECAST, pers. comm., 9-10 January 2008). There is also an area of primary occurrence of threatened and endangered sea turtles in southern San Diego Bay due to the year-round prevalence of green turtles in those waters (**Figure C-1b**).

- **Leatherback Turtle (*Dermochelys coriacea*)**

Description—The leatherback turtle is the largest living sea turtle. Adult leatherbacks average between 200 and 700 kg with carapace lengths ranging from 119 to 176 cm (NMFS and USFWS 1998c). This species is placed in a separate family from all other sea turtles, in part, because of their unique carapace structure. The leatherback's carapace lacks the outer layer of horny scutes possessed by all other sea turtles. It is instead composed of a flexible layer of dermal bones underlying tough, oily connective tissue and smooth skin. The body is barrel-shaped and tapered to the rear with seven longitudinal dorsal ridges, and is almost completely black with variable spotting. All adults possess a unique pink spot on the dorsal surface of their head. Scientists use this marking to identify specific individuals (McDonald and Dutton 1996). 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; 2000b; 2000a).

Status—Leatherback turtles are classified as endangered under the ESA (NMFS and USFWS 1998c). Spotila et al. (1996; 2000) noted that leatherbacks in all oceans are on the road to extinction and may become extinct in the next several decades if current trends in mortality persist. Lewison et al. (2004) estimated that more than 50,000 leatherbacks were taken as pelagic longline bycatch in 2000 and that thousands of these turtles die each year from longline gear interactions in the Pacific Ocean alone. Leatherbacks are seriously declining at most Pacific Ocean rookeries, including Indonesia, Malaysia, and Mexico (NMFS and USFWS 1998c). The Pacific Ocean may now contain as few as 2,300 adult females (Crowder 2000).

Due to the potential for leatherbacks to interact with drift gillnet fisheries off the U.S. west coast, NMFS has designated a portion of the eastern North Pacific Ocean as a "Pacific Leatherback Conservation Zone" (**Figure 3-11**). From 15 August through 15 November of every year, fishing with drift gillnets with a mesh size ≥14 inches (in.) is prohibited in the conservation zone. The conservation zone is located between 34°27'N (near Point Conception, California) and 45°N (northern Oregon) and is described fully in 50 CFR 660.713(c). The conservation zone provides this species with a strong level of protection from gillnet fishermen at a time of year when they are known to reside off the U.S. west coast.

Habitat Associations—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 *Sargassum* or other flotsam, as is the case for the other five sea turtle species found in U.S. waters (NMFS and USFWS 1998c). It is also known that juveniles up to 100 centimeters (cm) in curved carapace length (CCL) are generally restricted to lower latitudes where water temperatures are greater than 26°C. The transition at 100 cm is relatively abrupt, with leatherbacks as small as 107 cm CCL having been observed in waters as cold as 12°C. It appears that some juveniles migrate seasonally to higher latitudes but only when water temperatures there reach 26°C and above (Eckert 2002).

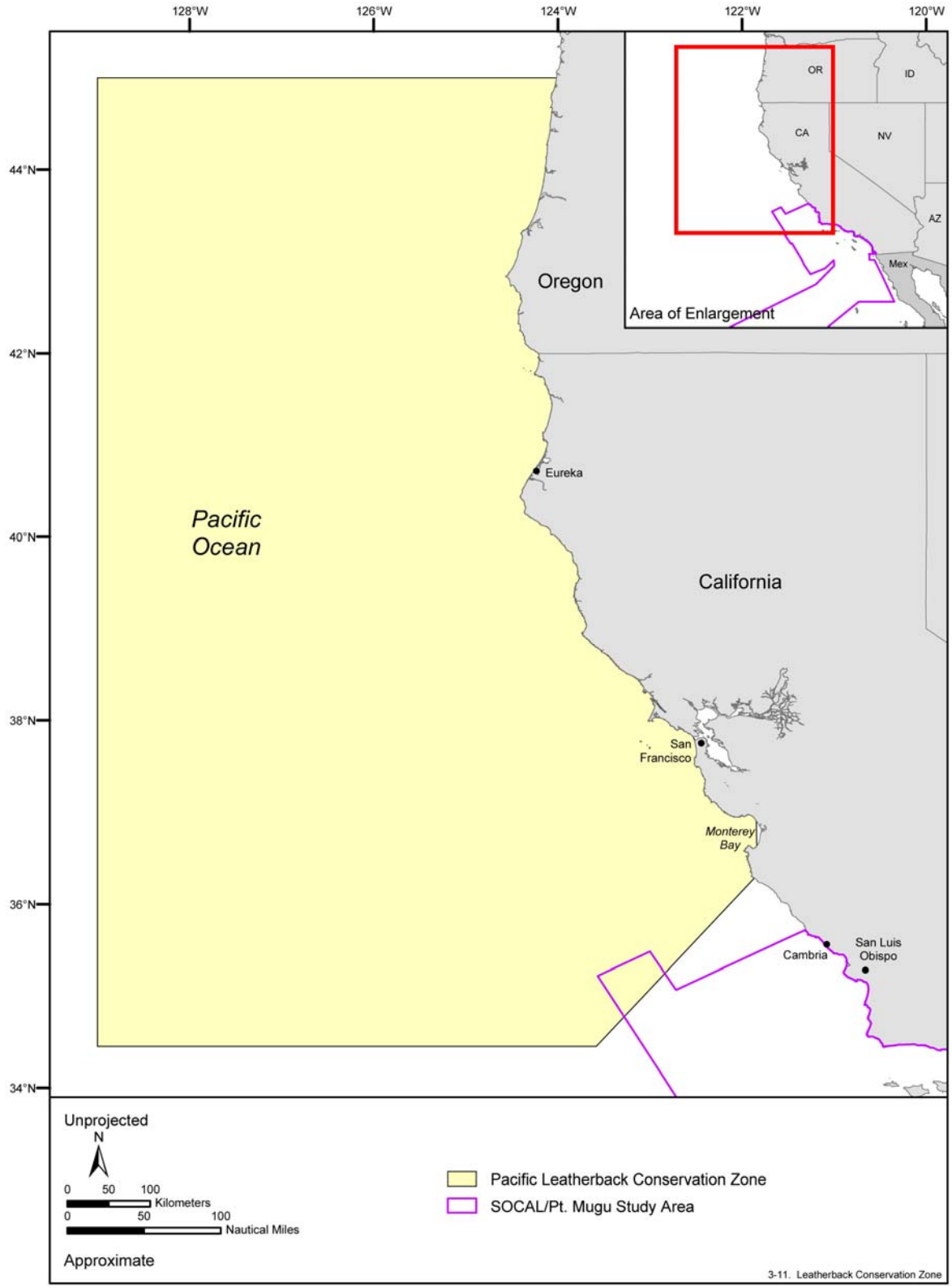

Figure 3-11. The location of the Pacific Leatherback Conservation Zone off the coasts of California and Oregon. This area is closed to drift gillnet fishing from August 15 through November 15 of every year to heighten the protection of leatherback turtles in the area. Source data: 50 CFR 660.713(c).

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

Distribution—The leatherback turtle is distributed circumglobally in tropical and sub-tropical waters throughout the year and into temperate waters during late summer and early fall (NMFS and USFWS 1998c; James et al. 2005a; James et al. 2005b). Leatherbacks are the most oceanic sea turtle species and have the widest distribution range (Boulon et al. 1988). This wide distribution range is a result of 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; 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 engage in some of the longest migrations of any sea turtle species, from hundreds to thousands of kilometers (Morreale et al. 1996; Hughes et al. 1998). Through the use of satellite telemetry, Morreale et al. (1996), Eckert and Sarti-M. (1997), and Eckert (1999) determined that post-nesting leatherbacks in the EPO use similar and, in some cases, identical migratory pathways. These studies demonstrated that leatherback turtles from eastern Pacific nesting stocks in Costa Rica and Mexico will navigate to South American waters after egg-laying is complete.

In the eastern North Pacific Ocean, leatherback turtles are broadly distributed from the tropics to as far north as Alaska, where 19 occurrences have been documented between 1960 and 2001 (Eckert 1993; Hodge and Wing 2000). Analyses of over 300 records of sea turtles sighted along the Pacific coast of North America (from 29°45'N northward) determined that the leatherback was the most common sea turtle in eastern Pacific waters north of Mexico (Stinson 1984). 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; Carretta and Forney 1993; Green et al. 1993; Bowlby et al. 1994); however, in the fall, leatherbacks off northern California regularly enter waters very close to shore, such as Monterey Bay (Starbird et al. 1993). The seasonal presence of leatherbacks off southern California 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 (Benson et al. 2003).

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 1998c). 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 EPO 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 1998c).

- Information Specific to SOCAL/Pt. Mugu Study Area—Numerous NMFS survey sightings of leatherbacks have been recorded in the SOCAL/Pt. Mugu Study Area and vicinity. Nearly all of

those sightings have been conducted in waters seaward of the Channel Islands. Satellite-tracking studies from 2002 have demonstrated that leatherbacks migrate south from nearshore waters off central and northern California (e.g., Monterey Bay) along the U.S. west coast before heading west towards nesting grounds (Eckert 2008; **Figure 3-12**). Therefore, the entire Study Area is listed as an area of primary occurrence (**Figure C-2**). Scientists used to think that leatherbacks exhibited inshore-offshore movements during the cold-water period, but recent satellite-tracking studies have shown that leatherbacks are migrating out of the area (Eckert, S.A., WIDECAST, pers. comm., 9-10 January 2008) (**Figure 3-12**).

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 1998c). Eisenberg and Frazier (1983) recorded an adult leatherback feeding on *Aurelia* jellyfish in ocean waters off 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 North Pacific, 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). Seasonal prey availability likely influences depth and duration of dives (Sale et al. 2006). Sale et al. (2006) found that leatherbacks dive for longer durations at night. Leatherbacks may make shallower dives and do not exhibit diel diving patterns in colder water; this is likely due to the shallower distribution and lack of vertical migration of prey in these areas (James et al. 2006). In temperate waters of the North Pacific Ocean, leatherbacks spend most of their time at depths less than 100 m although occasionally they will make a deep dive (Eckert, S.A., WIDECAST, pers. comm., 27 April 2006).

The leatherback is the deepest diving sea turtle. Leatherbacks in open ocean environments frequently exhibit V-shaped dive patterns (in which they descend to a certain depth and then immediately ascend to the surface), whereas leatherbacks in shallow water environments more often exhibit U-shaped dive patterns (in which they swim down to the ocean floor, remain 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 ranged from 35 to 122 m, with estimated maximum depths of over 1,000 m (S.A. Eckert et al. 1989; Eckert et al. 1996). Typical dive durations averaged 6.9 to 14.5 min per dive, with a maximum of 42 min (Eckert et al. 1996). On average, day dives in tropical waters tend to be deeper, longer, and less frequent than those at night (S.A. Eckert et al. 1989).

Mating was thought to occur prior to or during the migration from temperate to tropical waters (Eckert and Eckert 1988); however, the presence of males near nesting colonies suggests that mating may also occur near those colonies. Males have been satellite tracked from foraging areas in the North Atlantic to Caribbean nesting colonies, where the males reside until the peak of the nesting season (James et al. 2005a). The leatherback nesting season on the Pacific coast of Mexico extends from November to February, with some females arriving as early as August (Fritts et al. 1982; NMFS and USFWS 1998c). In the western Pacific there are two nesting seasons, one with a similar schedule to that seen in the Eastern Pacific and one with a peak of nesting in June. Female nesters lay between one and 11 clutches in a single season at 9- to 10-d intervals (NMFS and USFWS 1998c). Typical clutches range in size from 50 to over 150 eggs, with the incubation period lasting around 65 d. Females remain in the general vicinity (e.g. within 50 km) of the nesting habitat during inter-nesting intervals (about 10 d), with total residence in the nesting/inter-nesting habitats lasting up to four months (K.L. Eckert et al. 1989; Keinath and Musick 1993; Eckert 2006; Eckert et al. 2006). Most adult females return to nest on their natal beach every 2 to 3 yr (Boulon et al. 1996). However, remigration intervals (the number of years between successive nesting seasons) are much longer in the eastern Pacific and commonly exceed three years (Saba et al. 2007).

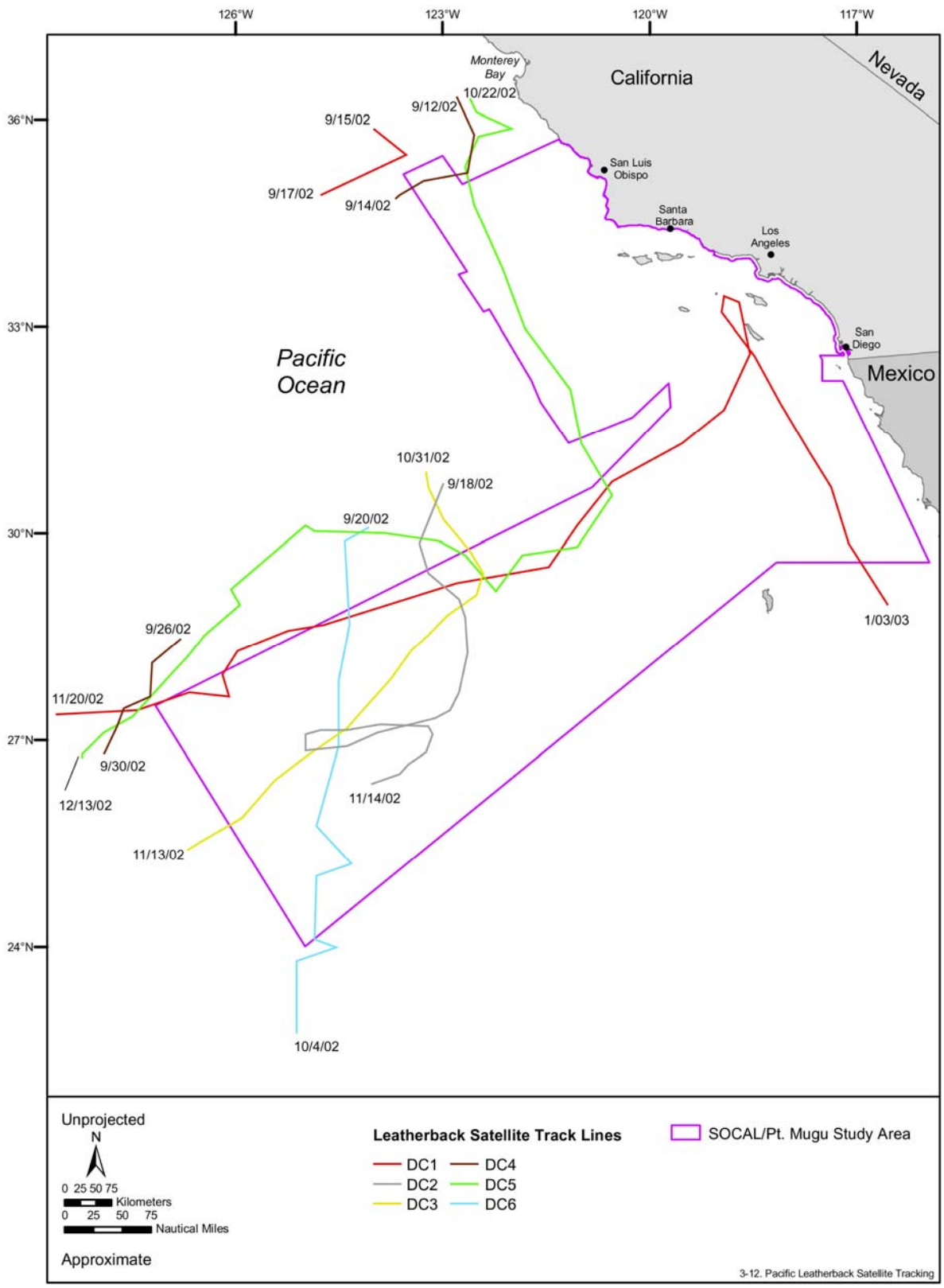

Figure 3-12. Migration tracks of multiple Pacific leatherbacks tagged in 2002. Tracklines are cut at the Study Area extent to show specific migration tracks (as well as the timing of those migrations) through the SOCAL/Pt. Mugu Study Area. Source data: Eckert (2008).

- **Green Turtle (*Chelonia mydas*)**

Description—The green turtle is the largest hard-shelled sea turtle. Adult green turtles commonly weigh over 100 kg and are greater than 100 cm in carapace length. Adult carapaces range in color from solid black to gray, yellow, green, and brown in muted to conspicuous patterns; the plastron is a much lighter yellow to white. Hatchlings are distinctively black on the dorsal surface and white on the ventral (NMFS and USFWS 1998d; 1998e).

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 1998d; 1998e). 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. 2000b). 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 Mexican Pacific nesting population, which is classified as endangered (NMFS and USFWS 1998d; 1998e). East Pacific green turtles are recognized as a distinct population segment by the NMFS and USFWS and are managed under separate recovery plans. East Pacific green turtles have exhibited an extreme decline in numbers over the last 35 yr. This is undoubtedly due to the 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). Primary threats to green turtles in the Pacific region include entanglement in debris, boat collisions, increased coastal development on nesting beaches, and illegal harvesting of turtles and eggs. There are no estimates for the current population size of green turtles in the Pacific Ocean (NMFS and USFWS 1998d; 1998e).

Habitat Associations—The early juvenile developmental habitat of the green turtle in the Pacific Ocean is unknown. Post-hatchlings are found in convergence zones where they spend an undetermined amount of time in the pelagic environment.[3] Nichols et al. (2001) documented several early juveniles basking near or on top of kelp mats (*Macrocystis* spp.) off Baja California Sur. Green turtles recruit to shallow, nearshore areas when they reach carapace lengths of 20 to 45 cm (depending upon the population) (Balazs 1980; Bjorndal and Bolten 1988; Ernst et al. 1994; NMFS and USFWS 1998d). The optimal habitats for late juveniles and adults (i.e., benthic life stages) are warm, shallow (3 to 10 m) waters that possess an abundance of submerged aquatic vegetation (seagrasses and/or algae) and are located in close proximity to nearshore reefs or rocky areas used for resting (Ernst et al. 1994). In the Hawaiian Islands, green turtles are known to forage and rest in waters as deep as 20 to 50 m (Brill et al. 1995).

Distribution—Green turtles are distributed worldwide in tropical and subtropical waters and prefer temperatures above 20°C (NMFS and USFWS 1998d; 1998e). 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 1998d; 1998e). During warm spells, green turtles have been sighted in waters as far north as Alaska where 15 occurrences have been documented since 1960 (Eckert 1993; Hodge and Wing 2000); however, most of these encounters involved individuals that were either cold-stunned, likely to become cold-stunned, or already dead (Hodge and Wing 2000).

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 reported 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 1998d). South of the U.S., green turtles are widely distributed in coastal waters off Mexico and Central America (Cliffton et al. 1995; Cornelius 1995).

The northernmost resident population of green turtles in the eastern North Pacific Ocean occurs in San Diego Bay. It is believed that this small population of green turtles (numbering between 30 and 60 individuals) favors the warm water effluent that is discharged by the Duke Energy power plant.[2] 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 waters offshore of San Diego (Dutton and McDonald 1990b). After studying green turtle movements in relation to tidal flow and water temperature, Stinson (1984) ascertained that green turtles migrate out of San Diego Bay at the onset of warm summer months and are only present in the bay from November through April. However, recent data indicates that green turtles reside in the bay almost year-round. Dutton and McDonald (1990b) observed green turtles in the effluent channel during all months except July and August. They noted that the period of absence corresponded to the time of year when water temperatures in both the inlet and outlet channels rose above 29°C. Green turtles have also been observed in the vicinity of intake pipes at the San Onofre Nuclear Generating Facility, located about 16 km south of San Clemente, California (Eckert 1993).

Green turtles nest throughout the Pacific Ocean, 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 central Pacific Ocean (Eckert 1993; NMFS and USFWS 1998d; 1998e). 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 SOCAL/Pt. Mugu Study Area—Green turtle occurrence is rare throughout the vast majority of the SOCAL/Pt. Mugu Study Area year-round (**Figure C-3a**). Ocean waters shoreward of the 100-m isobath off southern California and northern Baja California are designated as areas of secondary occurrence, as they are home to benthic (e.g., rocky ridges and channels) and pelagic (e.g., kelp beds) habitats that are suitable for green turtle foraging and resting (Stinson 1984; Dutton et al. 2002). These waters are not designated as areas of primary occurrence because they are often at temperatures below the thermal preferences of this primarily tropical species. Green turtles are much more common in the subtropical waters off southern Baja California, which are located several hundred kilometers south of the Study Area (NMFS and USFWS 1998d).

  San Diego Bay is home to a resident population of green turtles that inhabits the area year-round. Eelgrass beds and marine algae are particularly abundant in the southern half of the bay and green turtles are frequently observed foraging on these items (DoN 2000; Dutton et al. 2002). The southern portion of San Diego Bay (from Sweetwater Channel south) is designated as an area of primary occurrence year-round (**Figure C-3b**). Green turtles inhabit these waters throughout the year because they are sheltered from strong currents and are continually warmed by the Duke Energy power plant effluent (Dutton and McDonald 1990b, 1990a). Ultrasonic tracking studies have shown that green turtles in south San Diego Bay have relatively small home ranges (Dutton et al. 2002). During summer months, green turtles may venture into the northern part of the bay or out of it entirely as water temperatures rise. Therefore, during the warm water-period, the entire bay is designated as primary occurrence. During the cold-water period, the resident population of green turtles is predominantly found south of the Sweetwater Channel. The upper portion of the bay has been designated as an area of secondary occurrence; although it is unlikely turtles will be found there as temperatures will be below their thermal tolerance during the cold-water period (**Figure C-3b**).

Behavior and Life History— Early juvenile green turtles are omnivorous; feeding on a variety of algae, invertebrates, and small fishes (Ernst et al. 1994). Off Baja California, the abundant pelagic red crab (*Pleuroncodes planipes*) may be a potential source of prey for immature individuals. This has led to the assumption that green turtles in the eastern North Pacific Ocean have more carnivorous diets than those in other regions (Bjorndal 1997; Mendilaharsu et al. 2003). Late juvenile and adult green turtles feed primarily on seagrasses (e.g., turtle grass, manatee grass, shoal grass, and eelgrass), macroalgae, and reef-associated organisms (Burke et al. 1992; Ernst et al. 1994; Bjorndal 1997). Observations of foraging adult green turtles in the Hawaiian Islands suggest they lie down on the sea bottom to feed and crawl or swim to other sites when the nearby food source has been depleted (Hochscheid et al. 1999). Analyses of stomach contents indicate that green turtles in San Diego Bay feed predominantly on eelgrass, red algae, and sea lettuce (DoN 2000). In the Gulf of California, green turtles feed on eelgrass as well as sea slugs (*Aplesia californica*) (NMFS and USFWS 1998d).

Green turtles take between 27 and 50 yr to reach sexual maturity, the longest age to maturity for any sea turtle species (Frazer and Ehrhart 1985). In Michoacán, mature females nest from 1 to 7 times in a season (2 to 3 is typical) at approximately 2-wk intervals and reproduce every 2 to 3 yr. During the nesting season, females from the Mexican Pacific nesting stock appear to mate prior to and even between nesting attempts. In the eastern Pacific, average clutch sizes vary geographically. Green turtle nests in Michoacán contain an average of 65 eggs while nests in the Galapagos Islands contain around 84 eggs. In Michoacán, 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), although they have been observed at depths of 73 to 110 m in the EPO (Berkson 1967). Relatively few studies have been conducted on green turtle diving patterns in the eastern Pacific; however, 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 named for its proportionately large head and powerful jaws. Adult loggerheads weigh between 100 and 150 kg with average carapace lengths ranging from 90 to 95 cm (Dodd 1988; NMFS and USFWS 1998b). Adult loggerheads usually possess a reddish-brown carapace with scutes that are bordered with yellow (NMFS and USFWS 1998b).

Status—Loggerhead turtles are classified as threatened under the ESA (NMFS and USFWS 1998b). Recent data presented by Sato et al. (1997), Kikukawa et al. (1999), and the Sea Turtle Association of Japan[4] suggest that nesting populations in Japan are in decline. A few thousand to hundreds of thousands of loggerheads likely comprise the juvenile foraging population found off Baja California Sur while less than 1,000 females nest annually on the primary nesting beaches of Japan (Kamezaki et al. 2003; STAJ[4]).

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 bycatch in the Pacific pelagic longline fishery in 2000. Rapid declines in nesting females at all major Pacific rookeries suggest that longline bycatch is leading to increased levels of loggerhead mortality in the Pacific Ocean (Kamezaki et al. 2003; Limpus and Limpus 2003). NMFS concluded in 2004 that the pelagic longline fishery is likely to jeopardize the continued existence of loggerhead turtles in the Pacific Ocean. As a protective measure, NMFS is now prohibiting U.S. vessels from fishing with shallow longline sets throughout the Pacific Ocean (NMFS 2004).

Due to the potential for loggerheads to interact with drift gillnet fisheries off the U.S. west coast, NMFS has designated a portion of the North Pacific Ocean as a "Pacific Loggerhead Conservation Zone" (**Figure 3-13**). Fishing with drift gillnet gear is prohibited in the conservation zone from 1 June through 31 August during years of forecasted or occurring El Niño events. The conservation zone encompasses all U.S. Pacific waters east of 120°W and is described fully in 50 CFR 660.713(c).

Habitat Associations—The loggerhead turtle occurs worldwide in habitats ranging from coastal estuaries, bays, and lagoons to pelagic waters (Dodd 1988). Early juvenile loggerheads are primarily oceanic, occurring in pelagic convergence zones where they are transported throughout the ocean by dominant currents (Carr 1987). A common pattern in the developmental migration of this species is to reside on the eastern side of the Atlantic or Pacific Ocean (e.g., around the Azores, Madeira, and inside the western Mediterranean, or just offshore of the Baja Peninsula) for a number of years and then migrate back to coastal waters on the western side of these same ocean basins. Late juvenile and adult loggerheads are generally found around reefs and other hardbottom habitats (Dodd 1988).

Satellite-tracking studies on loggerheads captured in pelagic longline fishing gear indicate that individuals traveling west in pelagic 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; 2006). 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 (1998b) indicated that they are less common in the central Pacific than in the eastern or western Pacific. In the EPO, loggerheads are documented to occur as far north as Alaska and as far south as Chile (Bane 1992). Some scientists believe that southern California is the northern limit of the Pacific loggerhead's range, with occurrences farther north (including documented cold-stunnings and strandings on the Oregon, Washington State, and Alaskan coasts) identified as extralimital (Hodge and Wing 2000).

The largest juvenile foraging population in the EPO is found off the west coast of Baja California Sur in a band starting about 30 km offshore and extending out at least another 30 km (NMFS and USFWS 1998b; Nichols et al. 2000a). Juvenile loggerheads are 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 1998b).

Genetic analyses indicate that nearly all of the loggerheads found in the North Pacific Ocean are born on nesting beaches in Japan (Bowen et al. 1995; Resendiz et al. 1998). Pacific loggerheads appear to utilize the entire North Pacific Ocean during the course of development, much like Atlantic loggerheads use the North Atlantic Ocean (**Figure 3-14**) (Bolten et al. 1998). There is substantial evidence that both stocks make two separate transoceanic crossings. The first crossing (west to east) is made immediately after hatching from the nesting beach, while the second (east to west) is made upon reaching either the late juvenile or adult life stage. In the North Pacific Ocean, hatchlings born on beaches in the western Pacific swim with the NPSG system in order to reach developmental habitats in the eastern Pacific (off southern California and Mexico) (Polovina et al. 2000).

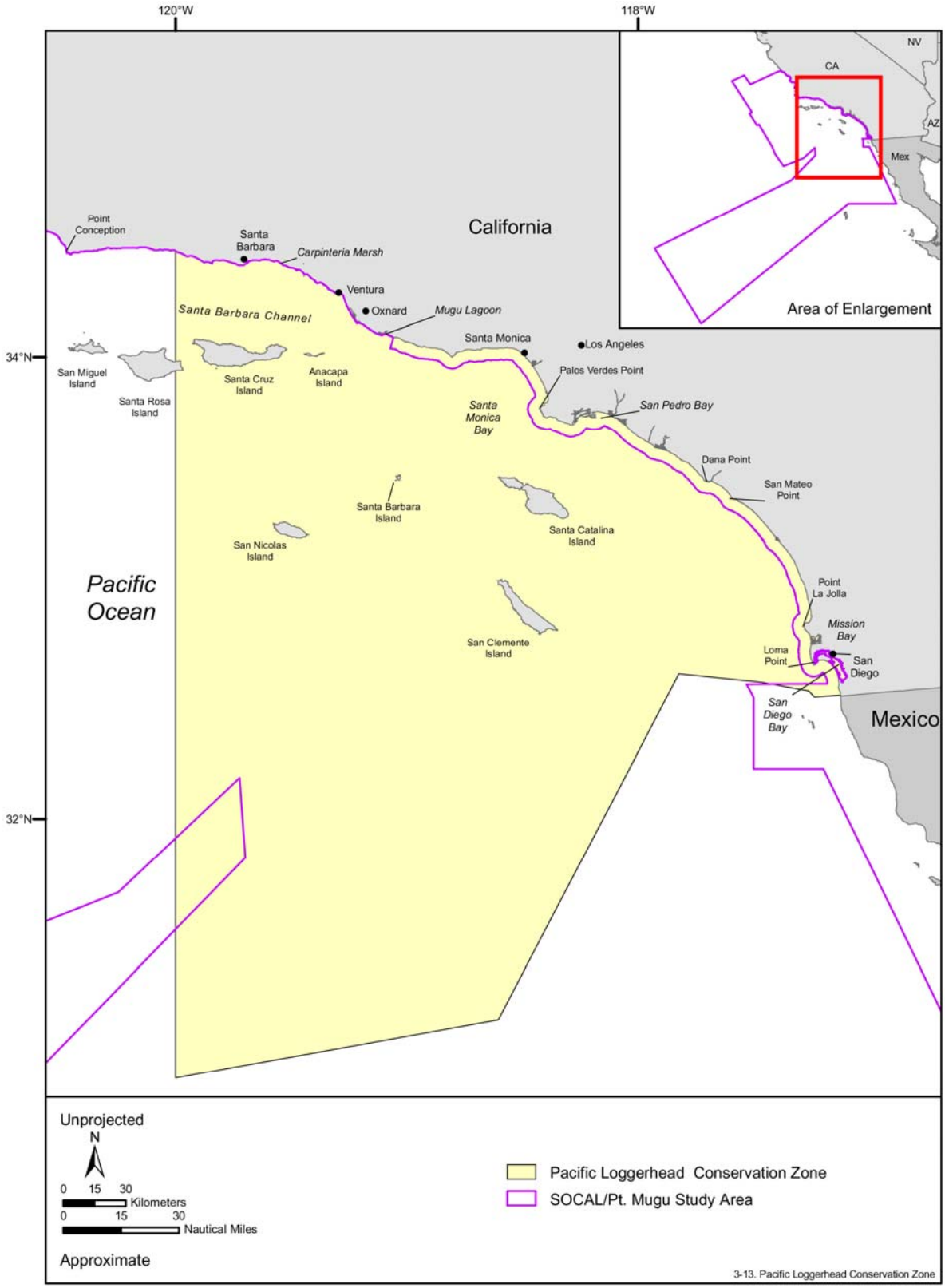

Figure 3-13. The location of the Pacific Loggerhead Conservation Zone off the coast of California. This area is closed from June 1 through August 31 during a forecasted, or occurring, El Niño event to heighten the protection of loggerhead turtles in the area. Source data: 50 CFR 660.713(c).

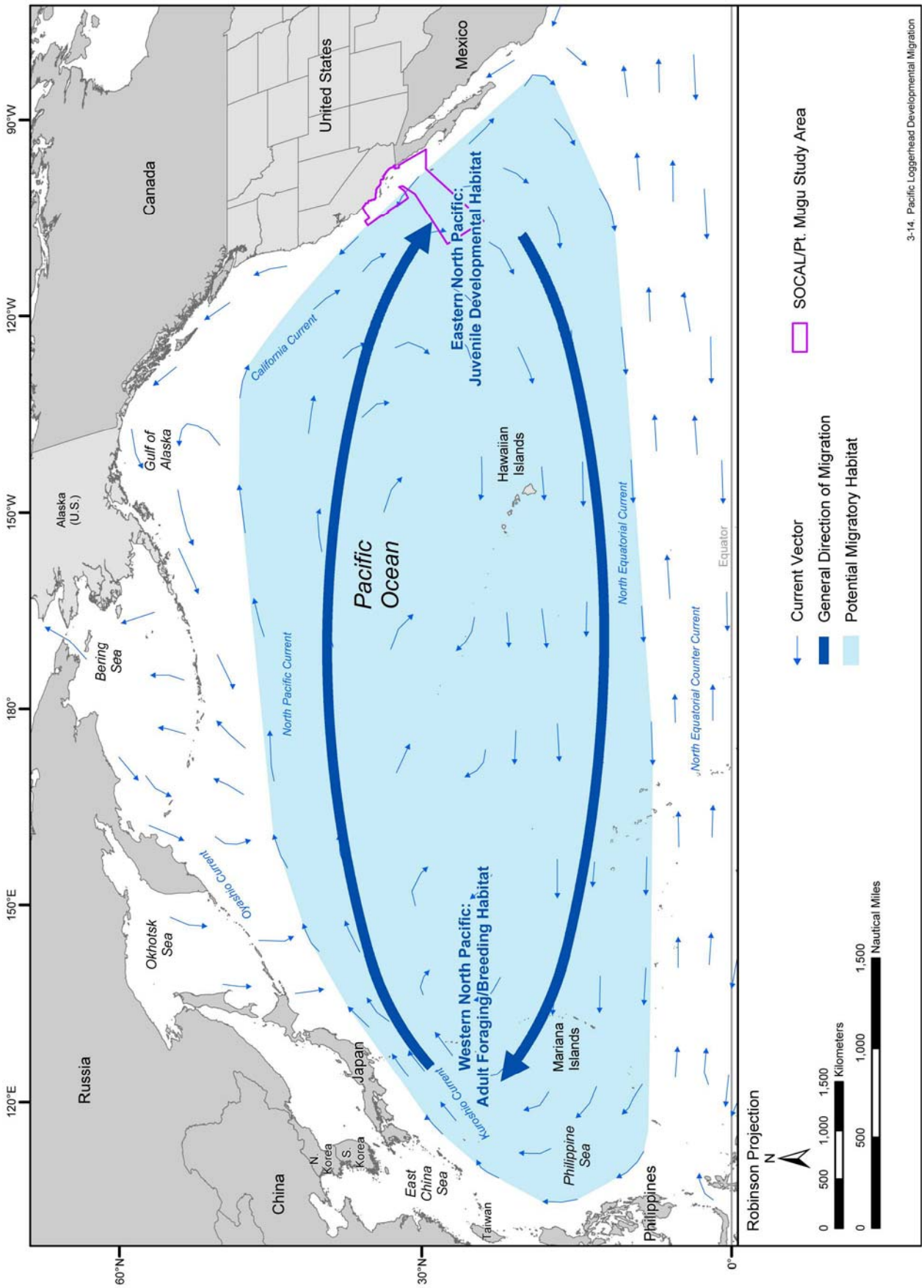

Figure 3-14. The generalized developmental migration of loggerhead turtles in the North Pacific Ocean. After hatching on nesting beaches in southern Japan, loggerheads travel across the North Pacific to developmental habitats in the eastern Pacific before returning as adults to foraging/breeding habitats in the western Pacific. Source information: Nichols (2005). Map adapted from: Pickard and Emery (1982).

Unlike the case in the eastern Atlantic, 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.

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

- Information Specific to SOCAL/Pt. Mugu Study Area—Loggerhead turtles primarily occupy areas where the SSTs are between 15° and 25°C. There have been a number of loggerhead turtle sightings, strandings, and incidental bycatches in the nearshore waters of southern California, notably during the warm-water period. During El Niño events, loggerheads that regularly occur off Baja California Sur, where they are highly abundant, may expand their nearshore range north into southern California waters. It is for this reason that U.S. Pacific waters east of 120°W are closed to drift gillnet fisheries from June through August during forecasted El Niño events (NMFS 2003). Therefore, during the warm-water period, this area is considered to be an area of primary occurrence. The rest of the SOCAL/Pt. Mugu Study Area is a region of secondary occurrence since water temperatures are within their preferred habitat regime (**Figure C-4**). The area of primary occurrence during the cold-water period is cut along the 18°C isotherm. The area of secondary occurrence during that period is cut along the 16°C isotherm. Loggerheads are not expected to be found in waters colder than 16°C, so the area north of the 16°C isotherm is depicted as an area of rare occurrence (**Figure C-4**).

Behavior and Life History—The diet of a loggerhead turtle changes with age and size. The gut contents of post-hatchlings found in masses of *Sargassum* contained parts of *Sargassum,* zooplankton, jellyfish, larval shrimp and crabs, insects, and gastropods (Richardson and McGillivary 1991; Witherington 1994). Late juvenile loggerhead turtles are omnivorous, foraging on pelagic crabs, mollusks, jellyfish, and vegetation captured at or near the surface (Dodd 1988). Off Baja California Sur, the distribution of juvenile loggerheads coincides with that of a large population of pelagic red crabs indicating a prey-predator relationship (NMFS and USFWS 1998b). Adult loggerheads are generally carnivorous, often choosing to forage on benthic invertebrates (mollusks, crustaceans, and coelenterates) and sometimes fish in nearshore waters. However, in deep offshore waters of the North Pacific Ocean, adult loggerheads may also feed on nutrient-poor items such as jellyfish, salps, and other gelatinous animals (Dodd 1988; Hatase et al. 2002).

Loggerhead nesting in the North Pacific Ocean occurs between April and August when nearshore water temperatures reach 20°C and above (NMFS and USFWS 1998b). Females from the Japanese nesting stock nest at least three times per season at about 2-wk intervals (Eckert 1993). Loggerhead clutches contain between 60 and 150 eggs and often take about 60 d to incubate. Dodd (1988) estimated that the global average hatching success for loggerheads is nearly 75%. Adult females nest at multiple year intervals, with the majority nesting every 2 yr (Frazer 1995).

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

- **Olive Ridley Turtle (*Lepidochelys olivacea*)**

Description—The olive ridley is a small, hard-shelled sea turtle named for its olive green colored shell. Adults often measure between 60 and 70 cm in carapace length and rarely weigh over 50 kg. The carapace of an olive ridley turtle is wide and almost circular in shape. The olive ridley differs from

the Kemp's ridley, the other member of the genus *Lepidochelys*, in that it possesses a smaller head, a narrower carapace, and several more lateral carapace scutes (NMFS and USFWS 1998a).

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

Habitat Associations—There is little information available on the 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 1998a).

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

Distribution—The olive ridley turtle is a pantropical species, occurring worldwide in tropical and warm temperate waters. It is by far the most common and widespread sea turtle in the North Pacific Ocean. Individuals 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 1998a). 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) have documented three occurrence records for Alaskan waters since 1960. A small number of strandings have been documented in Oregon and Washington State (Richardson 1997). Steiner and Walder (2005) have also documented two live olive ridleys off the coast of central California. 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 infrequent captures of this species in the Hawai'i-based longline fishery (Dutton et al. 2000b; Polovina et al. 2003; 2004).

The world's largest nesting aggregation of olive ridley turtles occurs along the shores of Orissa, India (Shanker et al. 2003). The second largest nesting population occurs along the west coasts of Mexico and Central America (NMFS and USFWS 1998a). 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 Sur (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). Nesting does not occur along the U.S. west coast (NMFS and USFWS 1998a). In August 1973, a Scripps Aquarium employee observed two olive ridleys mating in the waters off La Jolla, California. This reproductive encounter was located far from any known nesting beach (Hubbs 1977).

- Information Specific to SOCAL/Pt. Mugu Study Area—Olive ridleys are primarily found in oceanic waters that are between 23° and 28°C. Due to a lack of NMFS aerial and shipboard survey sightings data as well as their affinity for more tropical waters to the south, the entire Study Area

has been listed as an area of secondary occurrence for olive ridleys during the warm-water period. (**Figure C-5**). The scarcity records for the SOCAL/Pt. Mugu Study Area indicates that olive ridleys are much less common in the area than loggerheads. Also, the two live sightings off central California occurred during the warm-water period (Steiner and Walder 2005). The secondary occurrence delineation is considered to be a conservative estimate based off mean SST during the warm-water period (**Figure 2-6**). SST was also used to determine the occurrence polygon during the cold-water period. SSTs during this period are colder than temperatures preferred by olive ridleys. Therefore, the entire study are has been listed as an area of rare occurrence during this time (**Figure C-5**).

Behavior and Life History—The olive ridley turtle is considered omnivorous, eating a variety of benthic and pelagic prey items including fish, crabs, shrimp, snails, oysters, sea urchins, jellyfish, salps, fish eggs, and vegetation (NMFS and USFWS1998a). 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). Polovinia et al (2004) found that pelagic olive ridleys in the Pacific Ocean feed predominantly on tunicates found well below the water surface.

At sea, olive ridleys readily associate with floating objects such as logs, plastic debris, and even dead whales which provide shelter from predators as well as an abundance of prey items (Arenas and Hall 1992; Pitman 1992). Olive ridleys in the eastern Pacific are also known to bask at the surface in order to conserve energy, avoid predators, and raise their body temperature (Gulko and Eckert 2004). Oftentimes, they are accompanied by seabirds that roost upon their exposed carapaces and feed on fish that aggregate beneath them (Pitman 1993).

Olive ridleys reach sexual maturity between 10 and 18 yr (median age of 13 yr) (Zug et al. 2006). Carapace lengths for nesting female adults generally range between 50 and 75 cm (NMFS and USFWS 1998a). 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 Sur, most nesting takes place from July through November (López-Castro et al. 2000). Females usually nest every 1 to 2 yr. A typical female produces two clutches per nesting season, with each clutch averaging 105 eggs. Lone individuals nest at 15- to 17-d intervals while mass nesters arrive to the nesting beach at 28-d intervals. Incubation time from deposition to emergence is approximately 55 days (Eckert 1993; NMFS and USFWS 1998a).

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 300 m, although only about 10% of their time is spent at depths greater than 100 m (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).

- **Hawksbill Turtle (*Eretmochelys imbricata*)**

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

Status—Hawksbill turtles are classified as endangered under the ESA and are second only to the Kemp's ridley in terms of global endangerment (NMFS and USFWS 1998f). Only five regional populations worldwide remain with more than 1,000 females nesting annually (Seychelles, the Mexican Atlantic, Indonesia, and two in Australia) (Meylan and Donnelly 1999). A lack of regular quantitative surveys for hawksbill turtles in the Pacific Ocean and the discrete nature of this species' nesting have made it extremely difficult for scientists to assess the distribution and population status of hawksbills in the region (NMFS and USFWS 1998f; Seminoff et al. 2003). The status of the hawksbill is clearly of a higher concern for the Pacific due to the serious depletion of the species caused by international harvest and habitat destruction (NMFS and USFWS 1998f). Hawksbill populations in the EPO are believed to be very depleted, although there are currently no measurable trends in stock numbers (NMFS and USFWS 1998f; Meylan and Donnelly 1999).

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

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

Distribution—Hawksbill turtles are circumtropical in distribution, generally occurring from 30°N to 30°S within the Atlantic, Pacific, and Indian Ocean basins (NMFS and USFWS 1998f). In the eastern Pacific, hawksbills were common to abundant in nearshore waters from Mexico to Ecuador, particularly along the east coast of Baja California and in the southern Gulf of California, as recently as the early 1970's (Cliffton et al. 1995). Heavy exploitation of this species led to serious declines. There have been no confirmed hawksbill sightings from the U.S. west coast or within the data extent in recent history (Eckert 1993; NMFS and USFWS 1998f; Nichols, W.J., Wildcoast, pers. comm., 27 November 2007). Stinson (1984) did not mention the hawksbill turtle in her exhaustive summary of sea turtle occurrences in eastern North Pacific waters from Baja California to the Gulf of Alaska.

Hawksbills were originally thought to be a non-migratory species because of the close proximity of their nesting beaches to their coral reef feeding habitats and the high rates of local recapture. Hawksbills are now known to travel long distances over the course of their lives (Meylan 1999). Tag return, genetic, and satellite telemetry studies have indicated that hawksbill turtles utilize multiple developmental habitats as they age. However, within a given life stage, such as the later juvenile stage, some hawksbills may remain at a specific developmental habitat for a long period of time (Meylan 1999).

Hawksbill nesting in the North Pacific Ocean is widespread and occurs at scattered locations in very small numbers (Eckert 1993). Nesting activity is considered rare in the eastern Pacific region and does not occur along the U.S. west coast (Witzell 1983; NMFS and USFWS 1998f). Low-density nesting may occur at certain beaches along the Pacific coast of Central America; however, no major rookeries are known in the area (Cornelius 1995).

- Information Specific to SOCAL/Pt. Mugu Study Area—The occurrence of the hawksbill turtle is rare throughout the year in all waters of the SOCAL/Pt. Mugu Study Area (**Figure C-6**). There are no records for this species in the data extent. Hawksbills have not been observed off the coast of Baja California since the early 1970's (Cliffton et al. 1995). The potential for this species to occur in the study region is extremely low. If hawksbills were to occur in the SOCAL/Pt. Mugu Study Area, it would most likely be during an El Niño event as they are a highly tropical species. Although NMFS aerial and shipboard surveys have covered the entire eastern (landward) portion

of the Study Area during the warm-water period, this species is likely too small for effective detection by observers (Stinson 1984).

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

Hawksbills may have the longest routine dive times of all sea turtles. Starbird et al. (1999) reported that dive times for inter-nesting females at Buck Island, St. Croix averaged 56.1 min with a maximum of 73.5 min. Mean time at the surface was about 2 min. Average dives during the day ranged from 34 to 65 min, while those at night were between 42 and 74 min. Data from time-depth recorder studies in Puerto Rico indicate that foraging dives of immature hawksbills range from 8.6 to 14 min and have a mean depth of 4.7 m (Van Dam and Diez 1996).

Hawksbill turtles often nest in multiple, small, scattered colonies. The nesting season for hawksbills in the eastern Pacific is not known, although nesting probably occurs at a low level year-round (Eckert 1993). Very few data are available for hawksbills nesting in this region. Much of what is known about hawksbill nesting has been learned from studies at rookeries in the Caribbean, Indian Ocean, and western Pacific regions. Mating is believed to take place in the shallow waters adjacent to the nesting beach. Nesting occurs on both low- and high-energy beaches in tropical latitudes. It is often a nocturnal activity that occurs on beaches with sufficient vegetative cover. Females nest between 2 and 5 times per season with inter-nesting intervals of 14 to 16 d. The typical remigration interval is 2 to 3 yr. Clutch sizes in the Pacific Ocean are relatively large at 110 to 150 eggs, and incubation time is 50 to 61 d (Eckert 1993; NMFS and USFWS 1998f).

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3.3 BIRDS

3.3.1 Introduction

The varied and unique coastal topography found in the SCB provides habitat for a diversity of bird species associated with the marine environment. The complex physiography of the SCB is characterized by numerous submarine canyons, marginal, deepwater basins, steep escarpments, submerged banks, seamounts, and islands, all of which contribute to the unique oceanographic and atmospheric circulation pattern within the SCB (see **Chapter 2**).

The southward flowing California Current creates persistent upwelling along the coast and off of the Channel Islands (MMS 2001), and numerous sub-mesoscale eddies (which are often associated with upwelling) form throughout the SCB as a result of the merging of currents and the interaction of surface and deepwater currents with submerged geologic features. The upwelling creates nutrient "hotspots" where seabirds concentrate. More than 195 species of birds use coastal or offshore aquatic habitats in the SCB (Baird 1993). Many of the birds regularly travel in and out of the SCB while in search of food, migrate through the area, or use only specific parts of the area. Several seabird species have their northern or southern limit in this region.

Mainland coastlines in the SCB are characterized by highly exposed, rocky shorelines with deep water close to shore. Rocky coastlines extend south to Santa Barbara, at which point the coastline undergoes a transition to sandy beach habitat, with a large, relatively shallow shelf located off Ventura. Island coastlines in the offshore Channel Islands are primarily high wave-energy, rocky, shorelines. Approximately 80% of Channel Island shorelines are rocky coasts and the remaining 20% consist of sandy beaches (Richards 1996).

The Channel Islands provide important habitat for numerous avian species in the SCB. Habitat types found on the Channel Islands include coastal dune, coastal bluff, grasslands, coastal sage scrub, chaparral, island oak woodlands, mixed hardwood, conifer stands, riparian areas, and wetland communities. Coastal beach and associated dune habitats occur on the windiest locations of all of the northern Channel Islands and appear to be relatively undisturbed compared to similar habitats on the mainland (Cameron et al. 2005). Distance from the mainland; extensive acreage; and a wide variation in topography, geology, and habitat types have made the Channel Islands a rich and diverse ecosystem. This, combined with extensive development along the southern California coast, make the Channel Islands the only remaining area populated by some species whose home ranges formerly spanned the entire coastline (Lock-Dawson 2000). The Channel Islands also serve as important nesting habitats for some seabird species for which suitable habitats are scarce elsewhere in the SCB (Baird 1993). More than 20 species of seabirds breed in southern California; however, they breed almost entirely on the Channel Islands (Mason et al. 2007).

3.3.2 Birds of the Southern California/Point Mugu Study Area

Seabird species that are listed under the ESA and/or the State of California as endangered, threatened, candidate, or species of special concern and that are known to occur in the SOCAL/Pt. Mugu Study Area include the California brown pelican, short-tailed albatross, marbled murrelet, Xantus's murrelet, California least tern, western snowy plover, and ashy storm-petrel (**Table 3-3**). Information on the description, status, habitat preference, distribution (including location and seasonal occurrence in the SOCAL/Pt. Mugu Study Area), and behavior and life history of each species is discussed below. Six avian species that occur in the SOCAL/Pt. Mugu Study Area and have populations that are listed as either threatened or endangered will not be addressed in this report. They are mentioned only to indicate they were not overlooked in the SOCAL/Pt. Mugu Study Area seabird assessment. These species are the Hawaiin petrel (*Pterodroma sandwichensis*), Newell's shearwater (*Puffinus auricularis*), light-footed clapper rail (*Rallus longirostris levipes*), black storm-petrel (*Oceanodroma homochroa*), and Cassin's auklet (*Ptychoramphus aleuticus*).

Table 3-3. Protected seabird species occurring in the SOCAL/Pt. Mugu Study Area and vicinity.

	Scientific Name	ESA Status	California Status
Order Procellariiformes			
Family Diomedeidae (albatrosses)			
Short-tailed albatross	*Phoebastria albatrus*	Endangered	Bird Species of Special Concern
Family Pelecanidae (pelicans)			
California brown pelican	*Pelecanus occidentalis californicus*	Endangered*	Endangered
Family Hydrobatidae (storm-petrels)			
Ashy storm petrel	*Oceanodroma homochroa*		Bird Species of Special Concern
Order Charadriiformes			
Family Charadriidae (plovers)			
Western snowy plover	*Charadrius alexandrines nivosus*	Threatened	Bird Species of Special Concern
Family Alcidae (auks)			
Marbled murrelet	*Brachyramphus marmoratus marmoratus*	Threatened	Endangered
Xantus's murrelet	*Synthliboramphus hypoleucus*	Candidate	Threatened
Suborder Lari			
Family Laridae (gulls,terns,skimmers)			
California least tern	*Sternula antillarum browni***	Endangered	Endangered

* Proposed for delisting
** Note: The least tern, previously positioned in the genus *Sterna*, was recently re-classified by the American Ornithologists' Union Committee on Classification and Nomenclature—North America and placed within the genus *Sternula.*
Source: Banks et al. 2006, USFWS[1], USFWS 2008, CDFG[2], CDFG 2008.

- **California Brown Pelican (*Pelecanus occidentalis californicus*)**

***Description*—**The brown pelican is one of two pelican species occurring in North America (the other being the North American white pelican). The California brown pelican is the largest of six recognized subspecies of brown pelican. The distinguishing characteristics of this large, coastal seabird are a long bill, extendable throat pouch, and webbed feet. Overall body length ranges from 100-137 cm, with bill length ranging from 25-38 cm. Wingspans average approximately 2 m (Shields 2002). Adults in non-breeding plumage are characterized by gray to gray-brown upperparts with silvery grey streaking, a black-brown belly, and white neck with yellowish head (Johnsgard 1993). During the breeding season, the neck becomes dark brown and the proximal third of the throat pouch turns a bright red color, which is a distinguishing characteristic of the California brown pelican subspecies. The onset of egg incubation causes the pouch color to fade (Shields 2002). Juvenile (first year) brown pelicans are brown with a white belly and gradually transition into adult plumage by 3 to 5 yr.

***Status*—**Brown pelicans were first designated as endangered in 1970. This listing status was due largely to extensive population declines in the 1960's resulting from reproductive failure associated with pesticide exposure (Dichloro-Diphenyl-Trichloroethane [DDT]). The California brown pelican is currently still listed as endangered, but has been formally proposed for delisting (USFWS 2008a). The species is also listed as endangered by the state of California (CDFG 2008). The current total population estimate for the California brown pelican is 195,900±7,225 individuals (Anderson et al. 2007). There is no designated critical habitat for the California brown pelican (USFWS 1983)**.**

Habitat Associations—The California brown pelican is found in estuarine, marine subtidal, and marine pelagic waters along the California coast, usually within 30 km of shore (Briggs et al. 1981). Breeding occurs on small coastal islands, relatively free of predators (e.g., feral cats) and near a consistent and adequate food supply. Ground nests are generally located in the middle or upper parts

of steep rocky slopes on small islands off California and Baja California. In estuarine habitat and vegetated islands off Mexico, nesting occurs in trees or bushes.

Major loafing and roosting habitat includes sand beaches at the mouths of estuaries, offshore sand bars, and manmade structures such as piers, breakwaters, and jetties (Jaques and Strong 2003). Foraging occurs in shallow waters within 20 km of nesting islands during breeding season (**Figure 3-15**) and up to 75 km from the closest land during the non-breeding season (**Figure 3-16**).

Distribution—The breeding range of the California brown pelican extends from southern California into Mexico along the Pacific coast. Five breeding subgroups have been identified based on geographic distribution and the dominant nesting habitat association. These five subgroup designations are: 1) SCB, 2) Gulf of California, 3) southern Baja-Pacific Ocean, 4) Mexican mainland-island, and 5) Mexican mainland-estuarine (**Table 3-4**). California brown pelicans are present at nesting areas from approximately January to early August (Shields 2002).

Non- and post-breeding birds from Mexico and southern California range northward along the Pacific coast during summer and early fall into central and northern California and the Pacific Northwest as far north as British Columbia. The Salton Sea is also utilized by juveniles and subadults during the post-breeding season (USFWS 2007c). Individuals usually migrate south to return to breeding colonies sometime in January (Briggs et al. 1983).

- Information Specific to the SOCAL/Pt. Mugu Study Area—California brown pelicans are present year-round in the Study Area. Foraging habitat, roosting areas, and breeding colonies all occur within the Study Area. Population densities in the area fluctuate throughout the year as individuals from different nesting groups migrate to or from nesting, post-nesting, and wintering areas.

  A study by Briggs et al. (1981) found the lowest densities of California brown pelicans occurring from December through March, and most birds were observed foraging within 20 km of nesting islands and within 30 km of the mainland (**Figure 3-15**). The greatest densities of California brown pelicans occurred from September through October, with birds typically foraging within 30 km of shore, although observations of birds foraging up to 75 km from shore were reported (**Figure 3-16**). Mason et al. (Mason et al. 2007) reported similar findings for aerial transects conducted from 1999-2002 in the SCB from Cambria, California to the Mexican border. The greatest densities of birds were observed in September, and the majority of birds (83%) were sighted on transects less than 10 km from shore. This same study also noted that California brown pelicans were most abundant in all surveyed months (January, May, and September) near Point Loma, Palos Verdes (Santa Catalina Island), Point Sal, and along the coast of Santa Rosa Island. Sometime after September or October, brown pelican numbers in the SCB and vicinity begin to decline as individuals migrate south to winter along the coast of Mexico.

  In the San Diego Bay area, birds are observed year-round. Post-breeding juveniles, in particular, use the San Diego Bay area to forage, roost, stage for fall migration, and disperse to find new territory. Birds are common at the NAB Coronado and the surrounding vicinity. A dredge spoil island created in San Diego Bay immediately south of NAB serves as important roosting habitat (Shepherd, T., CIV NAVFAC SW, pers. comm., 14 April 2008). California brown pelicans forage in the moderately deep waters at the south end of the bay near the NAB, as well as in open water along bay margins where schooling fish concentrate (DoN 2002a). Birds are also observed roosting regularly on piers, pilings, and beaches at NAS North Island, the Naval Radio Receiving Facility (NRRF) Imperial Beach, and the western beach south of Zuniga Point (DoN 2002a).

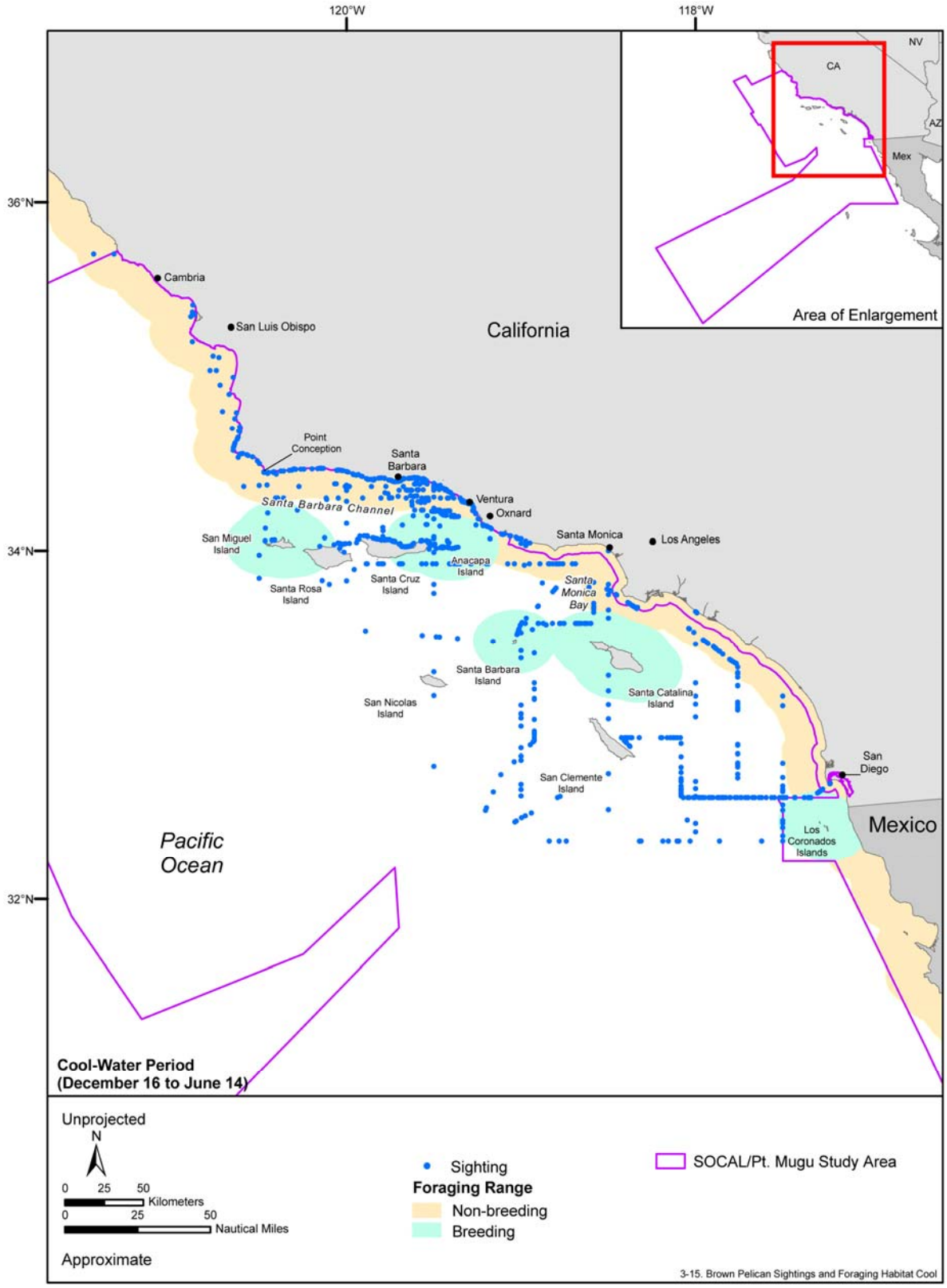

Figure 3-15. California brown pelican recorded sightings, breeding foraging range, and foraging range of immature and non-breeding birds during the breeding season (December to June). Source data: Bonnell and Ford (2001). Source information: Briggs et al. (1987).

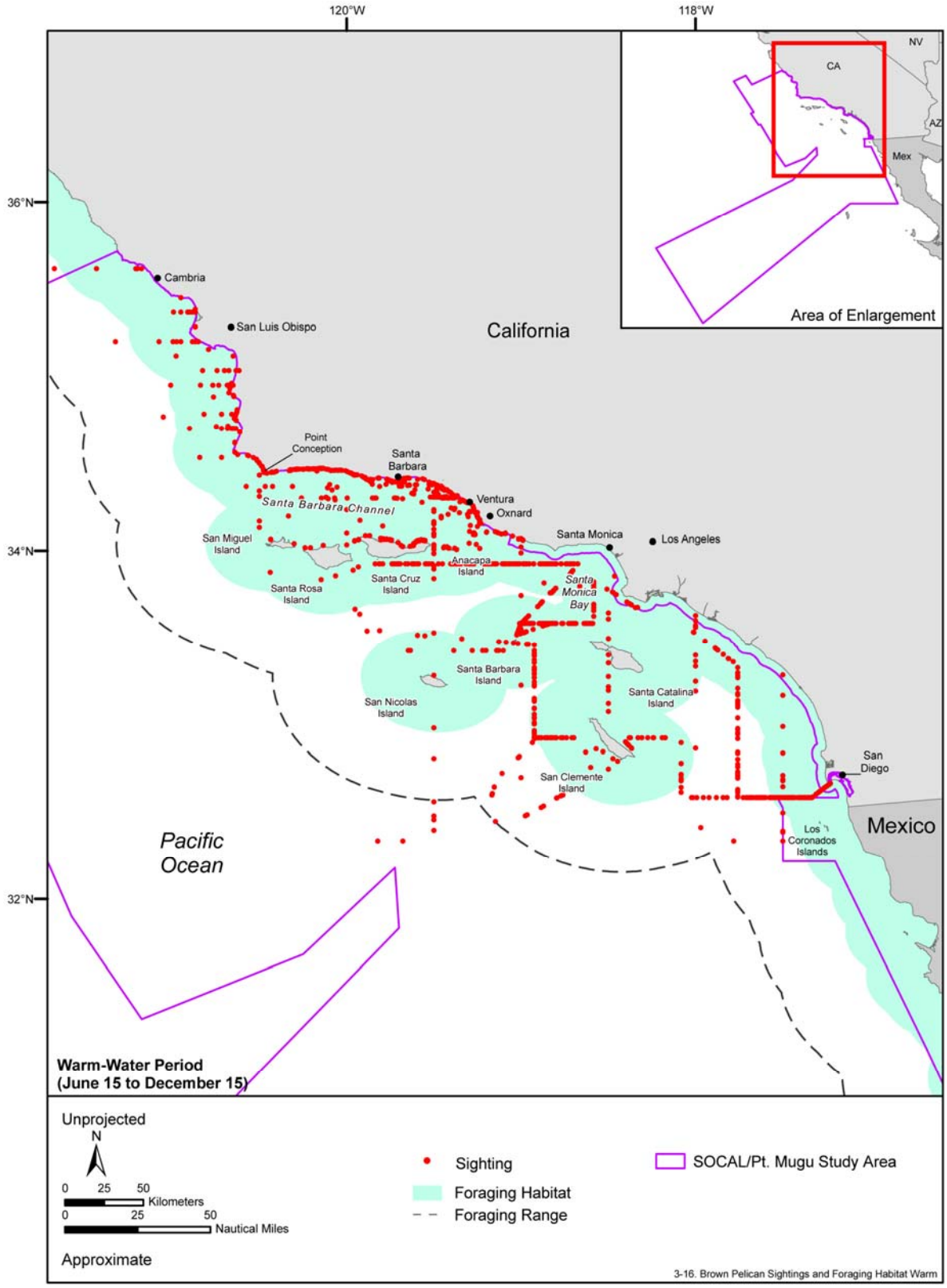

Figure 3-16. Recorded sightings and foraging range of the California brown pelican in the SOCAL/Pt. Mugu Study Area and vicinity during the non-breeding period (June to December). Source data: Bonnell and Ford (2001). Source information: Briggs et al. (1987).

Table 3-4. Estimated nesting subgroup sizes and percentage of total population of *Pelecanus occidentalis californicus* based on 2006 aerial and ground-truth surveys.

Designated Subpopulation	Percentage of total population	Dominant breeding substrate	No. of colonies-historical	No. of colonies-2006 surveys
Southern California Bight	16.6%	Vegetated oceanic island, ground nests	14	11
Southern Baja-Pacific Ocean	4.4%	Oceanic desert island, ground nests	11	5
Gulf of California	61.5%	Oceanic desert island, ground nests	42	24
Mexican Mainland-Island	2.6%	Vegetated oceanic island, tree/bush nests	15	8
Mexican Mainland-Estuarine	14.9%	Estuarine island, tree-bush nests	15	11

Source: Anderson et al. 2007

California brown pelicans regularly roost at Mugu Lagoon, with abundance peaking from June to September. Mugu Lagoon serves as an evening staging area for pelicans that forage or roost elsewhere during the night (Strong and Jaques 2003). The majority of pelican activity occurs at the mouth of the lagoon while small numbers of pelicans forage in the lagoon and adjacent nearshore waters. Mugu Lagoon is the closest mainland roost to the major breeding colony and roosting areas at Anacapa Island (Jaques et al. 1996). A later study analyzed aerial survey data from 1986-2000 to provide management information on the use of communal roost habitat. Sixty traditional roosts were identified, of which four were ranked as being of “major importance” (mean count >100 birds) (Strong and Jaques 2003) (**Figure 3-17**). The largest of these were the breakwaters of Long Beach Harbor and Marina Del Rey, followed by Zuniga Point breakwater and Mugu Lagoon estuary. Most roost habitat consists of artificial structures on lands owned and managed by federal agencies.

Additional roosting sites within the Study Area are found at Vandenberg Air Force Base (VAB) and on San Nicolas Island in the southern Channel Islands. There are 10 California brown pelican roosting areas scattered along the coastline of VAB (**Figure 3-17**). Three of these are at creek or river mouths along the coast (Shuman Creek, San Antonio Creek, and Santa Ynez River). On San Nicolas Island, a total of 17 roosting areas are scattered around the perimeter of the island (**Figure 3-17**). The largest of these is on a sandy beach on the eastern side of the island. Offshore rock outcrops or ‘sea stacks’ at various locations surrounding San Clemente Island are also historically known roosting areas (DoN 2002b).

Of the five California brown pelican nesting groups, only the SCB population nests in the Study Area, with several breeding populations on the Channel Islands and several islands off Baja California (**Table 3-4**; **Figure 3-17**). The number of nesting pairs in individual breeding colonies has been observed to fluctuate on interannual time scales with the climactic and oceanographic changes associated with the ENSO cycle. During El Niño conditions, warmer, nutrient-poor, equatorial waters extend farther north along the California coast, resulting in a reduction in primary and secondary production in the SCB, and ultimately decreasing the abundance of prey species (i.e., fishes) available to pelicans in the area [(See **Chapter 2**; (Anderson et al. 2007)].

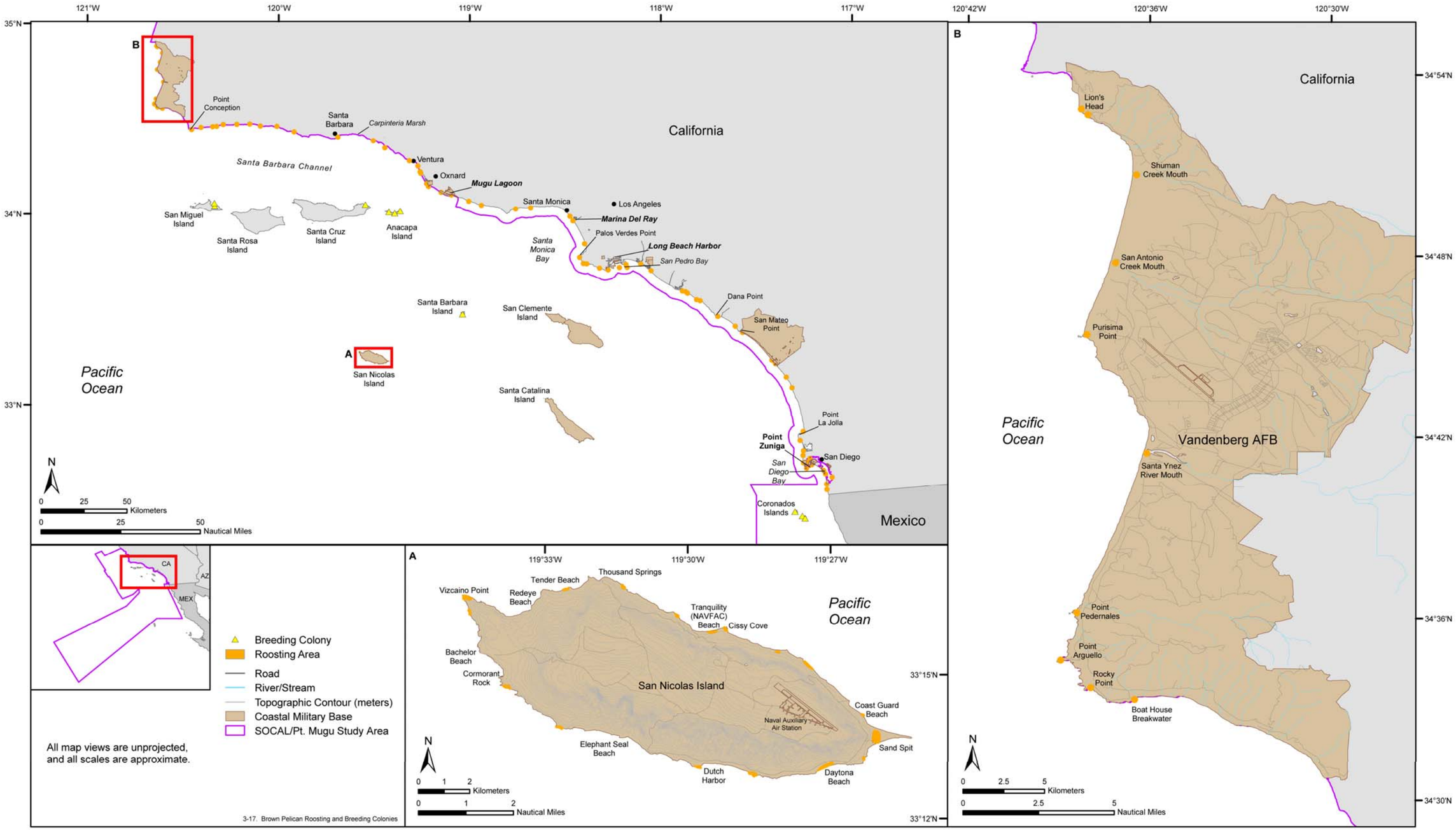

Figure 3-17. Nesting colonies and roosting sites of the California brown pelican in the SOCAL/Pt. Mugu Study Area. Source maps scanned: Strong and Jacques (2003), Capitolo et al. (2008), and USAF (2008).

The abundance of prey is vital to reproductive success. During El Niño events, pelicans and other seabirds often reduce their nesting efforts considerably, or do not nest at all (Anderson et al. 2007). Anderson et al. (2007) conducted nesting surveys in 2006 during a non El Niño year in the SCB and found Santa Barbara Island in the SOCAL OPAREA, contained the largest nesting colony with 4,000 nests, and the Anacapa Islands archipelago (East, West, and Middle Islands) also contained significant breeding colonies (**Table 3-5**).

Table 3-5. Active and historical breeding colonies of the California brown pelican within the SOCAL/Pt. Mugu Study Area for the SCB nesting subgroup.

Breeding site	Approximate LAT	Approximate LONG	Date	# of nests	Frequency of surveys
Scorpion Rock, CA	34°02.9’	119°32.8’	2006	0	multiple
San Miguel Island, CA	34°02.4’	120°20.1’	2006	0	multiple
Prince Island, CA	34°03.4’	120°20.2’	2006	100	multiple
East Anacapa Island, CA	34°00.9’	119°21.9’	2006	10	multiple
West Anacapa Island, CA	34°00.6’	119°25.4’	2006	2,500	multiple
Middle Anacapa Island, CA	34°00.2’	119°23.6’	2006	2,500	multiple
Santa Barbara Island, CA	33°28.5’	119°02.3’	2006	4,000	multiple
Isla Coronado Norte, BCN	32°26.4’	117°17.9’	23/03	1,800	multiple
Mid-Coronados Complex, BCN	32°25.0’	117°15.6’	23/03	60	multiple
Isla Coronado Sur, BCN	32°24.3’	117°14.7’	23/03	25	multiple
Isla Todos Santos Sur, BCN	31°48.0’	116°47.4’	23/03	250	multiple
Isla San Martín, BCN	30°29.3’	116°06.8’	23/03	250	multiple
Isla San Gerónimo, BCN	29°47.5’	115°47.5’	2007	200	04/2007

Source: Anderson et al. 2007

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 approximately 28 to 30 d. Young begin to appear by the first of April (Shields 2002). Most young leave their nests and form crèches 3 to 5 wk after hatching but do not attain flight until about 11 wk of age (Pinson and Drummond 1993). Most young have fledged by the end of July (Shields 2002). Juvenile year birds may wander extensively (Schreiber 1976), usually returning each subsequent year to the natal colony, but they generally do not breed until they attain adult breeding plumage at 3 to 5 yr 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 4 to 7 yr, with only 2% living longer than 10 yr (Schreiber and Mock 1988); however, California brown pelicans are biologically capable of living to 43 yr (Schreiber and Mock 1988).

Communal roost sites are essential habitat for California 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 (Capitolo et al. 2008; USAF 2008). Roost site selection is based on minimal disturbances and microclimate features that aid in thermoregulation.

Brown pelicans are diving birds that feed almost exclusively on fish and dive from up to 18 m in the air (Carl 1987). Past studies have shown that northern anchovies comprise 92% of the diet of California brown pelicans nesting in southern California (Anderson and Gress 1983).

- **Short-tailed Albatross (*Phoebastria albatrus*)**

Description—The short-tailed albatross is the largest of three North Pacific albatrosses with a body length of 84 to 94 cm and a wingspan of 210 to 230 cm (Harrison et al. 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 2001a). Juveniles go through successive plumage changes until developing the characteristic golden crown and nape of adulthood at about the age of 12 yr (Rice 1984; Sibley 2000).

Status—The short-tailed albatross was listed as endangered throughout its range in the U.S. under the ESA in 2000 (USFWS 2000). It is also listed as a California bird species of special concern.[2] No critical habitat has been designated in marine waters for this species because little is known regarding their pelagic ecology (Piatt et al. 2006).

During the late 1800s, the world population of short-tailed albatrosses was decimated for their plumage. By 1932, short-tailed albatrosses had been extirpated from at least a dozen known nesting locations in Japan and Taiwan, and volcanic eruptions in 1939 and 1941 were believed to have resulted in the disappearance of the last remaining colony; however, breeding was again reported at Torishima Island (Japan) in 1950, and by 2005, the Japan and Taiwan populations were estimated at 1,712 individuals and 513 pairs at Torishima, and 340 birds and 85 breeding pairs for Minami-kojima (USFWS 2005a), indicating that both colonies continue to grow steadily.

Since the 1930s, short-tailed albatrosses have been occasionally reported during the breeding season at Midway Atoll, where two million black-footed and Laysan albatrosses nest. Some of these individuals were recorded for several successive years, but the first confirmed nest site that produced an egg did not occur until 1993 (Harrison et al. 1984), although unconfirmed successful nesting was reported in 1961 and 1962 (Tickell 2000).

Sources of mortality include ingestion of plastics mistaken for food items, 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 2005a).

Habitat Associations—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 albatrosses nest on steep slopes of loose volcanic ash (Tickell 2000; USFWS 2005a). Plants help stabilize the soil around the nest, provide protection from weather, and minimize mutual interference between nesting pairs. This habitat also allows for safe, open takeoffs and landings.

Foraging occurs over open offshore ocean waters. Recent observational and telemetry data (USFWS 2005a) show that, while at sea, short-tailed albatrosses 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 albatrosses are so closely tied to the Alaskan shelf-edge upwelling zones that their distribution can be readily predicted. Past premises of the 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 also bring prey (e.g., squid and fish) typically found only in deeper water to the surface where they become available to albatrosses.

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 Ocean north of about 20°N latitude, including the Bering Sea and Okhotsk Sea. Short-tailed albatrosses

move seasonally around the North Pacific Ocean, with high densities observed during the breeding season (December through May) in Japan, and during the non-breeding season throughout Alaska (April through September) and along the west coast of North America (April through December) (McDermond and Morgan 1993). Non-breeding subadults could potentially be found in all areas throughout the year; however, recent telemetric and opportunistic observational data indicate that many birds concentrate along the continental shelf breaks of the North Pacific Ocean, especially along the Aleutians in the Bering Sea (Piatt et al. 2006).

Short-tailed albatross nesting colonies are restricted to two locations: the Japanese island of Torishima, a small island 600 km south of Tokyo, and the Senkaku Islands near Taiwan. Single nests have been found in other locations but with no viable eggs. This species disperses throughout the North Pacific Ocean when it is not breeding. Historic records indicate frequent use of nearshore and coastal waters in the eastern North Pacific Ocean, including off California (COSEWIC 2003). This is a highly mobile species, with a large marine range that is currently known to extend from Siberia south to the China coast and from the Bering Sea and Gulf of Alaska south to Baja California, Mexico, including the Northwestern Hawaiian Islands (Farrand 1983; COSEWIC 2003). As gradual recovery of the population began after 1950, sporadic sightings (11 from 1977 to 2002) have been recorded off California (Unitt 2004). Current sightings in the eastern North Pacific Ocean are mainly concentrated off the shores of Alaska and British Columbia. Roberson describes 12 recent (1977 to 2000) records from California; four are from Monterey Bay where they were once considered common in the late 1800s.[3] Roberson[4] also photographed a short-tailed albatross in Monterey Bay, California in April 2007, and in September 2007, a single bird (or possibly two different birds) was photographed off Cordell Bank, California.[5]

- Information Specific to the SOCAL/Pt. Mugu Study Area and Vicinity—Based on the number of sightings in the southern California area, the short-tailed albatross is considered a vagrant in the Study Area as well as off the entire California coast[6]. Breeding does not occur in the SCB, but due to the unique circulation and upwelling characteristics of this area, potential foraging habitat does exist. Research in Alaska and the Aleutian Islands, along with a historical review of sightings suggests that the short-tailed albatross is associated with upwelling areas and along continental shelf margins (Piatt et al. 2006).

  Three documented sightings of the short-tailed albatross have occurred in the SOCAL/Pt. Mugu Study Area (**Figure 3-18**). Roberson[3] reported a sighting in 1977 of an all-dark immature bird approximately 144.8 km west of the San Diego area. This sighting is located within the Pt. Mugu OPAREA. Another sighting in the summer of 1977 of an immature bird occurred approximately 100 km west of San Diego in the SOCAL OPAREA (Unitt 2004).[3] McCaskie and Garrett (2002) reported a sighting in the vicinity of Santa Barbara Island. Sightings of short-tailed albatrosses have the potential to increase in frequency if the species continues recovering.

Behavior and Life History—Short-tailed albatrosses are long-lived birds (>40 yr) that may begin breeding at age 7 or 8 but do not attain full adult plumage until age 12 (Harrison 1990; USFWS 2001a). This species is monogamous and returns to the same breeding site each year (COSEWIC 2003). Nests typically consist of a grass or moss-lined concave scoop approximately 0.75 m in diameter. Breeding begins in late October; each year females lay a single egg, which is not replaced if destroyed. The egg is incubated until it hatches in late December or early January. Fledging occurs in late April or early June. 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 (Schreiber and Burger 2002).

Like all albatrosses, short-tailed albatrosses use their long, low drag wings to skim the ocean waves employing 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 feed on squid, fish, shrimp and other crustaceans, and flying fish eggs (USFWS 2005a).

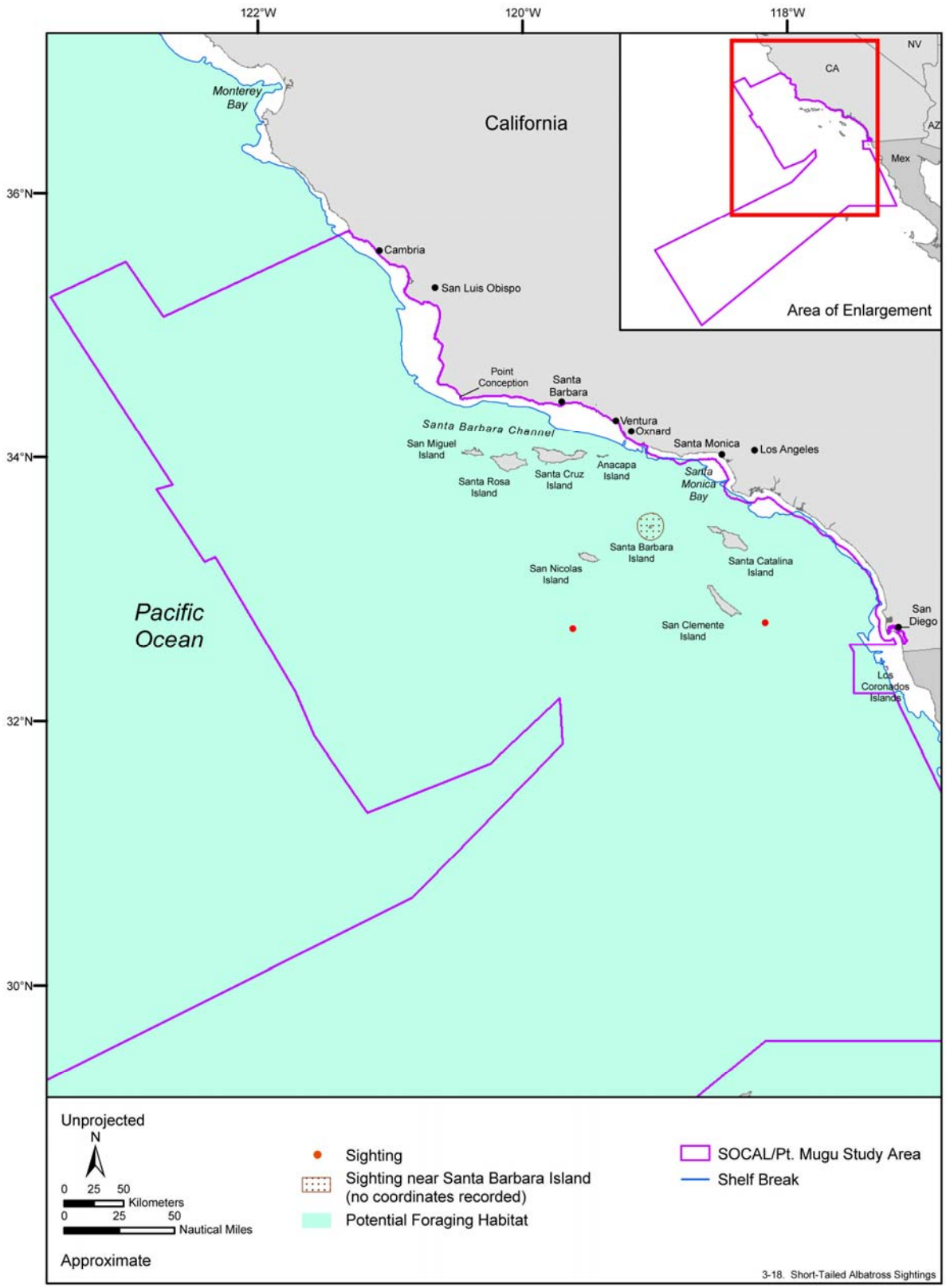

Figure 3-18. Recorded sightings and potential foraging habitat of the short-tailed albatross in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NPPSD (2005). Source information: Piatt (2006) and Roberson.[3]

- **Marbled Murrelet (*Brachyramphus marmoratus marmoratus*)**

***Description*—**The marbled murrelet is a small alcid or auk measuring 24 to 25 cm long with a wingspan of 12 to 15 cm. Plumage is sooty brown to brownish-black on its upper parts with rusty margins on the back between the rump and nape, and reddish scapulars (Carter and Stein 1995). Under parts (i.e., chest, sides, and flanks), the sides of head to above the eye, and the neck are light, mottled brown (i.e., white feathers with broad brown margins). The tail feathers and upperwing-coverts are dark brown with occasional white margins and brownish dots on the outer tail feathers. 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 (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 (Carter and Stein 1995).

***Status*—**The marbled murrelet is listed as a threatened species in California, Oregon, and Washington under the ESA (USFWS 1992) and is considered endangered by the state of California (CDFG 2008). Marbled murrelet populations have suffered significant 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 in 1996 in mature and old-growth forest nesting habitat within 50 km of the coast in Washington State, Oregon, and California (USFWS 1996). The entire critical habitat is located outside of the SOCAL/Pt. Mugu Study Area.

In addition to habitat loss, interactions with fisheries (especially gill-net fisheries) and oil spills have also contributed to population declines. An estimated 3,500 murrelets are killed annually in Alaska by gill-net fisheries (Piatt and Naslund 1995; Carter et al. 2005). And over 1,000 oiled marbled murrelet carcasses were collected after the *Exxon Valdez* oil spill in Alaska (Carter and Kuletz 1995).

The largest number of marbled murrelets occur in Alaska where the population is estimated at 270,000 individuals; although, the population has experienced a dramatic decline of approximately 70% over the last 25 yr (Piatt et al. 2007). The population in British Columbia is estimated to be between 54,000 and 92,000 individuals (Piatt et al. 2007). Current populations in Washington State, Oregon, and California are small compared to the historical populations of British Columbia and Alaska, which at one time were believed to number in the hundreds of thousands (Piatt et al. 2007). A recent population estimate for Washington State, Oregon, and California combined is approximately 20,200 individuals (Raphael et al. 2007).

***Habitat Associations*—**In general, marbled murrelets found south of southeastern Alaska nest in trees, whereas those found west of Kodiak Island nest on the ground; an overlap in nesting preference occurs between Kodiak and Prince of Wales islands. Adult murrelets do not actually build a nest; as an alternative, they seek out natural features, such as moss, clumps of mistletoe, or piles of needle to use as a nest site on a tree limb (Nelson 1997). Large conifers, such as coast redwood (*Sequoia sempervirens*), western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*), and Sitka spruce (*Picea sitchensis*) are utilized in old-growth stands typically within 60 km of marine waters. Stands of 500 ac or larger (USFWS 1997), multi-storied canopy layers, and stands with less than average canopy closures are important features in nesting habitat (Grenier and Nelson 1995; Hamer and Nelson 1995; Miller and Ralph 1995). In addition, habitat along major drainages is a key component (Nelson 1997), as murrelets tend to use these as flight corridors to and from inland nest sites.

Foraging habitat is generally found within 5 km from shore, and in water less than 60 m deep (Nelson 1997; Day and Nigro 2000). Birds occur closer to shore in exposed coastal areas, and farther offshore in protected coastal areas (Nelson 1997). Physical and biological oceanographic processes that concentrate prey (such as upwelling and rip currents) have an important influence on the foraging distribution of marbled murrelets (Kaiser et al. 1991; Ainley et al. 1995a; Burger 1995; Strong et al. 1995; Nelson 1997; Day and Nigro 2000; Burger 2002).

Distribution—The North American marbled murrelet (*Brachyramphus marmoratus*) population 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 as far as Santa Cruz County in central California (USFWS 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 disjunct breeding population is found around Half Moon Bay, in central California. (Strong et al. 1995; USFWS 1997).

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). In California, most birds appear to be year-round residents near breeding areas (Naslund 1993); however**,** dispersal in the winter as far south as southern California and northern Mexico has been documented (Erickson et al. 1995). A single sighting has occurred at Ensenada Harbor near the southeast corner of the SOCAL OPAREA (Erickson et al. 1995). Unitt (2004) classifies the species as a rare fall/winter vagrant to southern California, and 'accidental' from the U.S./Mexico border south along the Mexico coastline.

- Information Specific to the SOCAL/Pt. Mugu Study Area—Eight reported sightings of the marbled murrelet have been documented within the Study Area (**Figure 3-19**). Sightings have been reported at Marina del Rey, off Santa Barbara Island, Mugu Lagoon in Ventura County, along the coast in San Diego County, and at the northern end of the Study Area near San Simeon Point (McCaskie 1998, 2000; McCaskie and Garrett 2001; Unitt 2004). All of these documented sightings were recorded between the months of November through March.

  Foraging habitat in the Study Area occurs usually within 5 km of the coast in waters less than 60 m deep (Sealy 1975; Ainley et al. 1995b; Burger 1995; Strachan et al. 1995; Nelson 1997; Day and Nigro 2000) however, because upwelling areas comprise important foraging habitat for the marbled murrelet, the potential exists for individuals to be observed farther offshore in the SCB.

Behavior and Life History—Nesting phenology of the marbled murrelet 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). The timing of breeding is known to be influenced by food availability and weather conditions; nest initiation may begin as early as March or as late as mid-July (Nelson 1997). Adult birds travel long distances between at-sea foraging locations and nest sites (Whitworth et al. 2000; Burger 2002). The length of the nesting season changes with latitude; in California, the nesting season lasts about 170 d, while in Oregon it is about 149 d, and in Alaska it is only 106 d (Hamer and Nelson 1995; Nelson and Peck 1995). It is not known if late breeders will attempt to breed a second time after an 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 1995). Breeding pairs produce a single egg, and compared with other alcids, marbled murrelets have a short incubation period ranging from just 27 to 30 d. Both parents incubate the egg, switching every 24 hr, and they will abandon the egg for up to 1 d (De Santo and Nelson 1995). Chicks fledge anywhere from 27 to 40 d after hatching, with the variability probably due to differences in food-provisioning rates (De Santo and Nelson 1995; Nelson 1997). Fledglings begin arriving at sea during May and peak by mid-summer (Hamer and Nelson 1995).

Migratory movements are poorly known, however, Beauchamp et al. (1999) doubly recaptured a tagged individual, providing the first direct evidence of migration between breeding and non-breeding areas for this species.

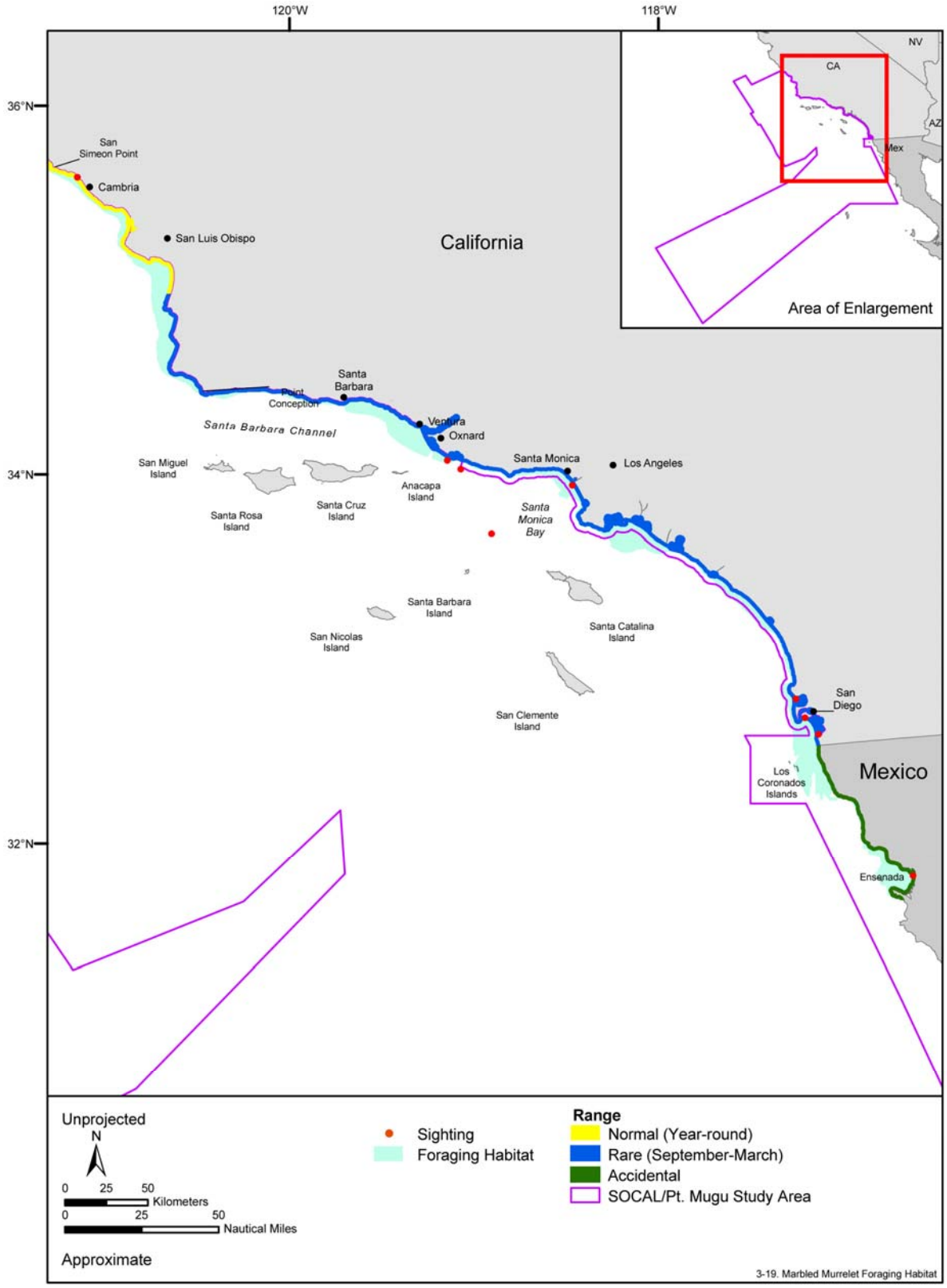

Figure 3-19. Recorded sightings and potential foraging habitat of the marbled murrelet in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Bonnell and Ford (2001). Source information: Erickson et al. (1995) and Nelson (1997).

Marbled murrelets feed opportunistically on small fish and invertebrates (USFWS 1997) in the nearshore marine environment, primarily in protected waters where both Pacific sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) occur (Whitworth et al. 2000; Burger 2002). Individuals forage by diving, using their wings for underwater propulsion. This species is capable of diving to great depths within nearshore waters; however, birds tend to forage in relatively shallow waters (less than 50 to 100 m in depth), usually appearing to feed both near the surface and at mid-water depths (USFWS 1997).

- **Xantus's Murrelet (*Synthliboramphus hypoleucus*)**

Description—The Xantus's murrelet is a small seabird measuring 23 to 25 cm in length with a wingspan of 40 cm. In fresh breeding plumage, the upperparts (including the dorsum of the head and neck, mantle, wings, and tail) are black with a bluish-gray cast (Drost and Lewis 1995). This plumage turns grayish with wear. The underparts from the throat to the under-tail coverts are white. The flanks are mostly white or mottled gray and white. Some individuals have dark feathers that form a short broad partial collar at the side of the neck. The underwing coverts are usually pure snowy white, although sometimes with a few gray feathers. With the exception of a shorter bill and fine barring on the flanks, juvenile and first winter Xantus's' murrelets are similar to the adults (Drost and Lewis 1995).

Two subspecies of Xantus's murrelet occur in the Study Area; *Synthliboramphus hypoleucus hypoleucus* and *S. h. scrippsi*. These subspecies can be distinguished by differences in breeding range, facial plumage, bill size, and vocalizations (Jehl and Bond 1975). In *S.h. hypoleucus*, the white plumage of the throat extends up to and sometimes in front of the eye (Drost and Lewis 1995). Although variable, the white may also extend up and into a broad patch behind the eye. In *S.h. scrippsi*, the area in front of and behind the eye is black, with the dividing line between the black crown, face, and white throat extending straight back from the bill (Jehl and Bond 1975).

Status—The Xantus's murrelet population as a whole is designated as a candidate species under the ESA and a threatened species in the state of California (CDFG 2008). Historical accounts of the species from the 1940's indicate that murrelets were once more abundant, although there are no reliable estimates of historical populations. Numerous threats exist that have contributed to declines in Xantus's murrelet populations. Examples include non-native mammals (e.g., rats) directly preying upon murrelets or causing habitat destruction/alteration; oil pollution; native predators feeding on eggs, chicks, or adults; artificial light pollution from sea going vessels; human disturbance at nesting colonies; oceanographic changes affecting prey species abundance; military operations; and bycatch in fisheries (Burkett et al. 2003).

The most recent worldwide population estimate based on at-sea surveys is 39,700 individuals, consisting of 17,900 breeding birds and 21,800 subadults and nonbreeders (Karnovsky et al. 2005). The California population is now considered 'uncommon' with estimated numbers of 3,460 breeding birds. Santa Barbara Island hosts the largest breeding colony in California with 500 to 750 pairs (Whitworth et al. 2005). Research in the SCB from the 1970s to 1991 indicated a decline of approximately 30% in Xantus's murrelets on Santa Barbara Island; however, multiple studies utilized different methodologies and are, therefore, difficult to compare for accurate population estimates (Burkett et al. 2003). Difficulty in accurately censusing populations at breeding colonies is also compounded by Xantus's murrelet's crevice-nesting behavior.

Anacapa Island murrelet populations historically experienced significant declines primarily due to predation following the introduction of the black rat (*Rattus rattus)* in the mid-1800s and early 1900s (Burkett et al. 2003). The eradication of rats in 2002 has resulted in improved hatching success and colony expansion (Whitworth et al. 2005). In 2005, Whitworth et al. (2005) recorded a considerable increase in nesting effort compared to previous years, with a 42% increase in the number of active nests following eradication.

The Coronado and Guadalupe Islands are important breeding areas for the Xantus's murrelet. The Coronado Islands breeding population is approximately 750 individuals, which totals about 20% of the total population of the subspecies *S.h. scrippsi* (Unitt 2004). Current population estimates are not available for Guadalupe Island. In 1968, Delong and Crossin estimated 2,400 to 3,500 Xantus's' murrelet breeding pairs on Guadalupe Island (USFWS 2007a). Updating the population estimate for Guadalupe Island is needed to more accurately estimate the world population for this species (Burkett et al. 2003).

Habitat Associations—Xantus's murrelets prefer to nest on offshore islands free from human disturbance and predators. Nest sites are typically in crevices or natural cavities near steep cliffs, within sea caves, on offshore rocks (Burkett et al. 2003), or hollows beneath adequate vegetation. (Ehrlich et al. 1988).

During the breeding season, Xantus's murrelets forage in waters surrounding nesting islands within 100 to 150 km from colonies (Whitworth et al. 2000). Non-breeding birds forage in epipelagic waters with the highest densities observed over the upper continental slope in water depths of 200 to 1,000 m (Briggs et al. 1987; Karnovsky et al. 2005). Moderately high densities of Xantus's murrelets are found foraging over the outer continental slope at depths of 1,000 to 3,000 m, and the lowest densities are observed over the continental shelf (depth less than 200 m) and over pelagic waters (depths greater than 3,000 m) (**Figure 3-20**). Karnovsky et al. (2005) also observed that Xantus's murrelets dispersed from breeding areas were associated with warmer, lower salinity waters characteristic of the main flow of the California Current during ENSO years.

Distribution—Xantus's murrelets are endemic to the Pacific coast of North America, ranging along the coast from Baja California, Mexico (23°N) to British Columbia (52°N) and offshore to a distance of approximately 500 km (Carter et al. 2005). Of the two subspecies, *S.h. hypoleucus* breeds almost exclusively on Guadalupe Island, with a small number on the San Benito Islands off central Baja California, Mexico. *S.h. scrippsi* nests primarily on the Channel Islands and Coronado Islands in the SCB, but also south to the San Benito Islands where it overlaps with *S.h. hypoleucus* (Jehl and Bond 1975; Carter et al. 2005; Karnovsky et al. 2005).

This species is present at nesting colonies in the SCB from approximately March to June. *S.h. hypoleucus* in central Baja California tends to breed about 1 mo earlier than *S.h. scrippsi* (Wolf et al. 2005). During this period, Xantus's murrelets occur from northern Oregon to southern Baja California but tend to be concentrated in the SCB (Karnovsky et al. 2005). Post-breeding dispersal results in a more uniform distribution extending from southern British Columbia to southern Baja California, with the highest concentrations offshore from Point Conception to Cape Mendocino and off Baja California (Briggs et al. 1987; Karnovsky et al. 2005).

The pelagic distributions of *S.h. hypoleucus* and *S.h. scrippsi* overlap extensively during the post-breeding dispersal period, and at-sea distributions (see previous discussion in habitat preferences) are highest over the upper continental slope at depths of 200 to 1,000 m (**Figure 3-21**).

- Information Specific to the SOCAL/Pt. Mugu Study Area—During the breeding season (approximately March to June), Xantus's murrelets are concentrated in the SCB with areas of high density observed in the vicinity of Santa Barbara Island and near the California/Mexico border northwest of the Coronado Islands (Karnovsky et al. 2005). Nesting sites are known to occur in the Channel Islands, specifically on San Miguel, Santa Cruz, Anacapa, Santa Barbara, San Clemente, and Santa Catalina islands (**Figure 3-20**).

  Although Santa Barbara Island is the smallest of the Channel Islands with an area of just 2.6 km^2, it is the most important of all the islands for Xantus's murrelets, because 51% of the California population utilizes this island for nesting (Burkett et al. 2003).

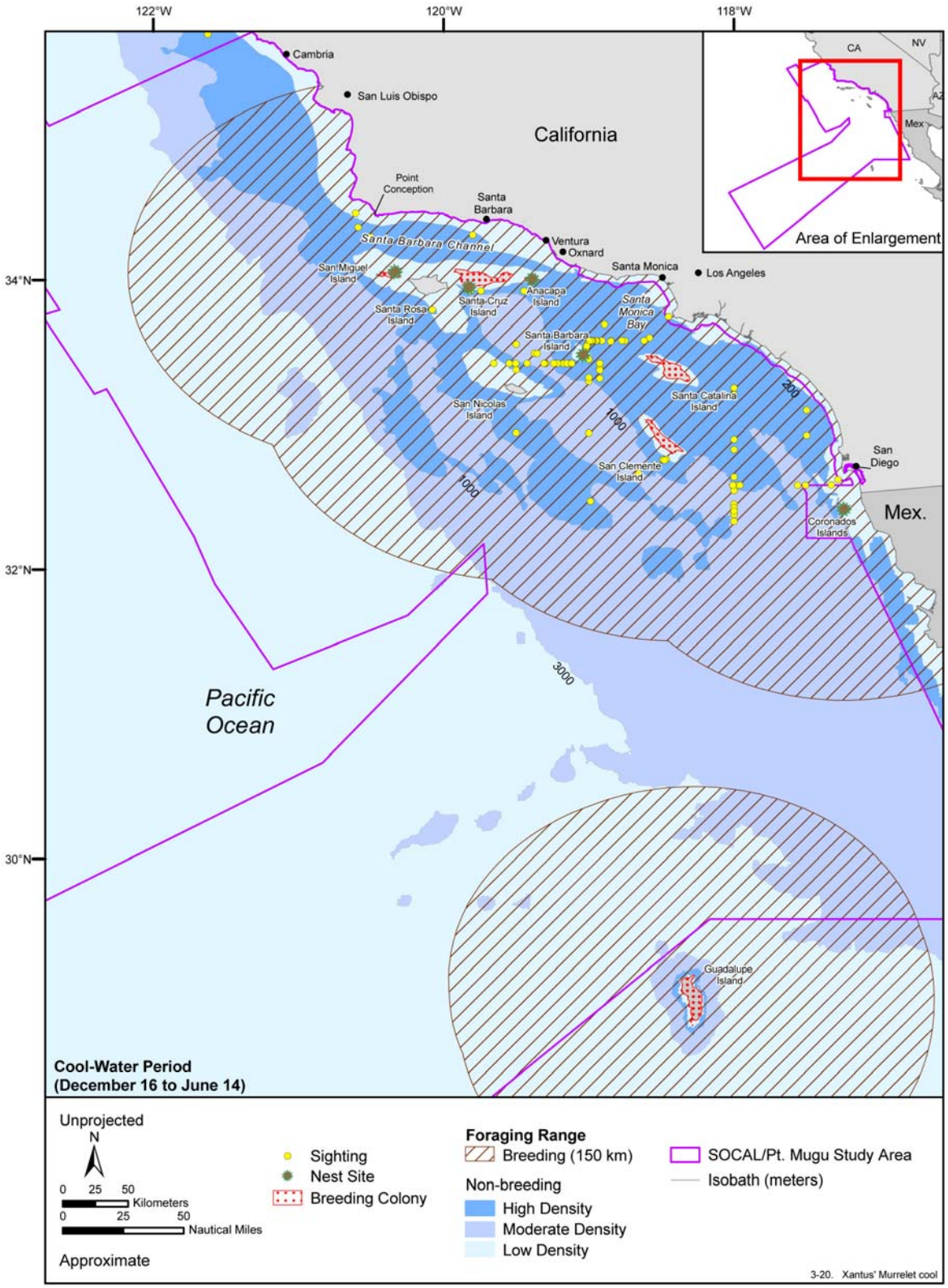

Figure 3-20. Known nesting site locations, islands with breeding colonies, and potential foraging habitat of the Xantus's murrelet in the SOCAL/Pt. Mugu Study Area during the breeding period (December to June). Source data: Bonnell and Ford (2001), NOS (2001), and NOS (2006). Source information: Drost and Lewis (1995), Karnovsky (2005), and USFWS (2007a).

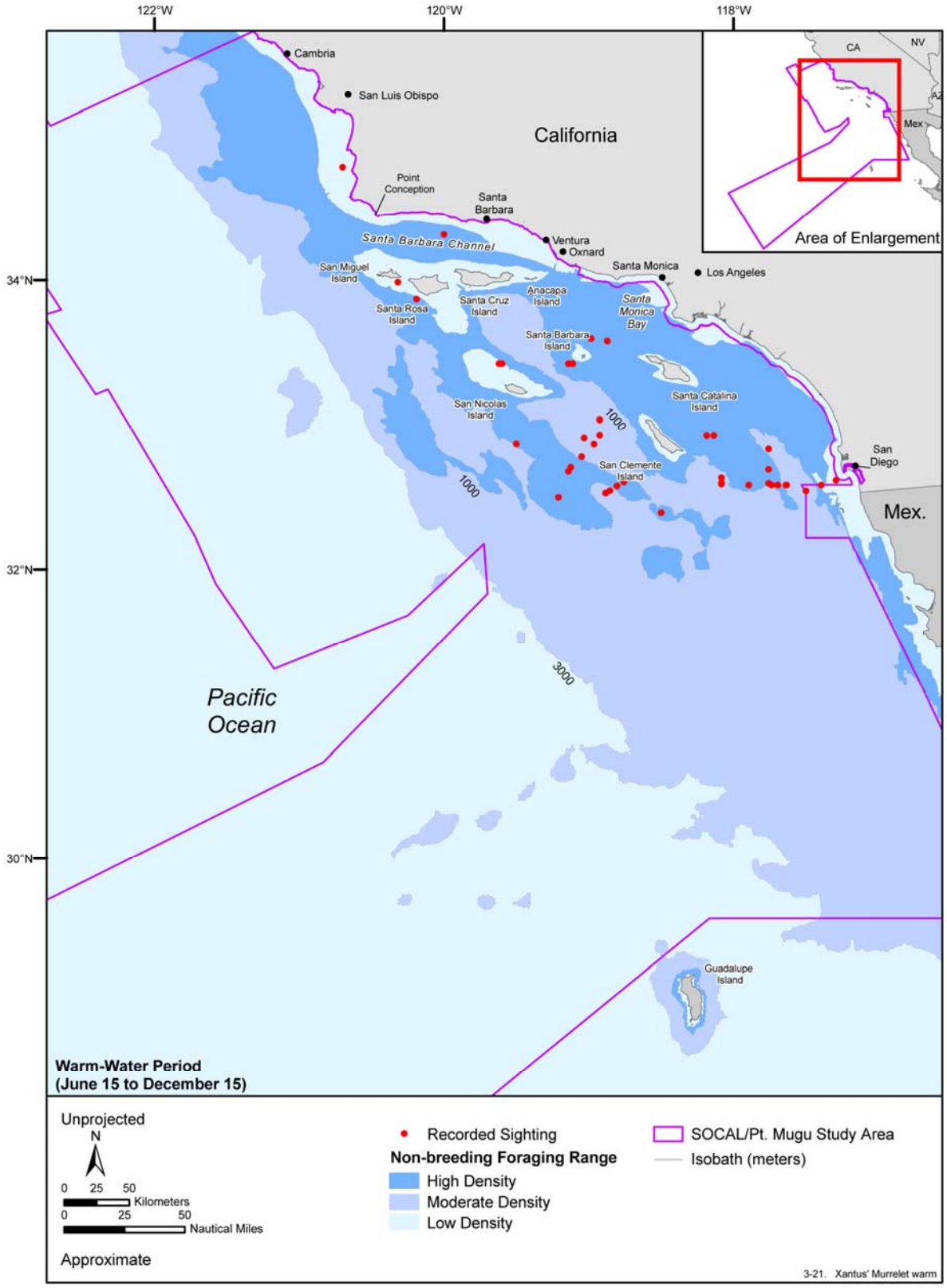

Figure 3-21. Recorded sightings and potential foraging habitat of the Xantus's murrelet in the SOCAL/Pt. Mugu Study Area during the non-breeding period (June to December). Source data: Bonnell and Ford (2001). Source information: Karnovsky et al. (2005).

Thirty-seven nests were recorded on Anacapa Island in 2005 (Whitworth et al. 2005). Nest locations were scattered on East, West, and Middle Anacapa Islands in sea caves, on cliffs, along shorelines, and on offshore rocky habitats. Burkett et al. (2003) estimated approximately 200 to 600 breeding pairs of Xantus's murrelets on Anacapa Island.

Xantus's murrelet breeding pairs on other Channel Islands in the Study Area include Santa Cruz (100 to 300); San Miguel (50 to 300); Santa Catalina (25 to 75) (USFWS 2007a); and San Clemente Island at Seal Cove and China Point (10 to 15) (DoN 2002b). Individuals have also been known to use sea stacks (off-shore rock outcrops) near the island for roosting and as take-off points for foraging (DoN 2002b). Other important breeding islands for the Xantus's murrelet in and adjacent to the Study Area include the Coronado and Guadalupe islands.

Behavior and Life History—Xantus's murrelets spend the majority of their lives at sea, only coming ashore to nest. Breeding begins at 2 to 4 yr of age. Pairs are monogamous and usually nest at the same site each year (Murray et al. 1983). Birds begin arriving in the vicinity of nesting colonies sometime in December and January (Murray et al. 1983). The primary period of nest colony attendance is March 15 to June 15 (Karnovsky et al. 2005).

Xantus's murrelets use a rudimentary nest site consisting of a shallow scrape or hollow on the ground with no lining material. Nests locations include natural cavities, under shrubs, along cliffs, and in sea caves (Burkett et al. 2003). Clutch size is typically two with occasionally only a single egg laid. Both parents incubate the eggs for a period of 34 to 41 d (Hunt et al. 1979; De Santo and Nelson 1995). The precocial young fledge at just 2 d, leaving the nest under cover of night to join their parents in ocean waters (Sowls et al. 1980; De Santo and Nelson 1995). Hatching and fledging usually begin in mid-April and continue through August.

During the breeding season, birds congregate at night on the water adjacent to nesting colonies (Hunt et al. 1979; Murray et al. 1983). It is hypothesized that the purpose for this nocturnal behavior is for socialization, courtship, pairing, pair bond maintenance, and to engage in vocal activities (Gaston and Jones 1998). It is also believed this nocturnal behavior serves to avoid detection by avian predators such as falcons, owls, and gulls ((Murray et al. 1983; Gaston and Jones 1998).

Xantus's murrelets capture prey underwater by using their wings for propulsion in a technique known as pursuit-diving (Gaston and Jones 1998). Birds usually feed in singles or pairs, but occasionally in groups of up to eight (Hunt et al. 1979). Few studies have been conducted regarding the food habits of the Xantus's murrelet. They are known to feed on small schooling fish and zooplankton near the surface of the water. Larval fish, especially anchovies but also Pacific sauries (*Cololabris saira*) and rockfish (*Sebastes* spp.), are major food items during the nesting period at Santa Barbara Island (Hunt and Butler 1980).

- **California Least Tern (*Sternula antillarum browni*)**

Description—The California least tern is the smallest of the North American terns. It is 21 to 23 cm in length and has a wingspan of approximately 48 to 53 cm (USFWS 1985; Thompson et al. 1997). The adult breeding plumage consists of a black cap and loral stripe (extending from the base of the bill to the eye), which contrasts with its white forehead. The striking yellow/orange bill is tipped with black. The upperparts are gray while the underparts are white. The outer primaries of the wing (two, rarely three) are black while the remainder of the upperwing is gray. Coloration for both males and females is similar; however, the black loral stripe is wider in males than females. Juveniles are distinguished from adults by the extensive dark *U*- or *V*-shaped markings on the gray to yellow-brown mantle (Thompson et al. 1997). During the non-breeding season, the crown has variable white flecking and the nape is dark; the loral stripe is black with white flecking at the base. The mantle is gray and the lesser wing coverts are dark. In juvenile and first year birds, the marginal wing coverts form a dark bar on the leading wing edge (Thompson et al. 1997).

Status—The California least tern was listed as endangered in 1970 (and subsequently under the ESA in 1973)[7] and by the state of California in 1971 (CDFG 2008). In 2006, the USFWS completed the most recent 5-yr status review for the species and recommended the California least tern to be downlisted to threatened under the ESA. The population has increased from 600 pairs in 1973 to approximately 7,100 pairs in 2005, and least tern nesting sites have nearly doubled since the species was first listed (USFWS 2006a). In 2007, an estimated 6,744 to 6,989 California least tern breeding pairs established nests at 48 locations in California (Marschalek 2008); however, the species' population increase does not meet specific requirements in the 1985 recovery plan to warrant delisting.

Historical accounts from the early 1900s indicate that the California least tern subspecies (*Sternula antillarum browni)* was abundant along the barrier beaches and beach strand on the southern California coast and by the 1930s was noted as seriously declining throughout its range (USFWS 2006a). Current threats to recovering least tern populations include habitat destruction/modification; human recreational and commercial use of remaining marginal habitat; numerous predators (e.g. gulls, crows, and raptors) feeding on eggs, chicks, or adults; environmental contamination; food shortages during the breeding period; and exotic/invasive vegetation encroachment impacting nesting habitat (USFWS 2006a).

No critical habitat has been designated for the California least tern. On military lands, habitat management and species-specific protection measures are provided for in federal cooperative plans [e.g. MOUs, and INRMPs]. Conservation for the California Least Tern is addressed in multiple MOUs and INRMPs for military lands in the Study Area, including Marine Corps Base (MCB) Camp Pendleton, NAB Coronado (DoN 2002a), Naval Base (NB) Ventura County Pt. Mugu, and VAB.

Habitat Associations—The preferred nesting habitat consists of beaches, dunes, sand bars, and spits on the ocean shore (USFWS 1985). The California least tern nests in areas generally free of vegetation above the high tide mark (some nests may be located between the high tide and highest-high tide marks). Colony sites are often located in the vicinity of estuaries, lagoons, rivers, or the seacoast (USFWS 1985). This species has also adapted to nesting in human-modified areas including agricultural fields, parking lots, bare land at airports, and gravel rooftops (Thompson et al. 1997). Atwood and Minsky (1983) noted that prior to the species' decline; at least 82% of known nesting sites in California were located within 2 km of a river mouth or estuarine habitat.

Roosting areas are also essential habitat components for this species and consist of two types: pre-season nocturnal roosts, such as the one documented in Belmont Shore, Long Beach California, and post-season dispersal sites where adults and fledglings congregate (USFWS 2006a).

Foraging habitats include near-shore ocean waters, bays, river mouths, salt marshes, marinas, river channels, lakes, and ponds (Thompson et al. 1997). The presence of eelgrass is important because it serves as habitat for several prey species of the least tern, however, no preference of California least terns for feeding in eelgrass areas has been demonstrated (Baird 1997). Foraging activity typically occurs within 3.2 km of the shoreline in ocean waters less than 18.3 m deep, with most foraging activity within 1.6 km of shore (Atwood and Minsky 1983). Atwood and Minsky (1983) also observed a tendency for foraging birds to be concentrated in nearshore waters near major river mouths. Foraging habitat utilization will vary within, and between years depending upon the stage of breeding and prey species availability (Atwood and Minsky 1983; Baird 1997). Prior to post-breeding dispersal, Atwood and Minsky (1983) noted in their coastal colony study, that foraging activity typically occurred within 3.2 km of nesting sites, although large groups were occasionally observed foraging at greater distances from colonies, including at inland water sources. A study by Baird (1997), found that adults in colonies in San Diego Bay tended to alternate between ocean and bay foraging areas depending upon the breeding stage (courtship, egg, chick, or fledgling) and food availability. When food availability was low, adults tended to travel farther, foraging in ocean waters in search of prey (Baird 1997).

Distribution—California least terns are neotropical migratory birds, spending the breeding season (April through August) along the central and southern California coast, as well as along the west and southwestern coast of Mexico. The California least tern historically nested on coastal beaches of Monterey, California to Cabo San Lucas, Baja California. The current nesting range is from San Francisco Bay and south along the California coast to San Diego County (Massey and Fancher 1989). In 2006, the five most populated breeding sites contained 71% of the entire population and were located at Los Angeles Harbor, MCB Camp Pendleton, NAB Coronado, Batiquitos Lagoon, and Pt. Mugu (Marschalek 2006).

Adults and juveniles disperse widely after leaving the colony but usually no farther north than the northern-most colonies in its range (Thompson et al. 1997). During late summer and fall, migrating California least terns often concentrate in coastal lagoons.

Migration routes and wintering range for the California least tern are not well known. It is thought that this subspecies winters along the Pacific coast of Central America (USMC 2001). Unitt (2004) reports that California least terns banded in San Diego Bay were found wintering along the Pacific coast of Guatemala, southern Mexico (Chiapas), and western Mexico (Colima).

- Information Specific to the SOCAL/Pt. Mugu Study Area—California least terns migrate north and begin arriving in the Study Area from early to mid-April to breed, and are usually present through the end of August (USFWS 1985). Specific locations for active 2007 California least tern nesting colonies within and adjacent to the SOCAL/Pt. Mugu Study Area are shown in **Figure 3-22**. **Table 3-6** lists the 2007 breeding survey colony locations along with the estimated numbers of breeding pairs, number of nests, estimated number of fledglings, and the ratio of fledglings per pair for each colony.

  San Diego County had the largest concentrations of breeding pairs in 2007 with 56.4% (Marschalek 2008). Los Angeles and Orange counties combined contained 29.2% of breeding pairs in the state. Nesting sites with the highest number of breeding pairs were observed at MCB Camp Pendleton (1,422 pairs), NAB Coronado (1,034 pairs), Los Angeles Harbor (669 pairs), Batiquitos Lagoon (575 pairs), and Venice Beach (449 pairs) (Marschalek 2008).

  Between Ventura County and the San Francisco Bay area, the only regularly used nesting sites in San Luis Obispo and Santa Barbara counties are at Purisima Point, Mussel Rock Dunes, and VAB (Marschalek 2006). VAB has three colonies located at San Antonio Beach, Purisima Point, and at the mouth of the Santa Ynez River. Eighteen nests were established at VAB in 2007 and produced 16 fledglings (Marschalek 2008).

  At Mugu Lagoon, the population has increased from 69 breeding pairs in 1996 (DoN 2002c) to between 349 to 428 pairs in 2007 (Marschalek 2008). The main established colony in 2006 and 2007 has been located on Ormond Beach East at the NB Ventura County Pt. Mugu (**Figure 3-22**). Nesting also occurs on the southwest arm of Mugu Lagoon (Ruane, M., K NAVFAC SW, MUGU, pers. comm., 15 April 2008). Marschalek (2008) also noted nesting for the first time at Holiday Beach Salt Panne adjacent to Holiday Beach. California least terns can be found foraging in shallow open water and breeding in sandy areas adjacent to Mugu Lagoon.

  Within the Study Area in San Diego County, the Santa Margarita River mouth on MCB Camp Pendleton has generally supported the largest numbers of terns in recent years, many of which are observed in open waters near the base (Marschalek 2006). In 2007, MCB Camp Pendleton continued to support the highest number of breeding pairs and nests in the state (Marschalek 2008). Since 1969, terns have nested on MCB Camp Pendleton beaches opposite or adjacent to the Santa Margarita River, on the salt flats in its estuary, and at French and Aliso Creeks. The terns typically arrive in mid-April and have mostly migrated south by September (Shepherd, T., CIV NAVFAC SW, pers. comm., 14 April 2008).

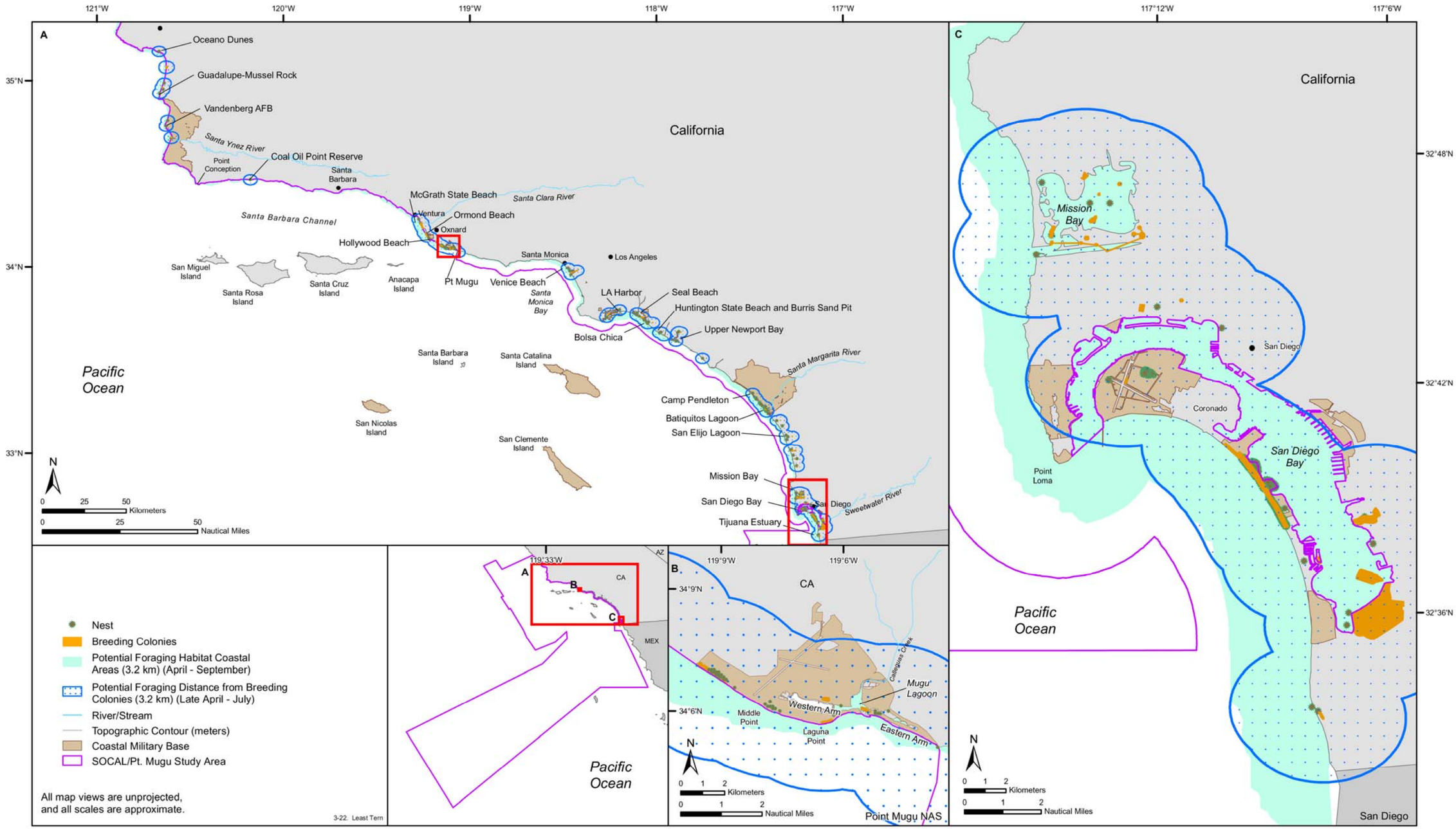

Figure 3-22. Breeding colony locations and typical foraging distances of the California least tern in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NOS (2001), NAVAIR Environmental (2002), CDFG (2004), CDFG (2005), NOS (2006), and USMC and DoN (2007a). Source map (scanned): USAF (2008). Source information: Atwood and Minsky (1983), Baird (1997), Unitt (2004), and Marschalek (2008).

Table 3-6. California least tern breeding and reproductive success for 2007 in the SOCAL/Pt. Mugu Study Area.

2007 Least Tern Nesting Site	Estimated Number of Breeding		Number of Nests	Estimated Number of Fledglings		Fledgling per Pair Ratio	
	Min	Max		Min	Max	Min	Max
San Luis Obispo/Santa Barbara Counties							
Oceano Dunes SVRA	54	54	66	70	70	1.30	1.30
Guadalupe-Mussel Rock	1	1	1	1	1	1.00	1.00
Vandenberg AFB	18	18	18	16	16	0.89	0.89
Coal Oil Point Reserve	4	4	6	0	0	0.00	0.00
Ventura County							
Santa Clara River/McGrath State Beach	56	77	77	76	76	0.99	1.36
Ormond Beach	49	50	52	35	35	0.70	0.71
Hollywood Beach	1	1	1	2	2	2.00	2.00
Pt. Mugu—Totals	349	428	431	139	139	0.32	0.40
Holiday Beach	57	63	65	4	4	0.06	0.07
Ormond Beach East	286	350	351	134	134	0.38	0.47
Holiday Beach Salt Panne	4	6	6	0	0	0.00	0.00
Eastern Arm	2	9	9	1	1	0.11	0.50
Los Angeles/Orange Counties							
Venice Beach	449	453	546	414	440	0.91	0.98
LA Harbor	669	669	710	186	186	0.28	0.28
Seal Beach NWR—Anaheim Bay	164	166	166	12	12	0.07	0.07
Bolsa Chica Ecological Reserve	200	200	226	15	15	0.08	0.08
Huntington State Beach	445	445	485	215	215	0.48	0.48
Upper Newport Bay Ecological Reserve	37	37	42	12	18	0.32	0.49
Burris Sand Pit	8	9	9	7	9	0.78	1.13
San Diego County							
MCB Camp Pendleton	1422	1422	1530	369	369	0.26	0.26
Red Beach	12	12	14	4	4	0.33	0.33
White Beach	109	109	117	38	38	0.35	0.35
Santa Margarita River—North Beach North	266	266	288	60	60	0.23	0.23
Santa Margarita River—North Beach South	922	922	984	260	260	0.28	0.28
Santa Margarita River—Saltflats	74	74	85	7	7	0.09	0.09
Santa Margarita River—Saltflats Island	39	39	42	0	0	0.00	0.00
Batiquitos Lagoon Ecological Reserve	575	578	594	146	226	0.25	0.39
San Elijo LagoonEcological Reserve	0	0	0	0	0	0.00	0.00
Mission Bay							
FAA Island	22	22	28	2	2	0.09	0.09
North Fiesta Island	20	30	39	6	8	0.20	0.40
Mariner's Point	75	75	105	20	30	0.27	0.40
Stony Point	30	40	45	8	10	0.20	0.33
San Diego River Mouth	20	20	30	8	10	040	0.50
San Diego Bay							
Lindbergh Field & Former Naval Training Center	120	127	135	34	42	0.27	0.35
U.S. Navy Totals	1149	1149	1285	231	232	0.20	0.20
North Island MAT	115	115	123	31	32	0.27	0.28
Delta Beach North	207	207	224	50	50	0.24	0.24
Delta Beach South	147	147	156	35	35	0.24	0.24
NAB Ocean Beach	680	680	782	115	115	0.17	0.17
D Street Fill/Sweetwater Marsh NWR	100	115	130	25	28	0.22	0.28
Chula Vista Wildlife Reserve	33	39	46	0	0	0.00	0.00
South San Diego Bay Unit, SDNWR—Saltworks	50	73	97	13	18	0.18	0.36
Tijuana Estuary NERR	188	239	291	29	47	0.12	0.25

MCB = Marine Corps Base; NWR = National Wildlife Refuge; SD = San Diego,
NERR=National Estuarine Research Reserve.
Source: Marschalek 2008.

MCB Camp Pendleton follows active management practices for protecting least tern breeding habitat. In 1988, the base retained protective fencing around the Santa Margarita River nesting site throughout the year. Additionally, during the breeding season a fence is put up along all known breeding locations to protect the colonies from military training on the beach (USMC 2001). In 2001, MCB Camp Pendleton adopted an INRMP to incorporate USFWS recommendations for least tern management and conservation on military base property (USFWS 2006a). Intensive predator control and monitoring programs are also practiced.

In San Diego Bay (**Figure 3-22**) at NAB Coronado, 13 California least terns were discovered in 1977 on the asphalt of the old airfield "MAT" site, which is an open area used for helicopter takeoffs, landings, and parking. In 1980, Naval Air Station North Island (NASNI) initiated a phased MAT repair plan that required consultation under the ESA with USFWS. In 1984, an MOU between the USFWS and NAB Coronado required the Navy to set aside, fence, and manage 0.32 km^2 (78 ac) of California least tern nesting habitat. In 1990, a 0.04 km^2 (10 ac) bed of eelgrass was planted immediately east of Delta II Beach to enhance foraging for California least terns. Currently, the least tern preserve is active at NAB Coronado and the primary nesting site consists of a fenced, 0.09 km^2 (23 ac) parcel of sand located on the MAT site (DoN 2002a). In 2007, 115 California least tern breeding pairs established 123 active nests at this site (Marschalek 2008). Breeding birds utilize the bay and adjacent nearshore ocean waters for foraging. Foraging areas utilized by California least terns in the Study Area fluctuate during the breeding season, with more open water foraging (farther from nesting colonies) occurring during the courting and incubation periods, and more nearshore water foraging occurring during the chick stage (Baird 1997). Docks and mooring areas are also utilized consistently for foraging in San Diego Bay (Baird 1997).

Vegetation management is needed in certain areas to maintain suitable least tern nesting substrate (USFWS 1985). Approximately 0.04 km^2 (9.8 ac) of coastal dunes at Delta Beach North (DBN) and 0.05 km^2 (13.4 ac) at Delta Beach South (DBS) are graded annually to remove vegetation (DoN 2002a). An additional 0.07 km^2 (17.7 ac) are protected but not graded (DoN 2002a). DBN and DBS are also restricted from training activities April through September due to the presence of nesting California least terns and western snowy plovers (*Charadrius alexandrinus nivosus*) (DoN 2002a). In 2007, NAB Coronado had 1,034 breeding pairs with the majority occurring at the NAB Ocean sub-colony (Marschalek 2008).

Since the early 1980s, the nesting of the California least tern has dramatically curtailed beach operations on the Silver Strand beaches at NAB Coronado. To avoid damaging nests and further endangering these birds, the Navy and USMC have had to limit amphibious landings and beach operations in these areas. Currently, units can only cross at certain beach sections, in order to avoid nesting California least terns (DoN 2002a).

Behavior and Life History—The California least tern is usually a colonial nester. In native habitats the nest is a simple scrape in the sand or dirt that is lined with broken bits of debris or shells. In disturbed habitats (e.g., Lindbergh Field and North Island in San Diego Bay), birds nest in pavement cracks, gravelly areas and in ground depressions. Nests may be well separated or closely packed (Unitt 2004). Two or three eggs are laid and hatch within 19 to 25 d. The young fledge a short distance from the colony site within 3 wk; birds depart the colony site 4 to 8 wk after fledging. Adults and juveniles disperse widely after leaving the colony, but usually no farther north than the northern-most colonies in its range (Thompson et al. 1997). During late summer and fall, migrating California least terns often concentrate in coastal lagoons. Fall migration begins in late July to August, with the majority of terns leaving California by September (USFWS 1985). The terns migrate along the coast to their wintering grounds south of the U.S.

Foraging areas utilized by California least terns vary throughout the breeding and nesting season. During courting and incubation of eggs, California least terns forage farther from the nest site and over open/deeper waters. When chicks hatch, foraging tends to subsequently shift to more nearshore/shallow water habitat closer to colonies (Baird 1997). Length of foraging and peak foraging behavior typically occur from the end of May through mid-July after chick hatching. In San Diego

County, Unitt (2004) reported that some birds forage at inland locations during the middle of the breeding season; more birds forage inland in northern than southern San Diego County; and more California least terns go inland to forage after the young have fledged in late July and August.

Least terns forage by plunge-diving to catch prey in upper surface waters. Prey species include anchovies, topsmelt, silverside smelt, opaleye, and gobies (Baird 1997). Prey species composition varies during the year depending on availability. Estuaries, particularly eelgrass areas, are important foraging areas because they provide habitat for topsmelt, one of the California least terns' preferred prey species (Baird 1997).

- **Western Snowy Plover (*Charadrius alexandrinus nivosus*)**

Description—The western snowy plover is a sparrow-sized shorebird 15 to 17 cm long, with a wingspan of 43 cm. This species has a pale gray-brown back which provides camouflage on sandy beaches, and a white neck collar and belly (Page et al. 1995; National Audubon Society 1998; Sibley 2000)). Individuals have a black/brown forehead bar and eye patches; large eyes; a small black mark on both sides of the breast; thin, somewhat long, blackish bills and legs; and short wings (National Audubon Society 1998; Sibley 2000). The head and body of this plover have been described as "roundish". During the breeding season, adults develop dark markings on the head and breast; these are generally black on males and brown on females. These markings exist in juveniles as well, although they are less conspicuous (National Geographic Society 1999). Males will also develop rufous crowns early in the breeding season. During the non-breeding period, adults lose their breeding plumage, and the sexes become indistinguishable. Usually three or four wk after hatching, juveniles become indistinguishable from adults as their juvenile plumage (white edges on wing coverts and scapulars) fades.

Status—Once widely distributed and abundant along the Washington, Oregon, and California coasts, this Pacific Coast breeding population has been reduced to about 2,000 birds (USFWS 1995; USFWS 2001b). In California, the population of western snowy plovers has been fluctuating between 1,000 and 2,000 birds over the past 30 yr (USFWS 2007b). In 1993, this population was listed as threatened under the ESA (USFWS 1993). A petition was set forth to delist the species in 2004; however, following a status review, the petition was deemed unwarranted (USFWS 2006c; USFWS 2006b). The species is still currently listed as threatened and the USFWS issued the latest recovery plan in 2007 (USFWS2007b).[8]

The western snowy plover is currently designated as a Bird Species of Special Concern in the state of California and is protected within 81 km of the coastline.[9,10] Based on window surveys conducted by the Point Reyes Bird Observatory during the 1977 to 1980 breeding seasons, this species had disappeared from a large portion of its coastal breeding range by 1980 (Page and Stenzel 1981). During the initial population surveys conducted in California in 1977, 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 declined to 19 birds. By 2002, the Humboldt population had increased to 63 individuals (although Del Norte County still did not support western snowy plovers) (USFWS 2007b).

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 2001b). In an effort to alleviate these impacts, the USFWS (**Figure 3-23**) (USFWS 2005b) designated critical habitat at 32 sites along the coasts of Washington, Oregon and California. Twenty-four critical habitat units have been designated in the SOCAL/Pt. Mugu Study Area or along adjacent coastline areas, extending from San Luis Obispo County south to San Diego County (**Figure 3-23**). Military properties in these areas may be exempted from critical habitat designation on the basis of several exclusions. In 2004, the ESA was amended under the National Defense Authorization Act (Pub. L. 108–136) to address the relationship of Integrated Natural Resources Management Plans (INRMPs) to critical habitat by the addition of section 4(a)(3)(B). This provision prohibits designation of critical habitat on lands owned or controlled by the

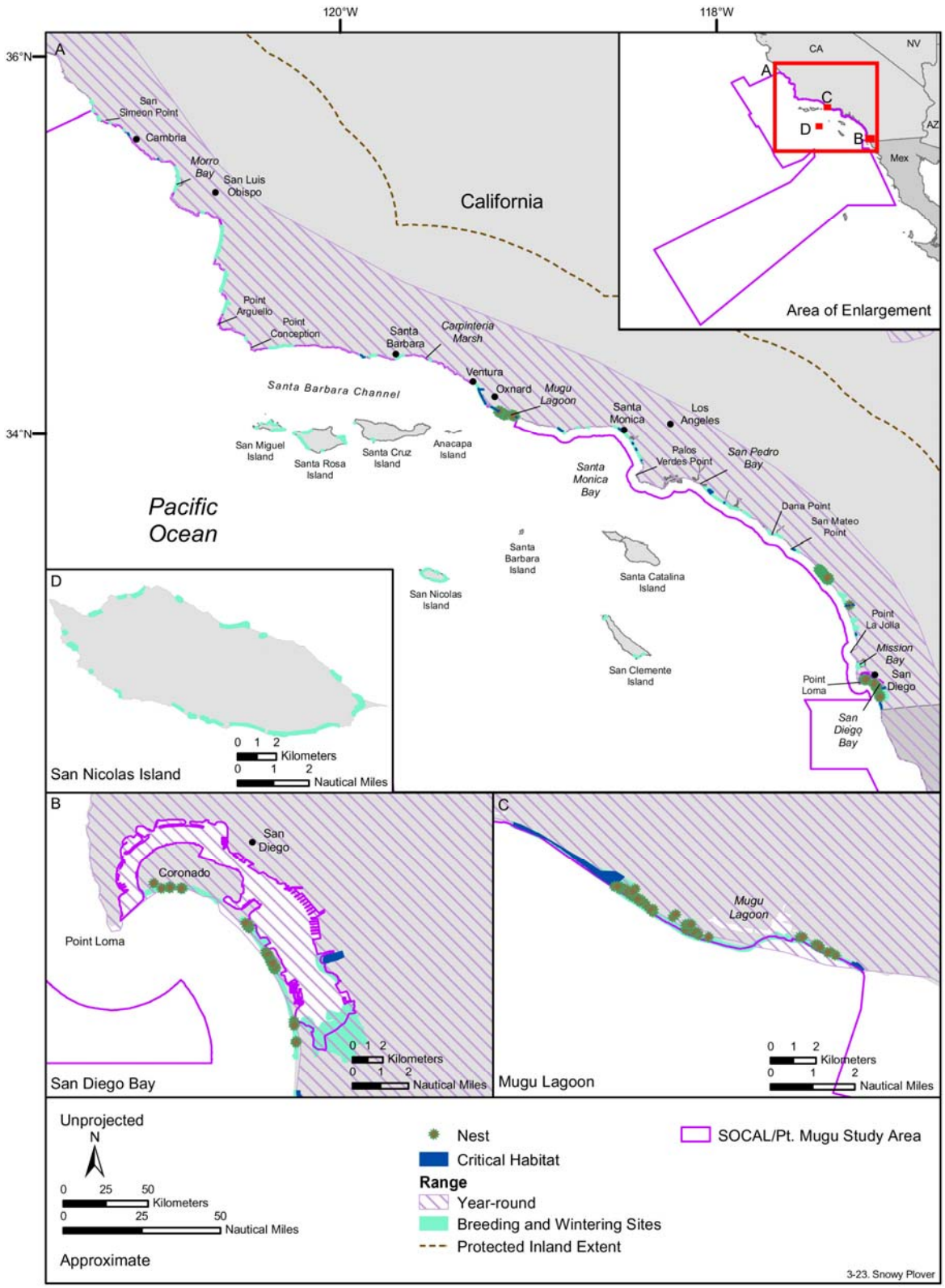

Figure 3-23. Recorded nesting sites, year-round range, critical habitat and wintering (November 1 to February 29) and breeding (February 1 to September 30) sites for the western snowy plover in the SOCAL/Pt. Mugu Study Area. Source data: NOS (2001), Ridgely et al. (2005), NOS (2006) and USMC and DoN (2007b). Source information: USFWS (2001).

DoD that are subject to an INRMP prepared under section 101 of the Sikes Act (16 U.S.C. 670a), providing the Secretary of the Interior determines that such plan provides a benefit to the species for which critical habitat is proposed for designation (USFWS 2005b). Also, ESA section 4(b)(2) mandates critical habitat designation or revision must be based on the best scientific data available after taking into consideration the economic impact, the impact on national security, and any other relevant impact prior to final critical habitat designation (USFWS 2005b). All or certain portions of San Nicolas Island, NAB Coronado, Naval Base Ventura County and MCB Camp Pendleton have been exempted from critical habitat designation pursuant to ESA section 4(a)(3) based on legally operative INRMPs that provide a benefit to the western snowy plover. Critical habitat designation on VAB is exempted under ESA section 4(b)(2) based on impacts to national security (USFWS 2005b).

Habitat Associations—The Pacific Coast population of the western snowy plover prefers beaches, flats, and other sandy areas with little vegetation (National Audubon Society 1998; National Geographic Society 1999). This species breeds (as early as 1 February to 30 September) and winters (1 November to 29 February) primarily on coastal beaches, including sand spits, dune-backed beaches, beaches at river and creek mouths, and lagoon/estuarine saltpans (**Figure 3-23**) (Page et al. 1995; USFWS 2001b). 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 or debris (Widrig 1980; Page and Stenzel 1981). Although western snowy plovers move up and down the west coast year-round, they primarily winter on the same beaches used for breeding. The waterlines of these same beaches constitute their foraging habitat (Page et al. 1995).

Distribution—The Pacific Coast population of the western snowy plover extends from the mudflats and sandy beaches of Grays Harbor (Damon Point), Washington, south to Baja Sur, Mexico. During the breeding season, western snowy plovers can be found at three nesting beaches in Washington, eight locations in Oregon, and about 25 locations in California (three in Humboldt County) (USFWS 2001b; Colwell et al. 2002; USFWS 2005b). Wintering birds can be found from southern Washington to Central America (USFWS 2001b). Some coastal birds remain on or near their breeding beaches, while others migrate south or north (USFWS 2001a). The coastal beaches of California are also used by snowy plovers migrating from inland breeding locations. Migration patterns are varied; in California, about a quarter to a half of the birds are year-round residents, while the remaining migrate north or south (Page et al. 1995).

- Information Specific to the SOCAL/Pt. Mugu Study Area—The western snowy plover occurs in the Study Area year-round. There are eight geographic areas which support around three-quarters of California's coastal breeding population. Six of these areas are located in the SOCAL/Pt. Mugu Study Area and include Morro Bay, the Callendar-Mussel Rock Dunes area, Point Sal to Point Conception, the Oxnard lowland, Santa Rosa Island, and San Nicolas Island (**Figure 3-23**) (Page et al. 1995). Western snowy plovers winter in roughly the same areas they breed (**Figure 3-23**) (USFWS 2007b).

Behavior and Life History—Breeding season for the Pacific Coast population of the western snowy plover occurs from 1 March through 30 September. In southern California, breeding can begin 2 to 4 wk earlier than in the rest of the Pacific Coast population. Some courtship activities in the southern California breeding population have been observed during February (USFWS 2001b). Western snowy plovers are generally monogamous breeders, but females may mate with another male after one clutch. Breeding pairs usually nest away from other birds, and the male defends the nest site from invaders (National Geographic Society 1999). The breeding season is protracted, and females often produce two or even three clutches in a single season. Eggs are layed in a sandy pit which is either lined with shell fragments or some blades of grass (National Audubon Society 1998). Clutch sizes are usually three or four eggs. Western snowy plovers can sometimes produce up to two broods (Warriner et al. 1986; Page et al. 1995; National Geographic Society 1999, 2003). Both sexes incubate, and the eggs hatch in 3 to 4 wk (Warriner et al. 1986; National Geographic Society 2003). Females generally leave the tending of the chicks to the males, preferring to initiate new nests with

new males (Page et al. 1995). Chicks are precocial and can fledge three to four wk after hatching (National Geographic Society 2003).

The western snowy plover emits a low sounding call described as a "krut" as well as soft whistling sounds (National Geographic Society 1999, 2003). Their calls are pleasant sounding and have a melodious nature. During the breeding season their vocalizations grow more complex and are accompanied by aerial displays (National Geographic Society 2003).

Pacific Coast populations of western snowy plovers feed on insects, crustaceans, worms, and other small marine species. During the breeding season they consume a great deal of calcium, and at times they feed on berries and seeds (National Audubon Society 1998; National Geographic Society 2003). When foraging, western snowy plovers run a short distance and then abruptly stop to pluck potential prey from the ground. They repeat this behavior as they move along a shoreline in search of food. Using sight, these plovers locate their food, which usually consists of motile prey found on the surface of the sand. If the prey attempts to escape by burrowing in the sand, the plover attempts to draw it to the surface by stomping on it. Western snowy plovers feed mostly during the day. They forage in small, dispersed groupings, and defend their foraging territory against other groups of western snowy plovers (National Geographic Society 2003).

- **Ashy Storm-Petrel (*Oceanodroma homochroa*)**

Description—The ashy storm-petrel is a small marine bird measuring 19 to 20 cm in length with a 43-cm wingspan (National Geographic Society 1999). This storm-petrel is mostly black with ashy colored plumage on the head and neck as well as some light coloring under the wings (National Audubon Society 1998; National Geographic Society 2003). This species has also been described as grayish-brown in coloring (National Geographic Society 1999) or "smoke-gray" (Wolf 2007). The ashy storm-petrel is the second smallest storm-petrel of all of the dark colored species off the U.S. Pacific coast.[11] This species has a forked tail which helps with maneuverability and rounded wings that are structured for powered flight (National Audubon Society 1998; National Geographic Society 2003). Ashy storm-petrels appear "long-tailed" when viewed from the side (National Geographic Society 1999). The bird is tubenosed like other storm-petrels and has a very well-developed sense of smell. Also, like other storm-petrels, this species has relatively long legs and webbed feet, which are not ideal for walking on land but are instrumental for their unique foraging behavior. Males are indistinguishable from females (National Geographic Society 2003). Ashy storm-petrels are difficult to identify in the field because of their small size and resemblance to other storm-petrels.[12]

Status—The estimated population of the ashy storm-petrel is approximately 5,200 to 5,400 individuals (National Geographic Society 2003; Wolf 2007). The ashy storm-petrel was identified by the USFWS as a Bird of Conservation Concern in 2002 and a likely candidate for listing under the ESA (USFWS 2002). As recently as 2007, the Center for Biological Diversity filed a petition to the USFWS to list the ashy storm-petrel as threatened under the ESA, to which USFWS has recently responded to by commencing a status review to see if the petition request is warranted (USFWS 2008b; Wolf 2007). According to the CDFG, the species still has a federal status of "none" while its state status is "Species of Special Concern".[13]

The South Farallon Islands, which contain the world's largest population of the species, have experienced a 42% decline over two decades. Another long-term study that took place at Santa Cruz Island (located in the species' southern range), revealed a population decline at two of five sites in the area, and the region also experienced the loss of three nesting colonies. A 36-yr study from 1971 to 2006 revealed that the reproductive success of the species in these two locations was found to decrease significantly as well. According to the Center for Biological Diversity, if the aforementioned trends continue, the ashy storm-petrel could possibly become extinct in the not too distant future, and thus the protections recognized under the ESA are warranted (Wolf 2007).

Habitat Associations—The ashy storm-petrel is a pelagic species which typically only comes ashore to breed and raise young (National Audubon Society 1998; Sibley 2000; National Geographic Society

2003). Ashy storm-petrels nest underground in existing burrows excavated by other seabirds or in crevices on rocky islands (Wolf 2007). Nesting activity usually takes place at night on islands (as opposed to the coastline) to avoid predators. After their long breeding season, which takes place approximately from March to December, the storm-petrels return to their offshore marine habitat (Ainley et al. 1976; McIver 2002; National Geographic Society 2003; Wolf 2007).

Distribution—The ashy storm-petrel has a range estimate of 227,000 km^2 which is limited to the pelagic waters off California and Mexico (National Geographic Society 2003; Wolf 2007, **Figure 3-24**). This storm-petrel nests on some islands offshore from the central and southern parts of the state, as well as northern Baja California, Mexico. It breeds at 17 different locations including Bird Island, the South Farallon Islands, six of the eight Channel Islands (San Miguel, Santa Cruz, Anacapa, Santa Barbara, Santa Catalina, and San Clemente islands) and the Coronados Islands off Mexico (Carter et al. 1992; Ainley 1995). The species has a restricted offshore foraging range which is confined to continental slope waters extending from northern California to northern Baja California. Approximately 89% of the global population of the ashy storm-petrel is located at the South Farallon Islands, San Miguel Island, and Santa Barbara Island (Wolf 2007). Ashy storm-petrels are overall a sedentary species; they are unique among storm-petrels in that they do not "disperse" across the oceans but remain relatively close to their breeding sites (Ainley et al. 1976; Schreiber and Burger 2002).

- Information specific to SOCAL/Pt. Mugu Study Area—Half of the global ashy storm-petrel population is concentrated in the Channel Islands located within the SOCAL/Pt. Mugu Study Area. Among the Channel Islands, the ashy storm-petrel is reported to breed on Prince Island, San Miguel Island, Santa Cruz Island, Santa Barbara Island, and San Clemente Island (**Figure 3-24**) (Carter et al. 1992; Wolf 2007). Ashy storm-petrels have a protracted breeding season, occupying nesting colonies for most of the year. Egg laying is asynchronous resulting in some pairs laying eggs, while other pairs are in the chick rearing stages (Wolf 2007). The breeding season for the Ashy storm-petrel in the SOCAL/Pt. Mugu Study Area spans from March through December (Wolf 2007). Adults usually visit the island breeding sites in February prior to breeding.[11] The very brief nonbreeding season occurs approximately in January and February (McIver 2002; Wolf 2007).

Behavior and Life History—Ashy storm-petrels are monogamous, breeding on rocky islands close to land and then dispersing farther offshore after the breeding season (National Geographic Society 2003). Courtship occurs during the night within the burrow. After copulation, the female goes offshore to feed. Both sexes incubate the eggs; however, it is common for only half of the eggs to hatch (Sibley 2000). Hatching occurs after 40 to 60 d. Females usually lay at least one white egg marked with a ring of red speckling. The eggs are typically layed in some sort of a crevice or a burrow (National Audubon Society 1998; Sibley 2000; National Geographic Society 2003). The young fledge at 7 to 11 wk from late summer to late winter (National Geographic Society 2003).

The wingbeats of the ashy storm-petrel are typically shallow and fluttery, but the flight is direct (National Audubon Society 1998; National Geographic Society 1999). They fly close to the water most of the time (National Geographic Society 2003). While generally silent at sea, they make purring noises when near the nest area and a squeaking sounds when over the colony (Sibley 2000).

Birds in the storm-petrel family feed mainly on plankton, squid, and small fish. Storm-petrels are known for their unique foraging behavior, which involves hovering over the surface of the water and "pattering" the water with their webbed feet to attract prey to the surface (Sibley 2000). When prey appears it is captured on the wing by the bird's hooked bill (National Geographic Society 2003). In southern California, the ashy storm-petrel feeds on spiny lobster larvae and small fish as well as other plankton and algae (National Audubon Society 1998). This species, like other storm-petrels, excretes an orange oil when it is disturbed (National Audubon Society 1998).

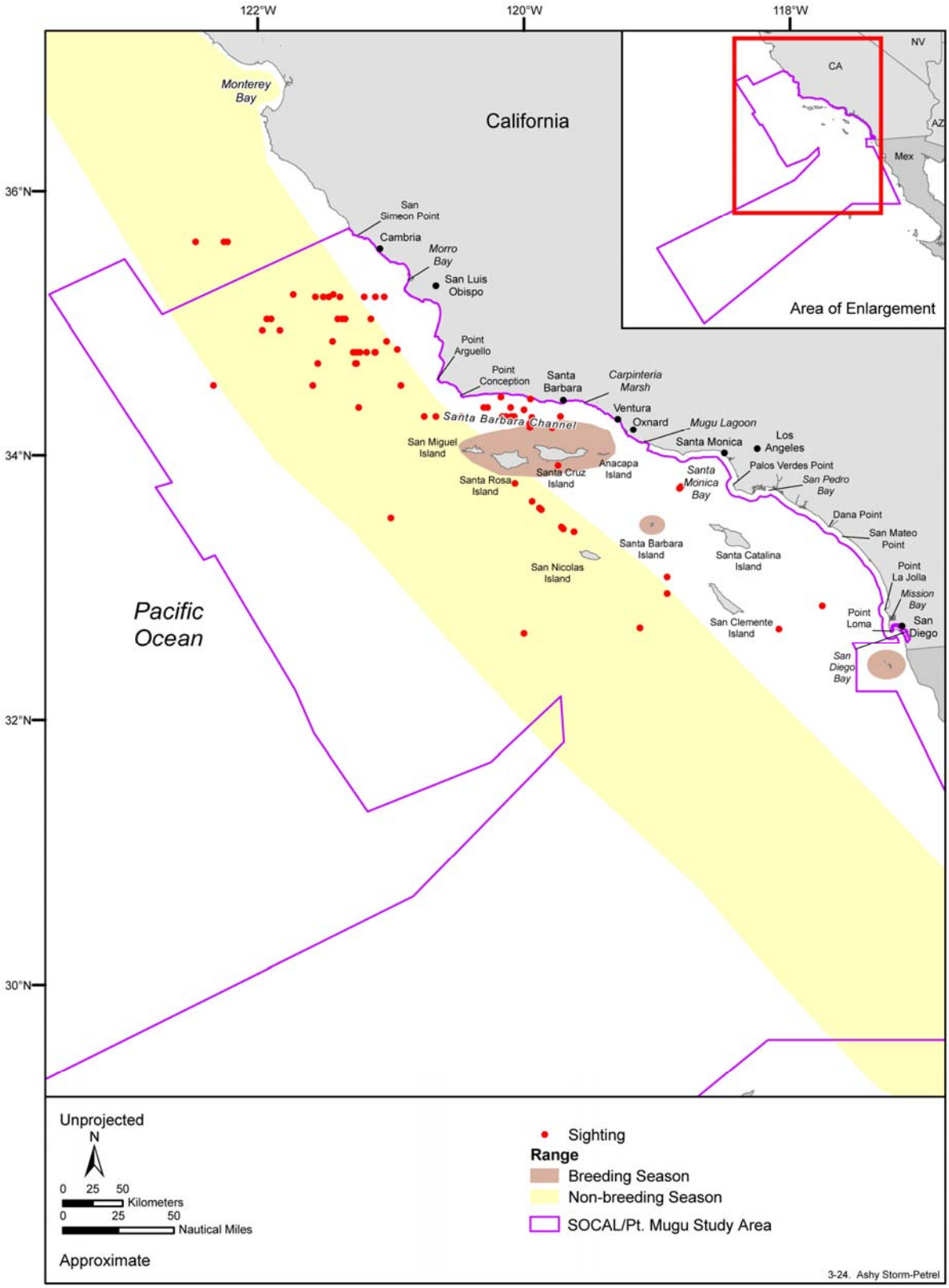

Figure 3-24. Sightings and breeding (March through December) and nonbreeding (January and February) ranges for the ashy storm-petrel in the SOCAL/Pt. Mugu Study Area. Source data: Bonnell and Ford (2001) and Ridgely et al. (2005).

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3.4 FISH AND INVERTEBRATES

3.4.1 Introduction

The SCB is one of the most productive marine environments off the west coast of California. Primarily, the SCB is unique because the geography causes the southward-flowing California Current to flow offshore before intersecting the coast in northern Baja California, creating a countercurrent mixture of warm southerly and cold northerly flowing waters (Schiff et al. 2000). Because of the combination of varied topography and oceanic conditions within the SOCAL/Pt. Mugu Study Area, there are many diverse habitats (rocky, sandy, mud, hard bottom, kelp beds) for marine fishes. Numerous fish species utilize spawning, nursery, feeding, and seasonal grounds in nearshore, inshore (including bays and estuaries), and offshore waters of the Study Area (Cross and Allen 1993). Approximately 480 species of marine fish and over 5,000 species of marine invertebrates inhabit the SCB (Cross and Allen 1993; Schiff et al. 2000; DoN 2002). Fish and invertebrates are essential components of the marine ecosystem in the SOCAL/Pt. Mugu Study Area.

3.4.2 Fish and Invertebrates of the Southern California/Point Mugu Study Area

Of the ESA-listed marine fish and invertebrate species under the purview of either the NMFS or the USFWS, two fish species (tidewater goby, *Eucyclogobius newberryi*, and steelhead, *Oncorhynchus mykiss*) and one invertebrate species (white abalone, *Haliotis sorenseni*) are known to occur or have the potential to occur in the SOCAL/Pt. Mugu Study Area (**Table 3-7**). The black abalone (*Haliotis cracherodii)* was recently proposed to be listed as endangered under the ESA (NMFS 2007a). In addition, two fish species (bocaccio, *Sebastes paucispinis*, and cowcod, *Sebastes levis*) and three invertebrate species (pink abalone, *Haliotis corrugata,* green abalone, *Haliotis fulgens,* and pinto abalone, *Haliotis kamtschatkana*) are designated as species of concern (NMFS 2004). As previously discussed in **Section 1.3.1**, these species are being considered by Secretary (of Commerce or Interior) for listing as endangered or threatened but are not yet the subject of a proposed rule (50 CFR 424.02). Therefore, these species are not discussed further in this MRA.

Each fish and invertebrate species is listed below with its description, status, habitat associations, distribution (including occurrence in the SOCAL/Pt. Mugu Study Area), and behavior/life history information. Acoustics and hearing information is also provided for the fish species.

Table 3-7. Protected fish and invertebrate species with known or potential occurrence in the SOCAL/Pt. Mugu Study Area and vicinity.

Classification	Scientific Name	Status	Evolutionary Significant Unit (ESU)
Class Osteichthyes (fish)			
Family Gobiidae (gobies)			
Tidewater goby	*Eucyclogobius newberryi*	Endangered	
Class Osteichthyes (fish)			
Family Salmonidae (salmon)			
Steelhead	*Oncorhynchus mykiss*	Threatened	South-Central California Coast
Class Osteichthyes (fish)			
Family Salmonidae (salmon)			
Steelhead	*Oncorhynchus mykiss*	Endangered	Southern California
Class Gastropoda (gastropods, slugs, and snails)			
Family Haliotidae (abalones)			
White Abalone	*Haliotis sorenseni*	Endangered	

3.4.2.1 Fishes

- **Tidewater goby (*Eucyclogobius newberryi*)**

Description—The tidewater goby is a small, elongate, benthic fish that rarely exceeds 50 millimeters (mm) SL. This species is characterized by having large pectoral fins with the pelvic fins joined to each other below the mid-body section anterior of the anus. The first dorsal fin has five to seven hard spines, the second dorsal has 11 to 13 soft rays, and the anal fin has 11 to 13 soft rays (USFWS 2005). In general, tidewater goby are grey-brown or olive with black flecking, and the body is covered with various small, fine, pearly-white spots (Swift et al. 1989).

Status—The tidewater goby is listed as endangered under the ESA, mainly as a result of population declines due to habitat degradation or loss from farming, coastal developments, pollution, and introduced species (USFWS 2005). Estimating tidewater goby metapopulations has been difficult primarily since the species is short-lived and population sizes fluctuate according to annual and seasonal environmental conditions (USFWS 2005). No overall reliable population estimates are available. The NMFS tidewater goby recovery plan defines six tidewater goby recovery units. From north to south, these units are: North Coast, Greater Bay, Central Coast, Conception, Los Angeles/ Ventura, and South Coast. The six recovery units are based on morphological and molecular data or on geomorphology where other data are lacking (USFWS 2005). Recovery units are further subdivided into sub-units (localities), which are considered different from each other genetically. The recovery plan lists localities that have been occupied by tidewater goby at least since the 1940s when better records of the species were available. The tidewater goby is estimated to occur at 135 localities within its historical range. Of these localities, 23 (17%) are considered extinct and 55 to 70 (41 to 52%) comprise extremely small populations. Currently, the population is believed to be found at 112 locations throughout the California coast (USFWS 2006).

ESA designated critical habitat for the tidewater goby was originally designated for 10 coastal stream segments encompassing 9 linear miles in Orange and San Diego counties, California (USFWS 2000). In 2008, an additional 44 critical habitat units totaling 4,053 ha were designated as critical habitat encompassing 12 coastal counties ranging from Del Norte County in northern California to Los Angeles County in southern California (**Figure 3-25**). No overall population estimates are available for these recovery units (USFWS 2008). Within the SOCAL/Pt. Mugu Study Area and vicinity, MCB Camp Pendleton and VAB are currently exempt from the critical habitat designation under Section 4(A)(3) of the ESA (USFWS 2008).

Habitat Associations—The tidewater goby is found in slow-moving, shallow, estuarine California coastal streams; backwater marshes; lagoons; and freshwater tributaries that flow into the Pacific Ocean (Swift et al. 1989). This species is often found at the mouth of coastal streams and marsh areas and typically at the brackish (freshwater-saltwater) interface zone (Swenson and McCray, 1996). The tidewater goby has never been found in areas where the coastline is steep, where the streams do not form lagoons (USFWS 2005), or where water velocities are greater than 0.15 m/s (USFWS 2006). The tidewater goby is able to tolerate seasonal fluctuations in water flow (winter rains versus summer) which can, at times, scour benthic sediments. This species is also able to tolerate a wide range of salinity (1.0 to 37.8 psu), temperature (9.0° to 25.4°C), and dissolved oxygen levels (0.2 to 15.5 mg per liter [mg/L]) (Swift et al. 1989). This species is associated with shallow (<1 m) sandy benthic waters with low salinities (10 to 15 psu). Reproduction occurs in waters ranging from 9° to 25°C and at salinities ranging from 2 to 27 psu (Swenson and McCray 1996). Tidewater gobies are usually found in association with sandbars; submerged or emergent vegetation utilized for shelter; and areas with rocky, muddy, or silty substrates (USFWS 2006).

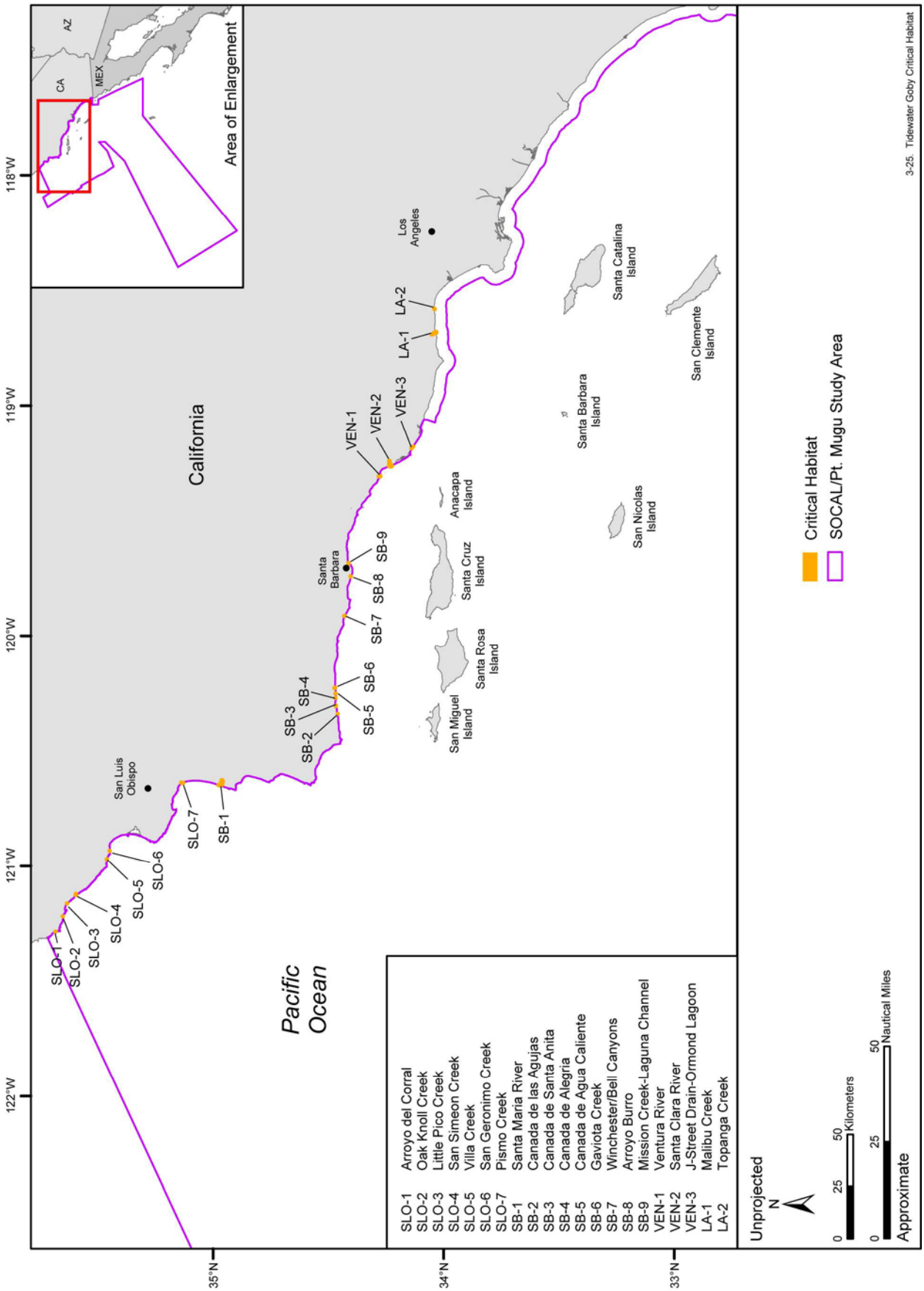

Figure 3-25. Designated critical habitat for the tidewater goby in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: USFWS (2008).

Distribution—The tidewater goby is limited to the coastal areas of California (Eschmeyer et al. 1983; Swift et al. 1989). Historically, this species ranged from Tillas Slough (mouth of the Smith River, Del Norte County, California) near the Oregon border to the Agua Hedionda Lagoon, which is located in Northern San Diego County, California. Currently, this species is still distributed throughout its historical range, except the southernmost extent of its range is in Cockleburr Canyon, 14.8 km north of Aqua Hedionda Lagoon (USFWS 2005).

- Information Specific to the SOCAL/Pt. Mugu Study Area—While no tidewater goby life history stages are found in the open ocean marine environment, tidewater gobies are found in marine coastal lagoon systems and, thus, may potentially be found within or in the vicinity of the SOCAL/Pt. Mugu Study Area. Of the 44 critical habitat units designated as tidewater goby critical habitat, there are a total of 15 tidewater goby critical habitat units that are found along the coastline adjacent to the SOCAL/Pt. Mugu Study Area. Of these 15 tidewater goby critical habitat units, 13 [SB-1 (Pismo Creek) through VEN-3 (J Street Drain-Ormond Lagoon)] are found within the Pt. Mugu OPAREA, and two (LA-1 and LA-2) are found just inshore of the SOCAL OPAREA (**Figure 3-25**).

Behavior and Life History—Tidewater goby size-at-maturity is around 27 mm SL (Swift et al. 1989). Spawning occurs year-round and peaks during the spring (late April or May to July) but may continue into the fall (November). Male tidewater gobies play a primary role in reproduction by excavating breeding burrows in unconsolidated, clean, coarse sand (0.5 mm in diameter) (USFWS 2005). They also monitor and protect the eggs until they hatch, which is approximately 9 to 11 d (Swift et al. 1989). After the eggs hatch, tidewater goby larvae are found in the water column, but as they mature, they switch to occupying the bottom substrate. In general, tidewater gobies only live for about 1 yr (Moyle 2002). Usually, most tidewater gobies expire after the spring spawning season (USFWS 2008).

As demersal fish, tidewater gobies feed mainly on macro-invertebrates such as crustaceans, arthropods, polychaetes, mysid shrimp, gastropods, gamarid amphipods, ostracods, and aquatic insects such as chironomid midge larvae (Swift et al. 1989; Swenson and McCray 1996). Diets are usually consistent but can vary slightly based on season and habitat with season being the main controlling factor (Swenson and McCray 1996). Diets are similar among juveniles and adults, and there are no diurnal preferences for tidewater gobies (Swenson and McCray 1996).

Acoustics and Hearing—Although few studies have investigated sound production and hearing abilities in fish, some information is available for the family Gobiidae since many of the species are known to produce and detect sounds for reproduction purposes. No specific studies have been conducted on the tidewater goby, but it is probable that this species has similar characteristics as other gobies in regards to sound abilities. Among various reproduction behaviors, the production and detection of sound is one of the most important attributes. For the painted goby (*Pomatoschistus pictus*), Amorim and Neves (2007) found that all male painted gobies actively courted females using two basic sounds: thump and drum. Most thump sounds were below 100 Hz and averaged around 4 s. Drumming sounds were produced less frequently and averaged around 300 Hz in only around 600 ms. In another study, Picciulin et al. (2006) found that the red-mouthed goby (*Gobius cruentaturs*) produced various sounds below 1.5 kHz to threaten intruders.

Sound production and detection in fish is often affected by the environment (Lugli et al. 2003). Thus, background noise has the ability to interfere with specific species sound production or detection (Lugli et al. 2003). Lugli et al. (2003) evaluated sound detection by gobies in relation to ambient noise. In laboratory studies, results showed that two Italian freshwater gobies, *Padogobius martensii* and Gobius *nigricans*, had similar hearing abilities. Both were most responsive at the 100 Hz sound level and hearing thresholds were 30 dB above the 1 S.D. of the nosiest location where gobies were measured. In addition, the study revealed that unlike other fish, the swimbladder, which is usually used for hearing, did not play a significant role in the resonation of sound (Lugli et al. 2003).

- **Steelhead (*Oncorhynchus mykiss*)**

Description—Steelhead coloration varies depending on the environment. In the marine environment adult steelhead generally have steel-blue coloration, silver-colored sides and ventral surface, and distinct black spots (< 0.6 cm in diameter) on their dorsal surface including the head, dorsal fin, and tail (Fry 1973). In the freshwater environment, the back may shade from blue-green to olive and there is a distinct reddish-pink band along each side about the midline that may range from faint to radiant. The lower sides are usually silver, fading to pure white beneath and there are small black spots above the lateral line, as well as on the upper fins and tail. In some locations, the black spots of adults may extend well below the lateral line and even cover the entire lower side. Adult steelhead typically range in size from 40 to 72 cm in length and 2.0 to 5 kg in body mass, while adult rainbow trout (freshwater version) typically range in size from 25 to 46 cm in length and 0.5 to 2.0 kg in body mass (Augerot and Foley 2005).

Status—A total of 26 salmonid ESUs are listed under the ESA: five are endangered and 21 are threatened. Currently, 15 DPSs of steelhead are designated in Washington State, Oregon, Idaho, and California. Within the vicinity of the SOCAL/Pt. Mugu Study Area, there are two steelhead DPSs: the threatened South-Central Coast DPS and the endangered Southern California DPS (NMFS 1997; NMFS 2007d). The overall population status for both of these DPSs is uncertain due to the lack of reliable population estimates. Based on the best available information, the South-Central Coast DPS population are estimated to have declined from annual runs totaling 25,000 spawning adults to less than 500. Available historical information indicates that the Southern California DPS run in four of the major river systems was once between 32,000 and 46,000 adults (NMFS 2007d). Today, recent run size for the same four systems (Santa Ynez River, Ventura River, Santa Clara River, and Malibu Creek) is estimated to be fewer than 500 adults.

In 2005, NMFS designated 30 occupied watersheds (1,250 mi of stream habitat and 3 mi^2 of estuarine habitat) as ESA designated critical habitat (NMFS 2005) for the South-Central Coast DPS. NMFS also designated 32 watersheds and 708 mi of stream as ESA designated critical habitat for the Southern California DPS (NMFS 2005); **Figure 3-26**). Although there may be essential habitat features for salmonids in the Pacific Ocean, no such areas have been identified or designated as critical habitat (NMFS 2005).

Habitat Associations—As a result of the steelhead's complex lifestyle, a variety of habitats (i.e., freshwater, brackish, and marine) are utilized at different life stages. When in freshwater habitats (i.e., as juveniles or freshwater residents), steelhead are more common in lakes than streams and are usually associated with fast flowing, cool (12°C), and highly oxygenated waters. In rivers and streams, McEwan and Jackson (1996) found that juveniles prefer areas of flowing water (i.e., riffles), while larger adults prefer areas of slower flowing water (i.e., pools or runs). In the marine environment, steelhead are found from nearshore to offshore areas with bottom depths of 200 m (Froese and Pauly 2005). The temperature preferences for steelhead vary by life stage (**Table 3-8** with fry and juvenile steelhead preferring warmer temperatures than spawning or adult steelhead (McEwan and Jackson 1996). Steelhead also have specific physical and chemical conditions for growth and development. Steelhead prefer water temperatures between 13° and 21°C, but can survive temperatures ranging from 0° to 28°C as long as the water is oxygen saturated (Emmett et al. 1991). In the freshwater environment, maximum growth occurs at pH levels between 7.0 and 8.0 (Emmett et al. 1991). Recently, Bond (2006) and Hayes (2008) evaluated the utilization of estuary lagoon habitats by the South-Central Coast DPS. Their results indicated that estuaries, particularly lagoons, are critical for the survival of steelhead in the southern areas of its range. These brackish lagoons provide protection from predators (marine mammals, prickly sculpin (*Cottus asper*), and birds) and provide feeding and growth opportunities which ultimately increase survival rates in the marine environment (Hayes 2008).

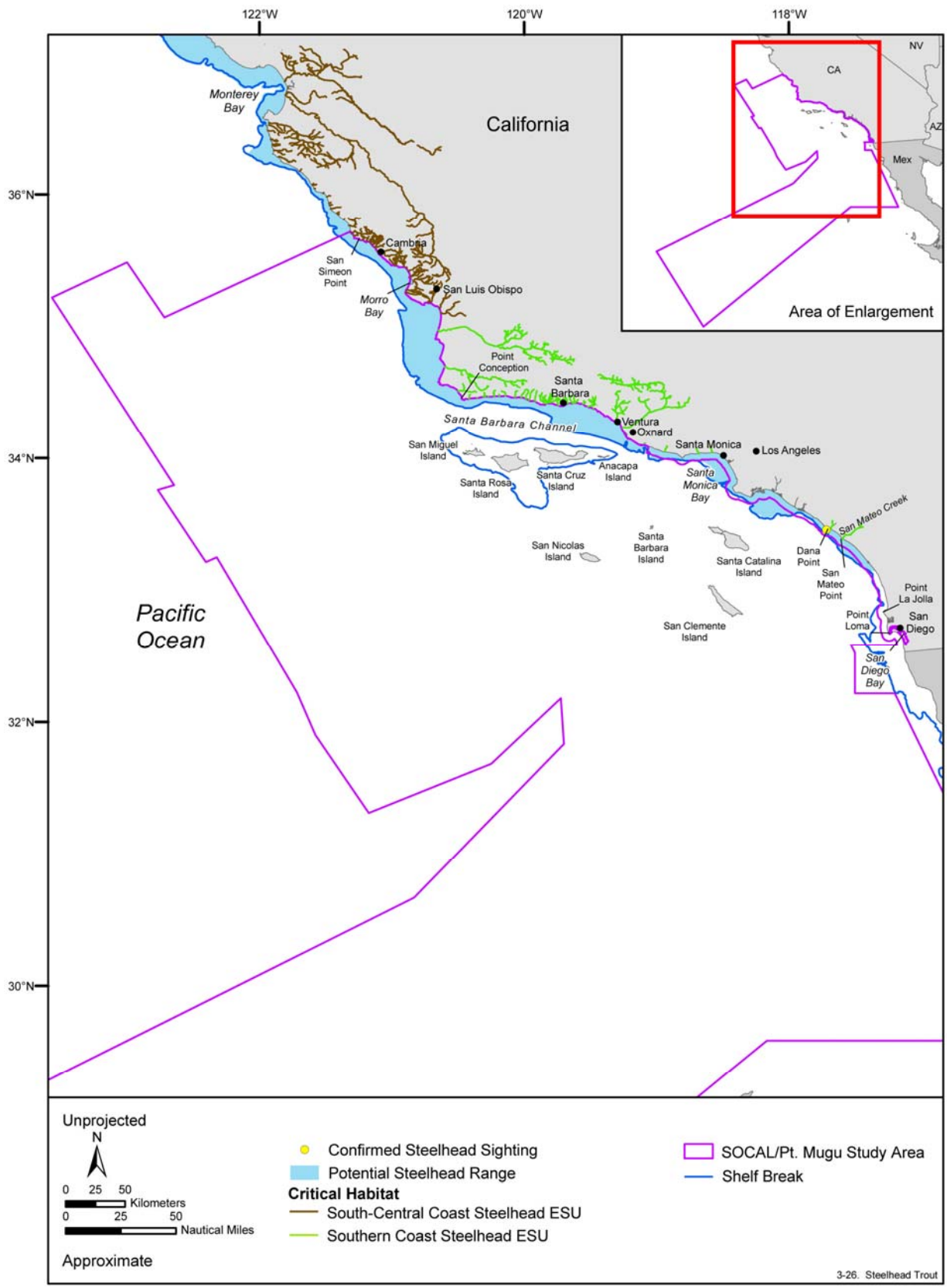

Figure 3-26. Designated critical habitat for the steelhead in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: NMFS (2005).

Table 3-8 Preferred water temperatures for various steelhead life stages (McEwan and Jackson 1996).

Lifestage	Temperature Range (°C)
Adult migration	7.8 to 11.1
Spawning	3.9 to 11.1
Incubation and emergence	8.9 to 11.1
Fry and juvenile rearing	7.2 to 15.6
Smoltification	<13.9

Distribution—Historically, steelhead were distributed from the southeastern Bering Sea to northern Baja California (Love et al. 2005). Current distribution of the South-Central Coast DPS includes all naturally-spawned populations of steelhead in streams from the Pajaro River (inclusive) in Monterey County to, but not including, the Santa Maria River in San Luis Obispo County (NMFS 1997). South-Central Coast DPS watersheds include Big Sur River, Little Sur River, and San Carpoforo and Arroyo de la Cruz creeks. The South-Central California Coast DPS is also known to occur in San Simeon, Santa Rosa, San Luis Obispo, Pismo, and Arroyo Grande creeks (NMFS 2007c). South-Central California Coast DPS distribution also includes those portions of coastal watersheds that are seasonally reachable by steelhead.

The Southern California DPS distribution includes all naturally-spawned anadromous steelhead populations below natural and man-made impassable barriers in streams from the Santa Maria River, San Luis Obispo County, California (inclusive) to the U.S./Mexico Border including the following watersheds: Santa Maria, Santa Ynez, Ventura, and Santa Clara River systems (NMFS 2007b) and a few small streams in Santa Barbara, Ventura, and northern Los Angeles counties as well as three watersheds in southern Orange and San Diego counties (San Juan Creek, San Luis Rey, San Mateo Creek). Although the range extends to the U.S/Mexico border, this species is considered extinct from the Santa Monica Mountains in California to the U.S./Mexico border (WCSBRT 2003), except for a small anadromous population located in San Mateo Creek.

- Information Specific to the SOCAL/Pt. Mugu Study Area—While steelhead early life history stages are only found in freshwater habitats and would not be within the SOCAL/Pt. Mugu Study Area, the later life history stages of the anadromous life form (i.e., juveniles and adults) may potentially be found in the marine environment within or in the vicinity of the Study Area. New occurrences of adult and/or juveniles in various freshwater drainages in southern California occur occasionally, but no new reports of steelhead in the coastal marine environment are available. Steelhead ocean distribution is poorly known and they are rarely if ever caught in the marine environment (unlike salmon). Nonetheless, steelhead must occur somewhere in the marine environment since they do migrate from freshwater to the ocean as part of their life history. (Wingert, C., NMFS-Southwest Regional Office, pers. comm., 3 April 2007). The California Cooperative Anadromous Fish and Habitat Data Program actively gathers, compiles, and analyzes fish and aquatic habitat data. The CalFish database has the most current information available regarding population trends and counts, migration, distribution, migration barriers, hatcheries, habitat restoration projects, genetics, and monitoring. According to the CalFish database, there is no current available information for steelhead distribution within the SOCAL/Pt.Mugu Study Area (Shannon, C., Pacific States Marine Fisheries Commission, pers. comm., 29 November 2007). Only one verified and confirmed steelhead has been documented within the Study Area. The fish was 51 cm long and was landed at Dana Point Harbor, California (approximately 14 km south of Laguna Beach and 12 km north of Camp Pendleton) on December 2002 (Strege 2003); Wingert, C., NMFS-Southwest Regional Office, pers. comm., 24 June 2004). The South-Central Coast DPS is expected to be rare in the SOCAL/Pt. Mugu Study Area since the Study Area is located in a small portion of this species' southern most extent of its known

range. The five major watersheds where this species is most commonly found are all north of the Study Area, and recent distribution information indicates that this species is mostly found inshore.

Behavior and Life History—Because of the complexity associated with steelhead life history, limited information is available for both the South-Central Coast and the Southern California DPS. Steelhead can either exhibit an anadromous life style (migrate as juveniles from freshwater habitats to marine environments and return to freshwater habitats to spawn) or exhibit a freshwater residency life style (commonly known as rainbow trout), residing only in freshwater (McEwan and Jackson 1996). Recently, a third life style group was accepted and termed the lagoon-anadromous which is characterized as temporally residing during the summer months in estuaries adjacent to natal creeks (Bond 2006; NMFS 2007c). Bond (2006) found that lagoon-anadromous forms have rapid growth during the first year of age and typically enter the marine environment larger in size than standard anadromous forms.

Anadromous steelhead typically spend the first two years in freshwater, migrate to the marine environment to spend 2 or 3 yr, and then return to the freshwater environment to spawn at 4 to 5 yr of age (NMFS 1997). Unlike other salmon that spawn once and expire, the steelhead is capable of spawning multiple times (Riva-Ross et al. 2007). Spawning usually occurs from December to June and peaks in February and March (NMFS 1997). After eggs are deposited and males have externally fertilized the eggs, females cover the eggs with small to medium size gravel (<85 mm), which are called redds (Emmett et al. 1991). Males protect redds during this period and spawning takes place during the day and night (Emmett et al., 1991). Females produce between 1,500 and 5,000 eggs; some large females can produce up to 12,000 eggs (Emmett et al. 1991). Eggs hatch between 3 and 8 wk depending on water temperatures (NMFS 2007b). Eggs are spherical, non-adhesive, and range in diameter from 3.0 to 6.2 mm (Emmett et al. 1991). Larvae or alevins are 14.0 mm long at hatching, and juveniles range in size from 2.8 to 40.6 cm (Emmett et al. 1991). The average steelhead lifespan is approximately 5 to 7 yr (McEwan and Jackson 1996; Augerot and Foley 2005) although a maximum age of 11 yr was recently reported for steelhead in Argentina (Riva-Ross et al. 2007).

Since steelhead are found in a variety of habitats, diets are unique, diverse, and change with life stage and time of year. In the mid-northern range of steelhead distribution, Pert (1993) discovered that the winter diet for juvenile steelhead consists primarily of aquatic invertebrates, such as mayflies (Ephemeroptera). Other important food items included miscellaneous aquatics consisting of the larvae of flies (Diptera) and beetles (Coleoptera). For young-of-the-year, steelhead primarily consumed zooplankton while juvenile and sub-adult steelhead fed upon amphipods, insects, and small fishes (Pert 1993). Adult steelhead diet consists of invertebrates, crustaceans, mollusks, small fish, and sometimes their eggs (Pert 1993; Froese and Pauly 2005). In the marine environment, steelhead diet consists of crustaceans, squid, and fishes (Emmett et al. 1991).

Acoustics and Hearing—Generally, acoustics and hearing information for fish are lacking (Popper et al. 2007). There is no specific acoustic or hearing information for steelhead; however, some hearing information is available for the Atlantic salmon (*Salmo salar*), which has a similar ear morphology to the steelhead (Popper et al. 2005a). Based on early studies, researchers found that Atlantic salmon can detect sounds at frequencies somewhat above 600 Hz; however, at above or around 150 Hz, the hearing sensitivity declines sharply (Abbott 1973; Hawkins and Johnstone 1978; Knudsen et al. 1992, 1994). In general, salmonids are unable to perceive high frequency sounds and have been documented to respond 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. Extrapolation to other fish species must be carefully examined since there can be significant differences in auditory systems between species (Hastings et al. 1996). This was later supported by Hastings and Popper (2005b) who cautioned against extrapolating information from Atlantic salmon to Pacific Coast salmonids. Although data on the ear anatomy of several salmonid species suggest that the auditory system is similar for all salmonids, extrapolation must be done with considerable prudence (Hastings and Popper 2005). Today, it is accepted that surrogate species, such as Atlantic salmon, rainbow trout (*Salmo gairdneri*), and Chinook salmon (*Oncorhynchus tshawytscha*) can be

used interchangeably since the fish are of the same genus, share similar ear anatomy, and share similar auditory systems (Popper et al. 2007).

3.4.2.2 Invertebrates

- **White Abalone (*Haliotis sorenseni*)**

Description—White abalone is characterized as having a thin, oval-shaped shell with rows of spiraling pores and a tan foot (a muscular organ used for locomotion) with an orange sole. The typical size ranges from 13 to 20 cm (measuring the widest part of the shell) and the maximum size is 25 cm (Hobday and Tegner 2000). The maximum weight is between 1 and 2 kg (Davis et al. 1996).

Status—The white abalone is listed as endangered under the ESA. White abalone survival and recovery continues to be negatively affected by reproduction failure (Hobday et al. 2001), rising sea surface temperatures (Vilchis et al. 2005), and diseases such as abalone withering syndrome or Rickettsiales-like prokaryote (WS-RLP) (Friedman et al. 2003). Because of these continuing threats, the current status and future is uncertain. It has been estimated that the current white abalone population is 1% of its historical level (Hobday and Tegner 2000). Hobday and Tegner (2000) used historical commercial landings and life history data to estimate the pre-exploitation population level at 725,518 abalone. There are no recent population estimates; however, the population is estimated to be between 15,187 and 22,123 abalone at Cortez Bank, Tanner Bank, and San Clemente Island, which are the only known locations for white abalone (Butler et al. 2006).

Because the CDFG estimates that approximately 4,800 abalone per day are taken illegally (NMFS 2006), the NMFS determined that there were more risks associated with the designation of critical habitat than benefits for white abalone due to concerns of increased poaching (NMFS 2001). As a result, ESA designated critical habitat for white abalone has not been defined. Nonetheless, it is believed that potential habitats exist between Point Conception, California and the California/Mexico border (**Figure 3-27)**. In particular, it is believed that much of the potential habitat is isolated in the deep waters off the Channel Islands. The white abalone does not have any defined DPS or ESU, it is believed to be one population (Hobday and Tegner 2000).

Habitat Associations—The white abalone is a cryptic, mostly sessile, benthic species that prefers rocky substrates (e.g., reefs and rock piles) with low relief areas surrounded by sandy areas (2006). Off southern California, white abalone typically inhabit depths ranging from 18 to 60 m with the highest densities occurring between 43 and 60 m (Hobday et al. 2001; Lafferty et al. 2004). Overall, habitat associations of white abalone are dependent on its main food source, attached or drifting brown algae (*Laminaria farlowii* and *Agarum fimbriatum*) (NMFS 2001). Thus, depth distribution is limited to water clarity and light penetration as well as substrate availability (Butler et al. 2006). It has been accepted that white abalone prefer the tops of most reef areas, but Cochrane et al., (2006) recently suggested that white abalone may only prefer edges of reefs (rock/sand boundary) rather than the middle sections of reefs. Historically, the estimated available habitat for white abalone was believed to be around 3% or 752 ha of the sea floor at depths between 25 and 65 m (1993). Butler et al. (2006) recently mapped 3,646 ha at just one location; thus, it is now believed that additional white abalone habitat may be available.

Distribution—White abalone were historically found between Morro Bay, California and Punta Rompiente, Baja California, Mexico (Geiger 1999). According to Hobday and Tegner (2005), white abalone was once abundant throughout its range, but was more common along the coast in the northern and southern extent of its range and more common near the Channel Islands (San Clemente and Santa Catalina islands) in the middle-portion of its range. In the southern end of the range, the species was also common around a number of islands, including Isla Cedros and Isla Natividad (Hobday and Tegner 2000). Today, white abalone have only been documented near the Channel Islands.

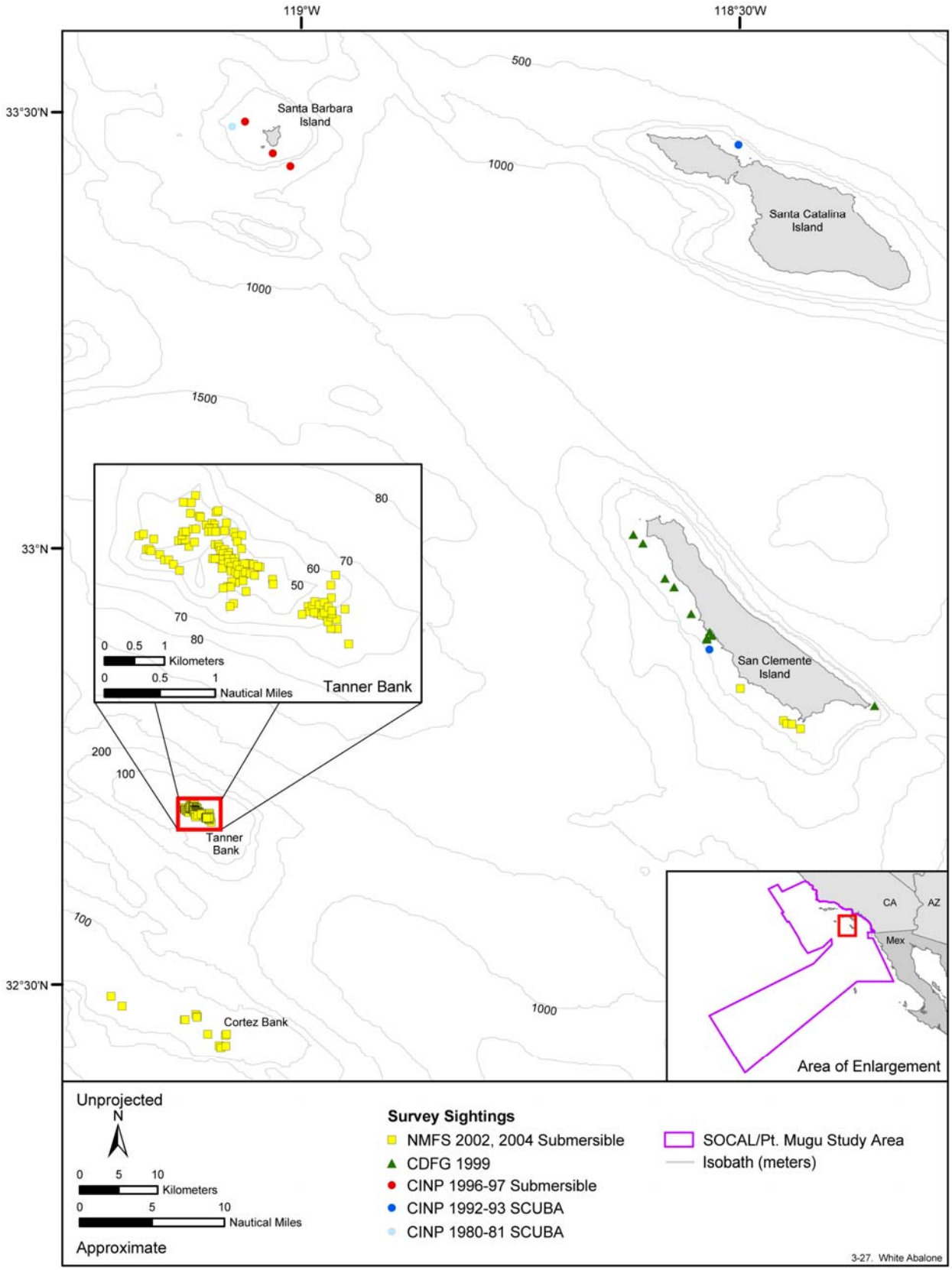

Figure 3-27. White abalone sightings in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Hobday and Tegner (2000), Haaker et al. (2001), and Butler et al. (2006).

- Information Specific to SOCAL/Pt. Mugu Study Area—All white abalone life stages may be found within the SOCAL/Pt. Mugu Study Area. Historically, white abalone populations were the greatest in southern California, especially around the Channel Islands (San Clemente and Santa Catalina) (Butler et al. 2006). Today, the species has only been found around the Channel Islands and along various banks within the area (Hobday and Tegner 2000; Rogers-Bennett et al. 2002); **Figure 3-28**). Since 1996, various researchers (Davis et al. 1996, 1998; Hobday and Tegner 2000; Butler et al. 2006) have conducted submersible surveys off Tanner and Cortes banks (approximately 80 km southwest of San Clemente Island) in order to map abalone habitat structure, examine distributions, and estimate the population size. Results found a total of 258 animals with 168 recorded on Tanner Bank in 2002, at depths ranging from 32 to 55 m. In 2004, 35 individuals were recorded at Tanner Bank, 12 at Cortez Bank, and 5 were found off San Clemente Island. Butler et al. (2006) also documented 1,359, 1,139, and 889 ha of available white abalone habitat at Tanner Bank, Cortez Bank, and the west side of San Clemente Island, respectively.

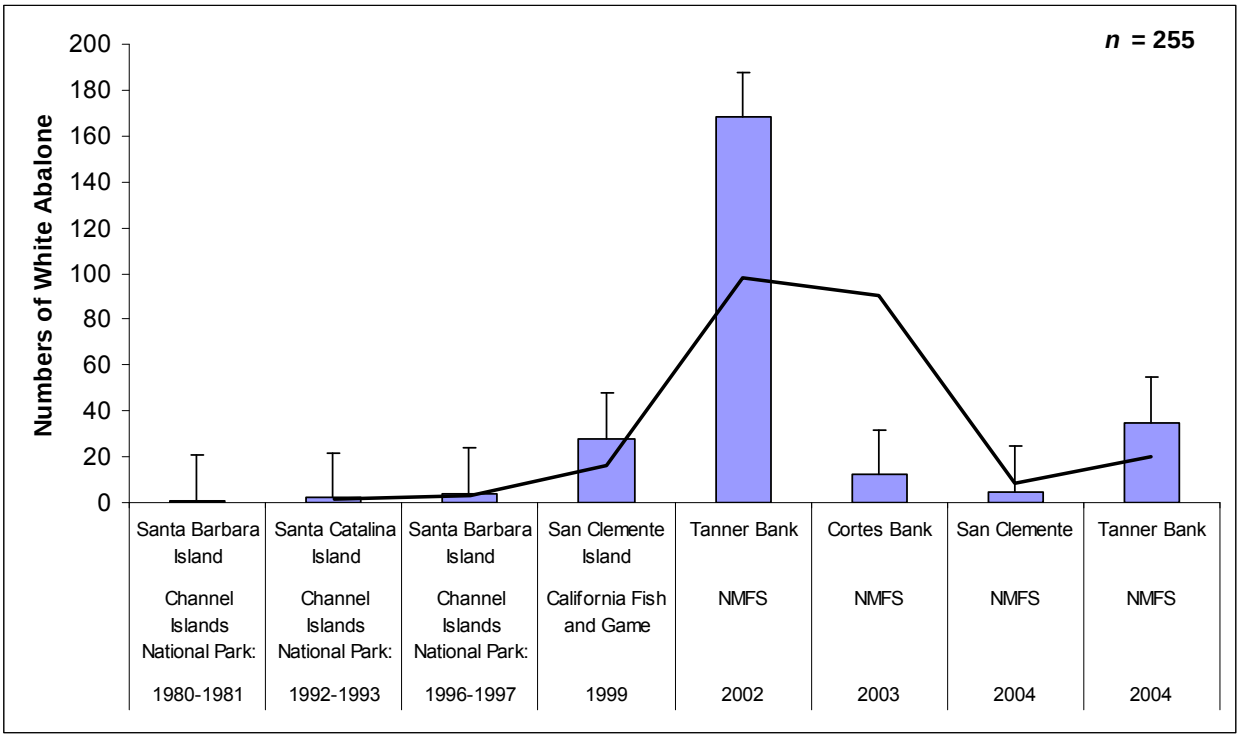

Figure 3-28. Recent white abalone survey data within the SOCAL/Pt. Mugu Study Area (2006). Mean ± 1 standard errors are plotted and trend line depicts moving average.

Behavior and Life History—Limited information is available on white abalone behavior and life history. Successful abalone recruitment is correlated with spawning density, fecundity, the spawning period, and duration (Davis et al. 1996, 1998; Hobday and Tegner 2000; Butler et al. 2006). Similar to other mollusks, white abalone reproduce via broadcast spawning. Thus, at low adult densities, fertilization success can be compromised since white abalone are sessile animals and, therefore, need to be close to each other for successful fertilization to occur (Hobday and Tegner 2000). However, new information indicates that white abalone have been shown to use drift macroalgae (e.g., kelp [*Macrosystis pyrifera*]) as a potential dispersal mechanism in a controlled environment (McCormick et al. 2008). In the laboratory, McCormick et al. (2008) found, for the first time, that juvenile and small white abalone displayed a behavior that enables them to climb onto drift algae and remain there for extended periods, which could assist with recruitment, dispersal, and settlement in

the wild. White abalone sexually mature around three to seven years of age which corresponds to size between 88 and 134 cm (Hobday and Tegner 2000). Spawning occurs during February through April (Hobday and Tegner 2000) with one gametic cycle per year (Haaker et al. 2001; Leet et al. 2001). No field studies on white abalone fertilization success rates have been conducted; however, from a single laboratory study, fertilization success was estimated at 5% (Hobday and Tegner 2000). Regardless, broadcast spawning usually has a low success rate and is density dependent (Leighton 1972).

Once fertilized, eggs settle to the ocean bottom and hatch into free-swimming larvae. Before settlement, white abalone obtain energy from egg yolks (Levitan 2005). After settlement, white abalone feed mostly on diatoms before switching to drift or attached algae (e.g., *Laminaria farlowii* and sieve kelp, *Agarum fimbriatum*) as adults. Larvae take approximately 5 to 14 d to settle to the benthic intertidal and subtidal habitats before developing into an adult form (Leighton 1972). The larvae stage is more prolonged than for other abalone species; therefore, dispersal distances might be greater for white abalone than for other species (Leighton 1972; NMFS 2001). Juvenile abalone are commonly referred to as “cryptic abalone” and spend the majority of the time hiding under rocks or in crevices until reaching a size (75 to 100 mm) less vulnerable to predators. Juveniles are capable of moving tens of meters daily, while adults rarely move and are more sedentary. Compared with the other abalone species, the adult white abalone is considered one of the least mobile; these animals typically reside in a small area for the duration of their lives (Hobday and Tegner 2000). Although no validated white abalone aging information is available, the estimated maximum age through indirect methods is around 35 to 40 yr (Hobday and Tegner 2000).

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4.0 FISH AND FISHERIES

4.1 FISH/INVERTEBRATES

The SOCAL/Pt. Mugu Study Area is situated in a region of diverse ichthyofauna and highly productive fisheries (Leet et al. 2001). Of the 554 species and 144 families of California marine fishes (Miller and Lea 1972), approximately 481 species (87%) and 129 families (90%) occur in the SCB (Cross and Allen 1993). Predominant ecosystems found in the SOCAL/Pt. Mugu Study Area include nearshore coastal (i.e., rocky habitats, soft bottom, and estuaries), continental shelf (i.e., upwelling zones, inner portion of California Current, and rocky reefs), and oceanic (i.e., epipelagic, mesopelagic, and bathypelagic) systems. 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), nearshore, shelf, and slope groundfish (flatfish, rockfish, roundfish, skates and sharks), salmonids (Chinook salmon, coho salmon, and pink salmon and steelhead), highly migratory (tunas, sharks, billfish, swordfish, and dolphinfish), other relatively large pelagic fishes (louvar, *Luvarus imperialis*; oarfish, *Regalecus glesne*; opah, *Lampris guttas*; Pacific saury, *Cololabis saira*; common mola, *Mola mola*, black skipjack, *Euthynnus afinis*; and others), invertebrates (California spiny lobster, *Panulirus interruptus*; red sea urchin, *Strongylocentrotus franciscanus*; Dungeness crab, *Cancer magister*; ocean shrimp, *Panadalus jordani*; warty sea cucumber, *Parastichopus parvimensis*, etc.), and kelp beds.[1] Currently the SOCAL/Pt. Mugu Study Area supports habitats of “endangered” and “threatened” populations of steelhead salmon (*Oncorhynchus mykiss*), Tidewater goby (*Eucyclogobius newberryi*), and white abalone (*Haliotis sorensensi*) (NMFS 2001a; NMFS 2005c; NMFS 2005b; USFWS 2008). For additional information on these species refer to **Section 3.4**.

The SOCAL/Pt. Mugu Study Area falls within the 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 the planktonic food supply of diatoms and small plankters. These diatoms and small plankters provide food for euphausiids and many other zooplanktonic organisms (shrimps, copepods, salps, amphipods, etc.), which in turn forage for larger species nearer the apex of the food chain, such as highly migratory species (i.e., sharks, tunas, and swordfish), seabirds, and marine mammals (NMFS-SWR 2006).

Along the Pacific continental margin off central and southern California, ichthyofaunal distribution is influenced by depth, substratum type, temperature, and ocean currents (i.e., CCS), which when integrated produce fish habitat (Field et al. 2006; Love and Yoklavich 2006; NMFS-NWR 2006). The pelagic ichthyofauna is composed of endemic coastal and offshore species within a mixture of warm-temperate, southern element (San Diegan Province) and a cool-temperate, northern component (Oregonian Province) as well as a subtropical group (Panamanic species) primarily from the Cortez Province (Allen and Pondella II 2006; Horn et al. 2006). The CCS is dominated by small, planktivorous larval and schooling fishes such as northern anchovy, Pacific sardine, jack mackerel, chub mackerel, and the herring family (Clupeidae) (Allen and Cross 2006; Moser and Watson 2006). North-south differences in the composition and relative distribution of the dominant species is also apparent especially north of the SOCAL/Pt. Mugu Study Area around the Columbia River, Cape Blanco, Oregon, and Cape Mendocino, California as species often differ substantially between these areas (Brodeur et al. 2004). With the SCB, the ichthyofauna around the CINMS is typically southern (warm) in the nearshore waters of San Clemente and Santa Catalina Islands and typically northern (cold) in the nearshore waters of San Miguel Island (Cross and Allen 1993; Graves et al. 2006; Love and Schroeder 2007). Around Anacapa, Santa Cruz, and Santa Barabra islands, the fish fauna is warm, intermediate, whereas the ichthyofauna around Santa Rosa and San Nicolas islands is cold, intermediate (Engle 1993). These fish communities show a distinctive grouping based on association with eastern islands (influenced by the Davidson Current) and western islands (influenced strongly by the California Current). Island kelpfish (*Alloclinus holderi*), opaleye (*Girella nigricans*), garibaldi (*Hypsyops rubicundus*), blacksmith (*Chromis punctipunnis*), and kelp bass (*Paralabrax clathratus*) occur more often in the eastern Islands, while rockfish (*Sebastes*

sp.), embiotocid (surfperches) species, and pile perch (*Rhacochilus vacca*) occur more in the western Islands (Halpern and Cottenie 2007).

The nearshore, continental shelf, and continental slope supports a large biomass of groundfishes (Dark and Wilkins 1994). Demersal fishes, particularly rockfishes, are a dominant feature of the benthic ecosystem along the U.S. West Coast (Anderson and Yoklavich 2007). Nearshore (shallower rockfish: China, kelp, and grass and deeper rockfish: blue, treefish, and quillback), continental shelf (bottom rockfish: yellowtail, canary, sharpchin, greenstriped, rosethorn, and redstripe), and continental slope (deep-water rockfish: darkblotched, splitnose, and yellowmouth, Pacific ocean perch, and shortspine thornyhead) assemblages exists along the California coast (Williams and Ralston 2002). The groundfish community in the southern CCS exhibits the strong-depth gradient in species composition and diversity (Tolimieri and Levin 2006) typically found in many other demersal fish communities inhabiting continental 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). Cross and Allen (1993) estimated that about 30% of the fish species and 40% of the families occur over hard substrates in the SCB.

Various physical and geographic features within the CCS such as the northward-flowing California Undercurrent, the Davidson Current, the Southern California Eddy, oceanic water masses (Subarctic-Transitional, Central, and Eastern Tropical Pacific), strong coastal upwelling regime extending northward from Point Conception, submarine canyons and gullies (i.e., La Jolla, Redondo), seamounts (i.e., San Juan), large submerged rocky reefs (i.e., Hidden Reef), deep banks (Tanners, Cortez), islands (San Clemente and Santa Rosa), coastal promontories (i.e., Point Conception), basins (13 in SCB), submarine ridges (i.e., Morro Ridge, Punta Gorda Escarpment), and kelp forests also influence the distribution and abundance of pelagic fishes and groundfishes (Doyle 1992; Bjorkstedt et al. 2002; Nishimoto and Nashburn 2002; Williams and Ralston 2002; Love and Yoklavich 2006; Neighbors and R.R. Wilson Jr. 2006).

4.2 HABITATS

The habitat for a given fish species consists of the geographic area and its characteristics where the species may be found during any phase of its lifestage. Habitat characteristics include geomorphological, physical, biological, and chemical parameters. Interactions between environmental parameters make up habitats and determine the biological niche of a species. Habitat parameters affecting fish distribution throughout the SOCAL/Pt. Mugu 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: Oregonian (north of Point Conception) and San Diegan (south of Point Conception) (Briggs 1974; Horn and Allen 1978; Allen and Smith 1988). The SOCAL OPAREA falls entirely within the San Diegan Province, whereas the Pt. Mugu OPAREA is situated in both the San Diegan and Oregonian provinces. Both of these provinces can further be broken down into three main habitat groups (shallow, deeper, and pelagic) utilized by managed fishes (NMFS-NWR 2005; Allen and Pondella II 2006) .

- **Shallow Habitats**

  - Bay-Estuary: these habitats include bays, estuaries, and lagoons influenced by the ocean and river and serve as the transitional zone between fresh and saltwater. The bay-estuary habitats fulfill fish and invertebrate needs for spawning and nursery sites, feeding, refuge, migratory routes, and other physiological necessities. In aaddition, they naturally support large populations of certain coastal fishes. Major bay-estuarine systems include:

    - Morro Bay – year-round estuarine residents, freshwater occupants, and marine species;

    - Carpinteria Marsh, Mugu Lagoon, and San Diego Bay – predominantly estuarine and marine, but lacking a freshwater component and anadromous species (Allen et al. 2006b)

- Surf Zone: an interface between the sea and land that receives nutrient and detrital input from the ocean and sandy beaches. This is a major habitat that comprises 57% of the coastline north of Point Conception and 82% of the mainland coastline from Point Conception south to the Mexican border and also consists of a subhabitat of drift algal beds. This habitat supports large populations of relatively few species on a diel and seasonal basis as well as providing nursery habitat for a number of coastal marine fishes. Major species within each region include:

    - Central California – true smelts (surf, *Hypomesus pretiosus*; night, *Spirinchus starksi*), silversides (Atherinopsidae), juvenile surfperches (Embiotocidae);

    - Southern California – silversides (topsmelt, Atherinops affinis; jacksmelt, A. californiensis), anchovies (*Anchova* spp.), juvenile queenfish, *Seriphus politus*; walleye surfperch, *Hyperprospon argenteum* (Allen 1985; Allen and Pondella 2006).

- Inner Shelf: this habitat is composed of a flat, soft bottom consisting of small particles (gravel, sand, mud, silt, or various mixtures of these particles). It contains little to no vegetation due to the lack of stable surfaces for attachment. Benthic fauna in this habitat often consists of infaunal organisms. The inner shelf encompasses more than 50% (and probably from 70 to >90%) of the shelf area. In southern California, the inner shelf comprises about 22% of the mainland shelf. Major species within both regions include:

    - Central/Southern California – shiner perch, *Cymatogaster aggregata*; white seaperch, *Phanerodon furcatus*; speckled sanddab, *Citharichthys stigmaeus*; and English sole (Allen 2006b).

- Coastal Pelagic: this habitat encompasses the open water environment extending out from the surf zone to the continental shelf break. Major species within each diel period within this habitat include:

    - Day – silvery, schooling fishes (northern anchovy, queenfish, white croaker, *Genyonemus lineatus*; silverside complex: jacksmelt, California grunion, *Leuresthes tenuis*; and topsmelt);

    - Night – white seabass, *Atractoscion nobilis*; black croaker, *Cheilotrema saturnum*; and gray smoothhound, *Mustelus californicus* (Allen and DeMartini 1983; Pondella II and Allen 2000; Allen and Pondella 2006).

- Rocky Intertidal: this habitat is composed of bedrock, boulders, cobble, or gravel/cobble in nearshore region where there are periods of water inundation and exposure to the air environment. This wave-swept and turbulent environment is separated by stretches of sandy or muddy shores, has temporal and spatial variations, often highly productive, and is rich in seaweed and invertebrates. Major species within each region include:

    - Central California – black prickleback, *Xiphister atropurpureus*;

    - Southern California – smoothhead sculpin, *Artedius lateralis* (Horn and Martin 2006).

- Rocky Subtidal: this habitat is composed of bedrock, boulders, cobble, or gravel/cobble in nearshore region below the rocky intertidal, where water inundation is continuous (>2 m) with abundant marine algal, *Laminaria andersonii* and other, occasionally present, large brown algae. Major species within each region include:

    - Central California – scalyhead sculpin, *Artedius harringtoni*; and brown Irish lord, *Hemilepidotus spinosus*;

- Southern California – bluebanded goby, *Lythrypnus dalli*; and reef finspot, *Paraclinus integripinnis* (Yoshiyama et al. 1986; Allen et al. 1992; Stephens et al. 2006).

- Kelp Bed/Rock Reef: highly diverse habitat consisting of two-major-forming kelps (giant and bull) and rocky substrates consisting of boulders and sedimentary (sandstone, mudstone, or shale), igneous (basalts, andesites) or metamorphic formations (schists, gneisses, or quartzites) formations. These habitats provide shelter, orientation, food availability, and nesting sites for fish complex (conspicuous, cryptic, and associated species). Major species within each region include:

- Central California – rockfishes (Scorpaenidae) and greenlings (Hexagrammidae);

- Southern California – blacksmith, senorita, *Oxyjulis californica*; and giant kelpfish, *Heterostichus rostratus* (Allen 1985; Stephens et al. 2006).

- Artificial Structures: consists of manmade objects that mimic reefs and hard substrates, such as artificial reefs, breakwaters, jetties, piers, and harbors. These altered structures are productive and heterogeneous environments that are representative composite habitats with fish assemblages sharing close affinities to those of bay-estuary, surf zone, inner shelf, and coastal pelagic habitats (Ambrose and Swarbrick 1989; Stephens Jr. et al. 1994; Stephens Jr. and D.J. Pondella 2002; Froeschke et al. 2005; Allen and Pondella 2006).

➢ **Deeper Habitats**

- Middle Shelf: this habitat is a flat, soft bottom consisting of small particles (gravel, sand, mud, silt, or various mixtures of these particles). It contains little to no vegetation due to the lack of stable surfaces for attachment. Benthic fauna in this habitat often consists of infaunal organisms. The middle shelf encompasses more than 50% (and probably from 70 to >90%) of the shelf area. In southern California, the middle shelf comprises about 54% of the mainland shelf. Major species within each region include:

  - Central California – stripetail rockfish and English sole;

  - Southern California – Pacific argentine, *Argentina sialis*; and California skate (Allen 2006b).

- Outer Shelf: this habitat is a flat, soft bottom consisting of small particles (gravel, sand, mud, silt, or various mixtures of these particles). Benthic fauna in this habitat often consists of infaunal organisms. It contains little to no vegetation due to the lack of stable surfaces for attachment. The outer shelf is exposed to the California Counter Current, strongly influenced by epipelagic productivity, and encompasses more than 50% (and probably from 70 to >90%) of the shelf area. In southern California, the outer shelf comprises about 24% of the mainland shelf. Major species within both regions include:

  - Central/Southern California – plainfin midshipmen, *Porichthy notatus*; spotted cusk-eel, *Chilara taylori*; and Dover sole (Allen 2006b).

- Mid-depth (middle shelf) Rocky Reef: this habitat comprises bedrock outcrops, isolated pinnacles and large rock banks, boulder fields, mixtures of low-relief sand or mud and cobble fields, and few offshore islands. Benthic fauna in this habitat consist of megafaunal invertebrates (corals, sponges, sea anemones, crinoids, and basket stars). Major species within both regions include:

  - Central/Southern California – rockfishes and lingcod (Allen and Smith 1988; Dark and Wilkins 1994; Yoklavich et al. 2000; Williams and Ralston 2002; Love and Yoklavich 2006).

- Deep Rocky (outer shelf/upper slope) Reef: this habitat consists of expansive mud fields interspersed with rock outcrop and scattered boulders and submarine canyons containing slumps of rock talus piles, scarps, and ledges. Benthic fauna in this habitat consists of megafaunal invertebrates (corals, sponges, sea anemones, crinoids, and basket stars). Major species within both regions include:

    - Central/Southern California – rockfishes and lingcod (Allen and Smith 1988; Dark and Wilkins 1994; Yoklavich et al. 2000; Williams and Ralston 2002; Love and Yoklavich 2006).

- Shallow (mesobenthal-upper) Slope: this habitat is a steep slope composed of fine sediments and is exposed to the California Counter Current. Major species include: Pacific hake, sablefish, and shortspine thornyhead (Allen 2006b).

- Deep Continental Slope: this habitat consists of silty-clay sediment containing organic material and many infaunal species. Major species include: longspine thornyhead, Pacific grenadier, and Pacific flatnose (Neighbors and R.R. Wilson Jr. 2006).

- Deep Bank: this habitat consists of rock and mud substrata. It is inhabited by large, mobile nektobenthic fishes: rockfishes, spiny dogfish, sablefish, spotted ratfish, and Pacific hake (Allen and Pondella 2006).

- Artificial Structures: consists of oil and gas platforms and pipelines. The oil and gas platforms supported three distinct fish assemblages: midwater, bottom, and shell mounds. The shell mound assemblage supports a rich invertebrate fauna (sea anemones, sea stars, brittle stars, crabs, and shrimps), serves as nursery ground, and harbors high densities of subadult and adult fishes. The pipelines are covered with both sessile and motile invertebrates and may act as nursery for fish. Major species within the southern California region include:

    - Southern California – juvenile rockfishes, lingcod, and surfperches (Love et al. 2000; Caselle et al. 2002; Love et al. 2003; Love and York 2005; Love and Yoklavich 2006; Love and York 2006).

➢ **Pelagic Habitats**

- Offshore water column: this habitat consists of the epipelagic, mesopelagic, bathypelagic, and benthopelagic zones. These zones are home to highly migratory species (sharks, tunas, billfish, and swordfish), other relatively large pelagics (Pacific bonito, *Sarda chiliensis*; and yellowtail, *Seriola lalandi*), and various life stages of groundfish inhabiting these zones in open water or in association with fronts, current systems, marcophyte canopies, or drift algae (Allen and Cross 2006; Allen and Pondella II 2006; Neighbors and R.R. Wilson Jr. 2006).

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). The central coast of California, between Monterey Bay and Point Conception is regarded as the southern end of the California upwelling zone and an area of biogeographic transition (Wilson et al. 2008). In this region, predominant northwest winds create upwelling favorable conditions throughout the spring and summer, while relaxation or reversal in wind stress leading to downwelling conditions occur infrequently (Huyer 1983). For more information on this and other 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 and invertebrate species may spawn during winter months before upwelling occurs (i.e., 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, *Thaleichthys pacificus*), or give birth to live precocious "juvenile" individuals (NMFS-NWR 2005).

4.2.1 Bay-Estuarine

Estuaries and/or bays 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, and biological cover) (Pacunski and Palsson 1998). The bay-estuarine fish assemblage in central and southern California can be characterized by ecological classification based on salt tolerance, latitudinal distribution patterns, and major ecological features. Fish species occur as freshwater taxa, diadramous (anadramous or catadramous) taxa, estuarine residents, marine migrants, or marine species that seasonally or occasionally enter the bay-estuarine system (Allen et al. 2006b). Thirty-eight fish species occur latitudinally in all thirteen major bay-estuarine systems in California with 60 fish species found in southern California and 133 fish species distributed north of Point Conception (Allen et al. 2006b). Horn and Allen (1976) reported that of the 224 fish species inhabiting these bay-estuarine systems, 25% of the southern species were most likely to occur in systems north of Point Conception, California whereas only 9% of the northern species would inhabit systems south of Point Conception, California. Major ecological features include low species diversity (usually dominated <5 species) (L.G. Allen et al. 2002), high productivity and biomass (usually seasonal with main peak in August) (Allen 1982), marked seasonality (few common species that reside year-round being joined in spring/summer by several abundant juvenile species) (Allen and Horn 1975; Horn and Allen 1985), strong interannual variability (Onuf and Quammen 1983; Matern et al. 2002), and prominent nursery function (L.G. Allen et al. 2002). Larval fish assemblages of the Californian bay-estuarine systems are composed predominately of resident species (central: Pacific herring, *Clupea harengus pallasii*; northern anchovy, arrow goby, *Clevelandia ios*; and southern California: goby species, *Anchova* spp.; longjaw mudsucker, *Gillichthys mirabilis*; northern anchovy, topsmelt, and blenny species, *Hypoblennius* spp.) often with relatively small contributions from open coastal species (Moser and Watson 2006).

Of the thirteen major bay-estuarine systems in California, only four of the bay-estuarine systems are located within the SOCAL/Pt. Mugu Study Area: Moro Bay in south-central California and Carpinteria Marsh and Mugu Lagoon in the northern SCB of the Pt. Mugu OPAREA, and San Diego Bay in the SOCAL OPAREA. In central California, Morro Bay supports a fish assemblage with varying numbers of year-round estuarine residents (Pacific staghorn sculpin, *Leptocottus armatus*; California killifish, *Fundulus parvipinnis* bay pipefish, *Syngnathus leptorhynchus*), freshwater occupants (threespine stickleback, *Gasterosteus aculeatus*), and marine species (topsmelt, shiner perch, northern anchovy, and English sole) from nearshore waters that enter the estuary to feed, mate, and spawn (Allen et al. 2006b; Christopher et al. n.d.).

In southern California, the various bay and estuaries are lagoon estuarine systems, resulting from relatively flat topographical features and low freshwater flows, except during occasional wintertime floods (Emmett et al. 2000). As a result, these systems are mostly small and mainly marine in character, with

fish assemblages largely devoid of freshwater and anadramous species that are dominated by estuarine residents and marine migrants. These bays and estuaries in the region vary greatly in size from small, canyon-mouth (Carpinteria Marsh and Mugu Lagoon) to large systems (San Diego Bay) (Allen et al. 2006b). All of these southern California bays and estuaries form distinct species assemblages found nowhere else (Horn 1980). Arrow goby, topsmelt, and California killifish are the most abundant fishes (91%) in Carpinteria Marsh, whereas the shiner perch, topsmelt, and Pacific staghorn sculpin are the most abundant species (77%) of the 43 species recorded in Mugu Lagoon (Onuf 1987; Allen et al. 2006b).

The fish fauna of San Diego Bay consists of 89 species of which northern anchovy, topsmelt, and slough anchovy (*Anchoa delicatissima*) account for 86% of the population that consist of 70% juveniles (L.G. Allen et al. 2002). Juveniles of non-commercial fishes can be extremely abundant and usually dominate fish assemblages in the SCB bay-estuarine systems (Allen 1982). San Diego Bay also serves as a significant nursery area for at least 28 species (i.e., California halibut, *Paralichthys californicus*; spotted sand bass, *Paralabrax maculatofasciatus*; and barred sand bass, *P. nebulifer*) with its unique combination nearshore soft bottom and bay-estuarine habitats. North San Diego Bay has the area of greatest fish productivity due to the better water circulation and greater exchange with ocean water, whereas, South San Diego Bay represents a critical habitat for the following indigenous bay-estuarine species (deepbody anchovy, *Anchoa compressa*; slough anchovy, California killifish, arrow goby, longjaw mudsucker, bay pipefish, barred pipefish, *Syngnathus auliscus*; cheekspot goby, *Ilypnus gilberti*; striped mullet, *Mugil cephalus*; spotted sand bass, bay blenny, *Hypsoblennius gentilis*, and shadow goby, *Quietula y-cauda*) (DoN 2000). The extensive shallow-water habitat and eelgrass beds also support high standing stock of midwater, schooling (forage) fishes (northern anchovy, topsmelt, and slough anchovy). In addition, the general warm and hypersaline waters offer a warm water refuge for a number of southern Panamic Province fish species, such as bonefish (*Albula* sp.), Pacific seahorse (*Hippocampus ingens*), and California needlefish (*Strongylura exilis*) (L.G. Allen et al. 2002).

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). California's estuarine environment sustains remarkably high levels of productivity. Representative organisms typifying the softbottom communities of California estuaries (e.g., Morro Bay, San Diego Bay) include crustaceans (Dungeness crab, caridean or bay shrimps; *Crangon* spp.) and molluscan bivalves (Pacific razor clam, *Siliqua patula*, gaper clams, *Tresus* spp.; Washington clam, *Saxidomus nuttali*; littleneck clams or "chiones", *Chione* or *Protothaca* spp.; blue mussel, *Mytilus edulis*) (Emmett et al. 1991; Kalvass 2001b). Polychaetes, crustaceans, and mollusks are the dominant invertebrate fauna living on and in the soft bottom sediment and the submerged aquatic vegetation of San Diego Bay (DoN 2000). For additional information on the estuarine benthic communities please refer to **Section 2.7.1**.

4.3 EPISODIC OCEANOGRAPHIC EVENTS

The influence of the California Current on the physical and biological environment of the SOCAL/Pt. Mugu Study Area undergoes significant year-to-year fluctuations. Its impact is also affected by larger-scale climate variations, such as ENSO, PDO, and global warming (Hickey 1993; Horn and Stephens Jr. 2006).

4.3.1 El Niño Southern Oscillation

ENSO comprise alternating warm El Niño and cool La Niña intervals with a mean recurrence interval of 2 to 7 yr (Fielder 2002). 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 2003c). El Niño-induced natural disturbances may also result in a cascade of changes to shallow-water estuarine systems by causing a reduction in the diversity and abundance of benthic invertebrate and fish communities (Onuf and Quammen 1983; Nordby and Zedler 1991), invasion by exotic and disturbance-colonizing species, and altered patterns of larval recruitment (Williams et al. 2001).

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). Alternating La Niña events can also cause reduced abundances among species of warm-water affinities (e.g., reef finspot) or increased abundance of even transitional species such as wooly sculpin (*Clinocottus analis*) in the same rocky intertidal habitat (Horn and Stephens Jr. 2006).

4.3.2 Pacific Decadal Oscillation (PDO)

Like an ENSO event, the PDO comprises a warm and cold interval, but the PDO regimes are each 20 to 30 yr in duration (Fielder 2002). Major ecological events occur on the decadal scale and in response to a shift from one regime to another (i.e., anchovy to sardine) (McGowan et al. 2003). During an anchovy (cool) regime, there are fewer sardines, higher nutrients, primary production, TZCF, salinity, and zooplankton levels, lower precipitation, SST, and stratification, more salmon, rockfish, anchovies, and seabirds, shallower thermocline, stronger upwelling and California undercurrent, and faster California Current, in contrast, during a sardine (warm) regime, the opposite conditions predominate (Horn and Stephens Jr. 2006).

Due to decadal timeframe of the PDO regime, there are still various issues needed to be addressed to fully understand this climatic change, such as, the underlying force behind these shifts, mechanisms through which they influence fish populations, time frame for a regime shift, and their relationship to El Niño and La Niña events (Chavez et al. 2003). Hollowed et al. (2001) found evidence that some northeast Pacific fish stocks were affected by the 1976 to 1977 and 1988 to 1989 phase changes in PDO, but that others were positively affected by the ENSO scale warm conditions on the eastern side of the North Pacific Ocean ('Niño North').

4.3.3 Global Warming

Global warming casts a shadow of uncertain magnitude over the shorter-term and more regional ENSO and PDO conditions. Whereas both ENSO and PDO regimes affect the distribution and abundance of fish populations, and may act in conflict or in consort with each other, the present occurrence of global warming and its prediction to increase over the next century appears to present the most important influences on the California marine fish fauna in the future. In summary, the SCB looks to become primarily a marginal Panamic and Mexican fauna of conspicuous warm-water affinities with marine regions of central and northern California increasingly warm-temperate in character (Horn and Stephens Jr. 2006). Ichthyofaunal spawning (i.e., sardine, northern anchovy) that shifts geographically with change in the environment rather population productivity is also predicted to occur with global climatic change (Reiss et al. 2008).

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 SOCAL/Pt. Mugu Study Area from Point Sierra Nevada, south-central California to the U.S./Mexico 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 HAPC in the PFMC region (Moncada et al. 2004) except for the recently designated groundfish HAPC (NMFS-NWR 2006).

A total of 107 fish and invertebrate species with designated EFH occur in the SOCAL/Pt. Mugu Study Area (**Table 4-1**). They are grouped into the Pacific Salmon Species (3 species), CPS (13 species), Pacific Coast Groundfish Species (78 species), and Highly Migratory Species (HMS: 13 species). The status, distribution, Habitat Associations (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; 2003a). 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 bay-estuarine waters of the inshore habitats (e.g., littoral: intertidal – sandy beach and rocky intertidal, water column, soft bottom: vegetated [eelgrass] and unvegetated, hard bottom: rocky reef) of San Diego Bay support various designated EFH species (Robbins 2006). A list of designated EFH species and their associated habitats are listed in **Table 4-2**.

Table 4-1. Fish and invertebrate species with EFH designated in the SOCAL/Pt. Mugu Study Area.

Pacific Salmon Species

Chinook salmon (*Oncorhynchus tshawytscha*)
Coho salmon (*Oncorhynchus kisutch*)
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*)

Flatfish (continued)
Dover sole (*Microstomus pacificus*)
English sole (*Parophrys vetulus*)
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*)
Calico rockfish (*Sebastes dallii*)
Canary rockfish (*Sebastes pinniger*)
Chilipepper (*Sebastes goodei*)
China rockfish (*Sebastes nebulosus*)
Copper rockfish (*Sebastes caurinus*)
Cowcod (*Sebastes levis*)
Darkblotched rockfish (*Sebastes crameri*)
Flag rockfish (*Sebastes rubrivinctus*)
Gopher rockfish (*Sebastes carnatus*)

Table 4-1 (*continued*). Fish and invertebrate species with EFH designated in the SOCAL/Pt. Mugu Study Area.

Rockfish (continued)
Grass rockfish (*Sebastes rastrelliger*)
Greenblotched rockfish (*Sebastes rosenblatti*)
Greenspotted rockfish (*Sebastes chlorostictus*)
Greenstriped rockfish (*Sebastes elongatus*)
Honeycomb rockfish (*Sebastes umbrosus*)
Kelp rockfish (*Sebastes atrovirensis*)
Mexican rockfish (*Sebastes macdonaldi*)
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*)
Starry rockfish (*Sebastes saxicola*)
Stripetail rockfish (*Sebastes saxicola*)
Tiger rockfish (*Sebastes nigrocinctus*)
Tree rockfish (*Sebastes nigtocinctus*)
Vermilion rockfish (*Sebastes miniatus*)
Widow rockfish (*Sebastes entomelas*)
Yelloweye rockfish (*Sebastes ruberrimus*)
Yellowtail rockfish (*Sebastes flavidus*)

Scorpionfish
California scorpionfish (*Scorpaena guttatta*)

Thornyhead
Longspine thornyhead (*Sebastolobus altivelis*)
Shortspine thornyhead (*Sebastolobus alascanus*)

Roundfish
Cabezon (*Scorpaenichthvs marmoratus*)
Kelp greenling (*Hexagrammos decagrammus*)

Roundfish (continued)
Lingcod (*Opiodon elongatus*)
Pacific cod (*Gadus macrocephalus*)
Pacific hake (*Merluccius productus*)
Sablefish (*Anoplopoma fimbria*)

Skates and Sharks
Big skate (*Raja binoculata*)
California skate (*Raja inornata*)
Longnose skate (*Raja rhina*)
Leopard shark (*Triakis semifasciata*)
Soupfin shark (*Galeorhinus zyopterus*)
Spiny dogfish (*Squalus acanthias*)

Other Species
Pacific flatnose (*Antimora microlepis*)
Pacific grenadier (*Coryphaenoides acrolepis*)
Spotted ratfish (*Hydrolagus colliei*)

Highly Migratory Species

Sharks
Bigeye thresher shark (*Alopias superciliosus*)
Common thresher shark (*Alopias vulpinus*)
Pelagic thresher shark (*Alopias pelagius*)
Shortfin mako (bonito shark) (*Isurus oxyrinchus*)
Blue shark (*Prionace glauca*)

Tunas
Albacore tuna (*Thunnus alalunga*)
Bigeye tuna (*Thunnus alalunga*)
Northern bluefin tuna (*Thunnus orientalis*)
Skipjack tuna (*Katsuwonus pelamis*)
Yellowfin tuna (*Thunnus albacares*)

Billfish
Striped marlin (*Tetrapturus audax*)

Swordfish
Broadbill swordfish (*Xiphias gladius*)

Dolphinfish
Dorado (Mahi Mahi) (*Coryphaena hippurus*)

Source: Turgeon et al. (1998); Nelson et al. (2004); McLaughlin (2005)

Table 4-2. EFH designated fish species in San Diego Bay.

Species	Habitats					
	Sandy Beach	Rocky Intertidal	Water Column	Vegetated (eelgrass)	Unvegetated (soft bottom)	Rocky Reef
Coastal Pelagic						
Jack mackerel		X	X			X
Northern anchovy			X	X	X	X
Pacific mackerel			X	X	X	X
Pacific sardine			X			
Flatfish						
Curlfin sole			X		X	
English sole	X			X	X	
Rockfish						
Grass rockfish		X				
Kelp rockfish		X				
Scorpionfish						
California scorpionfish		X	X		X	X
Roundfish						
Cabezon		X				
Skates/Sharks						
Leopard shark	X	X		X	X	X
Highly Migratory						
Common thresher shark			X			

Source: (PFMC 2003a; Craig and Pondella II 2006; Robbins 2006)

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 eight species of Pacific salmon; two species, masu (*Oncorhynchus masou*) and amago (*O. rhodurus*) only occur in Asia, and six species, sockeye (*O. nerka*), pink (*O. gorbuscha*), chum (*O. keta*), Chinook (*O. tshawytscha*), coho (*O. kisutch*), and steelhead (*O. mykiss*) reproduce in North America and Asia (Groot and Margolis 1991; Quinn 2005). 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 1 to 7 yr 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 have led 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 (Quinn 2005). Three species of Pacific salmon have EFH designated within the SOCAL/Pt. Mugu 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.[2]

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 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). 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).

Pacific salmon EFH species are listed in **Table 4-1** and discussed in the following subsections. Status and EFH designations for Pacific salmon species are discussed as a group, while individual species information (e.g., distribution, Habitat Associations, 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.[3]

Status—Pacific salmon are federally protected by the designation of 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.). Of the six species of Pacific salmonids that have ESUs with critical habitat designated along the west coast, only the steelhead salmon is located within the SOCAL/Pt. Mugu Study Area (NMFS 2005b; NMFS 2005c). Because this species ESU is considered "threatened" or "endangered", their status is addressed in Section 3.4.

EFH Designations—The geographic extent of marine EFH for Chinook, coho, and pink salmon include all marine waters from the shoreline to the 200-mile limit of the EEZ and beyond north of Point Conception, California (PFMC 2000; **Figure D-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. Currently, no freshwater EFH occurs within the SOCAL/Pt. Mugu Study Area.

HAPC—Currently, the PFMC has not designated any HAPC for Pacific salmon species (PFMC 2000).

- **Chinook Salmon (*Oncorhynchus tshawytscha*)**

  Distribution—Chinook salmon range extends from northern Japan to Point Hope, Chukchi Sea, Alaska to Ventura River, California (Myers et al. 1998) with strays across northern Alaska to Coppermine River, Canada and to Bahia de Sebastian Vizano, central Baja California (Love et al. 2005b). The natural freshwater range for Chinook salmon includes large portions of the Pacific rim of Asia and in North America from the Mackenzie River, northern Canada to the San Joaquin River, northern California with strays as far south to the Carmel and San Luis Obispo rivers in central California (Healey 1991). Along the U.S. west coast, the oceanic range encompasses Washington State, Oregon, and California (La Jolla), and as far south as the U.S./Mexico border (PFMC 2000), although they are uncommon south of Morro Bay (MBC 1987).

Habitat Associations—Chinook salmon are anadromous and found in freshwater to euhaline water at depths ranging from the surface to 250 m depending on lifestage.[3] They spawn in rivers at depths ranging from 0.1 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).

Chinook salmon may be found in water temperatures ranging from 0.0° to 26.0°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°C is the optimum temperature for both eggs and fry (Beauchamp et al. 1983). Optimum temperature for fingerlings is 17°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).

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 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).

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).

Adult Chinook salmon spawn in gravel ranging from 6 to 14 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).

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). 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 rivers 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 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 (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 4 to 5 yr (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 habitat 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).

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 mo (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 d (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).

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). 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 1 to 2 mo (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 2 to 3 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 cm/s (Healey 1991). Typically, Chinook redd are 5 to 15 m^2 in areas with water velocities from 40 to 60 cm/s (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).

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 (*Ammodytes hexapterus)*, eulachon, herring, anchovy, copepods, euphausiids, cephalopods, isopods, and amphipods (Beauchamp et al. 1983).

- **Coho Salmon (*Oncorhynchus kisutch*)**

Distribution—Coho salmon range from North Korea and Japan to Point Hope, Chukchi Sea, Alaska to Monterey Bay, central California with strays to Prudhoe Bay, Beaufort Sea, Alaska and to Bahia Camalu, northern Baja California (Love et al. 2005b). This species is found in freshwater drainages the San Lorenzo River, Monterey Bay, central California north along the west coast to Point Hope, Alaska, through the Aleutian Islands around the Bering Sea and south through Russia to Hokkaido, Japan (CDFG 2002a). They are absent from rivers south of Monterey Bay and from the Sacramento-San Joaquin River system, California (MBC 1987). Oceanic lifestages can be found from Camalu Bay, northern Baja California north to Point Hope, Alaska and from there, south to Korea (MBC 1987; Sandercock 1991). In the northeastern Pacific Ocean, coho can be found south of 40°N, but only rarely in the coastal waters of the California Current (MBC 1987).

Habitat Associations—Coho salmon are anadromous and found in freshwater to euhaline water at depths ranging from the surface to 250 $m.^3$ 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).

Eggs and alevins are found at temperature from 4.4° to 21.0°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).

Eggs, alevins, fry, and parr inhabit freshwater while juveniles and adults are anadromous (Laufle et al. 1986). Embryos and juveniles require the highest dissolved oxygen concentrations. Embryo survival is sharply reduced at dissolved oxygen levels less than 8 ppm, whereas juvenile food consumption is reduced at levels less than 4 ppm (Laufle et al. 1986; Emmett et al. 1991). Levels below 2 ppm for extended periods of time are lethal (PFMC 2000).

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).

Life History—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/s (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 and Puget Sound, Washington State (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 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).

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).

Adult coho migrate into streams where they deposit their eggs in clean, coarse gravel (Sandercock 1991; PFMC 2000). They typically spawn in small streams with water velocities ranging from 0.08 to 0.70 m/s, with preferred velocities between 0.3 and 0.5 m/s (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).

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 mo 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).

- **Pink Salmon (*Oncorhynchus gorbuscha*)**

Distribution—Pink salmon range from Northern Siberia to western Canada, North Korea and Japan to Beaufort Sea coast of Alaska and Canada, and south to La Jolla, southern California (Love et al. 2005b). This species occurs in freshwater rivers and small streams from northern California north to Norton Sound, Alaska and into Canada's Mackenzie River, Northwest Territory (Bonar et al. 1989; Emmett et al. 1991). Their oceanic distribution in the Pacific Ocean 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 Associations—Pink salmon are anadromous and found in fresh water to euhaline water at depths ranging from the surface to 250 m.[3] 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).

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).

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).

Embryos and alevins need well oxygenated water (>6 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).

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).

Life History—Pink salmon are the most abundant of the Pacific salmon species and have the simplest and most specialized life history (Heard 1991). 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, 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).

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/s with average velocities from 60 to 80 cm/s (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). Fry migrate quickly to sea after emergence where they make extensive feeding migrations (Heard 1991). Pink salmon spend approximately 18 mo 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 (4 finfish, 1 invertebrate, and 8 crustaceans) representing 6 families (anchovies, jacks, herrings, mackerels, squids, and krill). All CPS species have EFH designated within the SOCAL/Pt. Mugu 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 HAPC were identified for the euphausiid species (PFMC 2006).

EFH species are discussed in the following subsections and listed in **Table 4-1**. Status and EFH designations for CPS finfish and invertebrate are discussed as a group, while individual species information (e.g., distribution, habitat associations, 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 Associations, 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 et al. (1983) and Wikipedia[4], respectively. Additionally, Froese and Pauly[3] provide photographs of the finfish species.

Status—Recent stock assessments indicate that the two actively managed species: Pacific sardine is increasing in relative abundance while the Pacific mackerel has continually declined in abundance since the 1970s (Dorval et al. 2007; Hill et al. 2007). Neither the actively managed or monitored stocks (northern anchovy, jack mackerel, and market squid) managed under the CPS FMP are considered overfished (NMFS 2007; PFMC 2007a). Additionally, none of the actively managed and/or monitored species are currently listed on the IUCN red list of threatened species.[2]

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; PODAAC 2004; **Figure D-2**).

For the SOCAL/Pt. Mugu 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 HAPC 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. 2005b). The population is divided into northern, central, and southern subpopulations or stocks (Kucas 1988). Only the central subpopulation, which ranges from San Francisco, California to Punta Baja, Baja, California occurs within the Study Area (Vrooman and Smith 1970). The bulk of the central subpopulation is located within 37 km of shore of the SCB, bound by Point Conception, California on the north and Punto Descanso, Mexico on the south (Baxter 1966). The subpopulation also supports significant commercial fisheries in the U.S. and Mexico (PFMC 1998b).

    Habitat Associations—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 310 m (Love et al. 2005b) 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 – 14.0° to 17.4°C, and eggs – 10.0° to 23.3°C (Emmett et al. 1991). The central subpopulation are typically found in waters ranging from 12.0° to 21.5°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). In southern California, young-of-the-year and yearling anchovies utilize shallow inshore areas (Parrish et al. 1985). Adult 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 SOCAL/Pt. Mugu Study Area, the spawning season takes place throughout the year off southern California, occurring mostly between February and May but is most restricted to the north occurring off central California in December and January (Baxter 1966; Hart 1973; MBC 1987; Love 1996). Females spawn eggs at intervals as short as 6 to 8 d. 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: *Thysanoessa spinifera* and large copepods), arrowworms, and fish larvae (MBC 1987; PFMC 1998b; Miller and Brodeur 2007).

- **Jacks (Carangidae)**

  - **Jack Mackerel (*Trachurus symmetricus*)**

    Distribution—Jack mackerel range throughout the northeastern Pacific Ocean, from the Pacific coast of the U.S. to an offshore limit approximated by a line running from the eastern Aleutian Islands, Alaska to Cabo San Lucas, southern Baja California (Mecklenburg et al. 2002; Love et al. 2005b). Much of its geographical range lies outside the 200-mi EEZ (MacCall and Stauffer 1983).

    Habitat Associations—All lifestages of the jack mackerel are pelagic (Eschmeyer et al. 1983). Adults occur offshore from the surf zone 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 – 10.0° 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 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). This species may spawn eight or more times per year (Weber 1997).

    Common Prey Species—Jack mackerel prey upon zooplankton (copepods, pteropods, euphausiids: *Thysanoessa spinifera* and *Euphausia pacifica*), juvenile squid, lanterfishes, northern anchovy, small crustaceans, and larval/juvenile Osteichthyes (Hart 1973; Feder et al. 1974; Weber 1997; PFMC 1998b; Miller and Brodeur 2007).

- **Mackerels and Tunas (Scombridae)**

  - **Pacific Mackerel (*Scomber japonicus*)**

    Distribution—Pacific (blue or chub) mackerel circumnavigate temperate and tropical seas (Collette and Nauen 1983; Love 1996). In the northeastern Pacific Ocean, this species ranges the western Gulf of Alaska to Chile including Islas Galapagos and Panama, Gulf of California, and Banderas Bay (Puerto Vallarta), Mexico ((Hart 1973; Mecklenburg et al. 2002; Love et al. 2005b) 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 Associations—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 – 10.0° 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 Ocean, 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 (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 SOCAL/Pt. Mugu Study Area, 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; Miller and Brodeur 2007).

- **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: 30°-55°N), a southern stock (off Baja California: 23°-30°N), and a Gulf of California stock: 23°-31°N (Parrish et al. 1989; Wolf and Smith 1992; Wolf et al. 2001). This species ranges from southeastern Alaska to Guaymas, Mexico including Gulf of California and Islas Galapagos (Miller and Lea 1972; Mecklenburg et al. 2002; Love et al. 2005b).

Habitat Associations— Pacific sardine are pelagic occurring in the surface and surf zone to 150 m (Mecklenburg et al. 2002; Love et al. 2005b) 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 SOCAL/Pt. Mugu 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 (Oregon and Washington State) and Canada (British Columbia) (Parrish et al. 1989). Younger adults (age: 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. Larvae and eggs are concentrated 50 to 150 km offshore (e.g., area north of Point Conception, California and around the Channel Islands) 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). Spawning has also been 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 and euphausiids: *Euphausia pacifica*) (Wolf et al. 2001; Miller and Brodeur 2007).

- **Squids (Loliginidae)**

  - **Market Squid (*Loligo opalescens*)**

Distribution—Market or opalescent squid range throughout the California and Alaska current systems, from southeastern Alaska (55°N) to the southern tip of Bahia Asuncion, Baja California, Mexico (23°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 Associations—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 from October to April/May, off central California from April to October, off Oregon from May to July, and off Washington State and British Columbia from May to September (Roper et al. 1984; NMFS-NWR 2004; CDFG 2005). 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, brachyuran larvae, and hyperiid amphipods), small fish (northern anchovy), and other squid (PFMC 1998b; Miller and Brodeur 2007).

- **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). Their EFH designation is the same as for the *E. pacificia*.

The two remaining 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 that 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.[2]

- **North Pacific Krill (*Euphausia pacifica*)**

Distribution—*Euphausia pacifica* is broadly distributed across the North Pacific Ocean occurring from the California Current west across the Pacific Ocean to Japanese waters. It ranges throughout the subarctic Pacific Ocean, including the Gulf of Alaska and as far south as 25°N (Brinton 1981).

Habitat Associations—*Euphausia pacific* is oceanic generally occurring within the west coast EEZ from the surface to over bottom depths greater than 183 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 this inner third of the EEZ (60 to 100 nautical miles [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 southern California, larvae occur beyond the shelf as well as inshore (NMFS-SWR 2006). Off central and southern California, this species' greatest concentration appears to be located further offshore (e.g., island shelves, banks, canyons, and promontories) than the 10 to 20 nm on either side of the shelf break (~200 m isobath) reported off Oregon (Gómez-Gutiérrez et al. 2005). Aspects of the life history of this species may differ in the lower part of its range south of 40°N than to the north of that latitude, where environmental characteristics show a stronger seasonality than to the south (NMFS-SWR 2006). A strong cross-shelf gradient in euphausiids and age-segregated for this species may represent maintenance of egg, nauplius, and metanauplius stages in rich nearshore area, offshore drift of older larval stages, and concentration of reproductive adults at the shelf break linking inshore and offshore segments of the population (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.[4]

Euphausia 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 2 mo (summer and autumn) in southern California (NMFS-SWR 2006) and from March through September along the Oregon coast (Gomez-Guiterrez et al. 2007). 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 southern California, there are at least four generations each year (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—*Euphausia pacific* preys primarily upon phytoplankton, particularly diatoms, small zooplankton, as well as fish eggs and larvae (Field et al. 2001; Wikipedia[4])**.**

EFH Designations—(NMFS-SWR 2006; **Figure D-3)**

- o Larvae/Juveniles/Adults—EFH is identified 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 Ocean ranging from southeastern Bering Sea south to northern Baja California (NMFS-SWR 2006).

Habitat Associations—*Thysanoessa 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). Off southern California, larvae occur beyond the shelf as well as inshore (NMFS-SWR 2006). Off central and southern California, this species' greatest concentration appears to be located further offshore (e.g., island shelves, banks, canyons, and promontories) than the 10 to 20 nm on either side of the shelf break (~200-m isobath) reported off Oregon (Gómez-Gutiérrez et al. 2005). A strong cross-shelf gradient in euphausiids and age-segregated for this species may represent maintenance of egg, nauplius, and metanauplius stages in rich nearshore area, offshore drift of older larval stages, and concentration of reproductive adults at the shelf break linking inshore and offshore segments of the population (Gómez-Gutiérrez et al. 2005). Brinton and Townsend (2003) reported *T. spinifera* disperses extensively offshore toward the main flow of the California Current. There also may be significant latitudinal differences in the inshore versus offshore dispersion patterns and retention mechanisms off Oregon and California (NMFS-SWR 2006).

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 Santa Barbara Channel Islands NMS (Fiedler et al. 1998). Mass strandings have been reported along Oregon beaches to as far south as La Jolla, California (NMFS-SWR 2006).

Thysanoessa 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 (March through September), northern California (April through June/July, and central and southern California (August through October (NMFS-SWR 2006; Gomez-Guiterrez et al. 2007). 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—*Thysanoessa spinifera* preys primarily upon unicellular phytoplankton, primarily diatoms along with small zooplankton and fish eggs/larvae (Field et al. 2001; Wikipedia[4]).

EFH Designations—(NMFS-SWR 2006; **Figure D-3**)

- Larvae/Juveniles/Adults—EFH is identified 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 more than 90 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 1 left-eye flounders), 60 rockfish, 2 thornyheads, 1 scorpionfish, 6 roundfish, 6 assorted skates and sharks, and 3 other species (i.e., 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, dwarf-red, freckled, half-banded, pinkrose, pygmy, and swordspine have been added to the FMP. All of these species occur in the SOCAL/Pt. Mugu Study Area. Limited information covering distribution, depth, habitat, migration/spawning, and prey species, if available, is present in **Table 4-3**. Currently, information is lacking to define EFH for these additional species (NMFS 2004d).

Description—Approximately 78 of the more than 90 PFMC managed groundfish species are known to occur in the SOCAL/Pt. Mugu 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. Managing Pacific Coast rockfish is also problematic due to the different habitat requirements at different stages of their life history(e.g., adults: various coastal benthic habitats - subtidal kelp forest, rocky reefs, and rocky outcrops in submarine canyons; subadults/juveniles: shallow waters - rocky reefs, kelp beds, and artificial structures; and small juveniles/larvae: dispersed in surface waters extending several hundred kilometers offshore for several months), their episodic recruitment (i.e., tide pools, shallow coastal waters with rocky bottoms/algae), and their susceptibility to overfishing (i.e., slow-growing, long-lived species) (Parker et al. 2000; Rooper 2008). To summarize the ecological variation among the species found in the SOCAL/Pt. Mugu Study Area, limited information for individual species will be presented, when available. Short biological characterizations covering the distribution, Habitat Associations (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.[3]

Status—According to NMFS (2007) and PFMC (2008), seven rockfish species (bocaccio, canary rockfish, cowcod, darkblotched rockfish, widow rockfish, yelloweye rockfish, and Pacific ocean perch) are designated as overfished.

Ten additional groundfish species (sablefish, Dover sole, English sole, Petrale sole, arrowtooth flounder, chilipepper, yellowtail rockfish, shortspine thornyhead, longspine thornyhead, and cabezon) are identified as emphasis species. Emphasis species are described as groundfish stocks that are particularly susceptible to bycatch (PFMC 2004b). One of the emphasis species, the shortspine thornyhead, has been determined to be subject to overfishing (PFMC 2004b).

In addition, some groundfish species (cabezon, Petrole sole, and sablefish) are considered to be precautionary zone species. Precautionary zone species are some assessed species that are below their target biomass, although they are not overfished. This precautionary zone provides surplus to allow these stocks to increase to their target biomass over time (PFMC and NMFS 2008).

Table 4-3. SOCAL/Pt. Mugu Study Area groundfish species life history information.

Family/ Species	Range/Depth	Habitat	Migration/ Parturition	Prey
Rockfish				
Chameleon	Point St. George, northern California to Nine Mile Bank, southern California: 174 to 274 m	Rocky substrata	No Information	No Information
Dwarf-red	Offshore banks/islands, southern California to San Miguel Island, Channel Islands: 58 to 167 m	Rocky outcrops in deep water	No information	No information
Freckled	Point Conception, central California to Isla Guadalupe, central Baja California and Punta San Roque, southern Baja California: 22 to 290 m	Boulder fields either sheltering in crevices or hovering (3 m) above the seafloor, oil platforms	Occur with swordspine, squarespot, and greenspotted rockfishes/March	No information
Half-banded	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
Pinkrose	Carmel Submarine Canyon, central California to Cabo Colnett, northern Baja California and Isla Guadalupe, central Baja California: 99 to 450 m	Near caves, crevices, or undercut rocks, or underneath sponges, anemones, crinoids, in boulder fields, on cobble, or in rock-mud; deepwater oil platforms on adjacent shell mounds and next to pipelines	Solitary, occur with swordspine and bank rockfishes and cowcod/February and March	No information
Pygmy	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
Swordspine	San Francisco, northern California to Banco Ranger, central Baja California: 50 to 433 m	Boulder fields, over high-relief rocky bottoms/cobblestones, mud near rock outcrops, mussel mounds that surround oil platforms	Occur with half-banded, pinkrose, pygmy, speckled, and greenstriped rockfishes/January to June, peaking in March	No information

Source: (Love et al. 2002; Love et al. 2005b)

The cowcod and bocaccio are listed by NMFS (NMFS 2006a) a species of concern in the SOCAL/Pt. Mugu Study Area. Five groundfish species are on the IUCN Red List of Threatened Species.[2] Bocaccio is considered critically endangered due to an estimated reduction of at least 80% of its population over the last 10 yr or 3 generations.[2] The shortspine thornyhead is considered endangered due to an estimated reduction of at least 50% of its population over the last 10 yr or three generations.[2] The leopard shark is listed as lower risk/conservation dependent and big skate is listed as a lower risk but near threatened.[2] 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 yr), and a low intrinsic population rate increase of 2 to 7% per year.[2] 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; PFMC 2004b).

Within the SOCAL/Pt. Mugu 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 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; **Figure D-4**; NMFS 2006b). 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 2005a; 2005b; 2005c; 2005e; 2005f). 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).

All lifestages of the Pacific coast groundfish occur within the SOCAL/Pt. Mugu Study Area. Reproductive adults are separated into spawning (external fertilization, release eggs/sperm) represented by flatfish, roundfish, scorpionfish (*Scorpaena*), and thornyheads (*Sebastolobus*) and mating (internal fertilization, release live young) represented by rockfish (*Sebastes*) and sharks (i.e., soupfin, leopard, and spiny dogfish). Skates (*Raja*) and chimeras have internal fertilization (mating adults) but produce egg cases into the water to develop (Love et al. 2002; McCain et al. 2005). Appendix **Table D-1** provides a list of Pacific coast groundfish species, their individual lifestage and associated habitats, and HSP percent in the SOCAL/Pt. Mugu Study Area (NMFS-NWR 2005).

HAPC—HAPC have been designated for both areas (e.g., seamounts) and habitat types based on one or more of the following criteria (**Figure 4-1**) (NMFS-NWR 2005; NMFS 2006b):

- 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, and
- The rarity of the habitat type.

HAPC based on habitat types may vary over time. For this reason, **Figure 4-1** is only an approximation of their location. These HAPC may also overlap with each other or with specific areas designated as HAPC. Defining characteristics of habitat-type HAPC that are found in the SOCAL/Pt. Mugu 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 HAPC within the SOCAL/Pt. Mugu Study Area:

- California—all seamounts including Davidson and San Juan seamounts; specific areas in the federal waters of CINMS; and specific areas of the Cowcod Conservation Area (CCA).

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 lowest concentrations south of Cape Blanco, Oregon (Allen and Smith 1988; Dark and Wilkins 1994; Kramer et al. 1995; Mecklenburg et al. 2002).

Habitat Associations—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 (Ramsey et al. 2002) 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. 2005b). 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

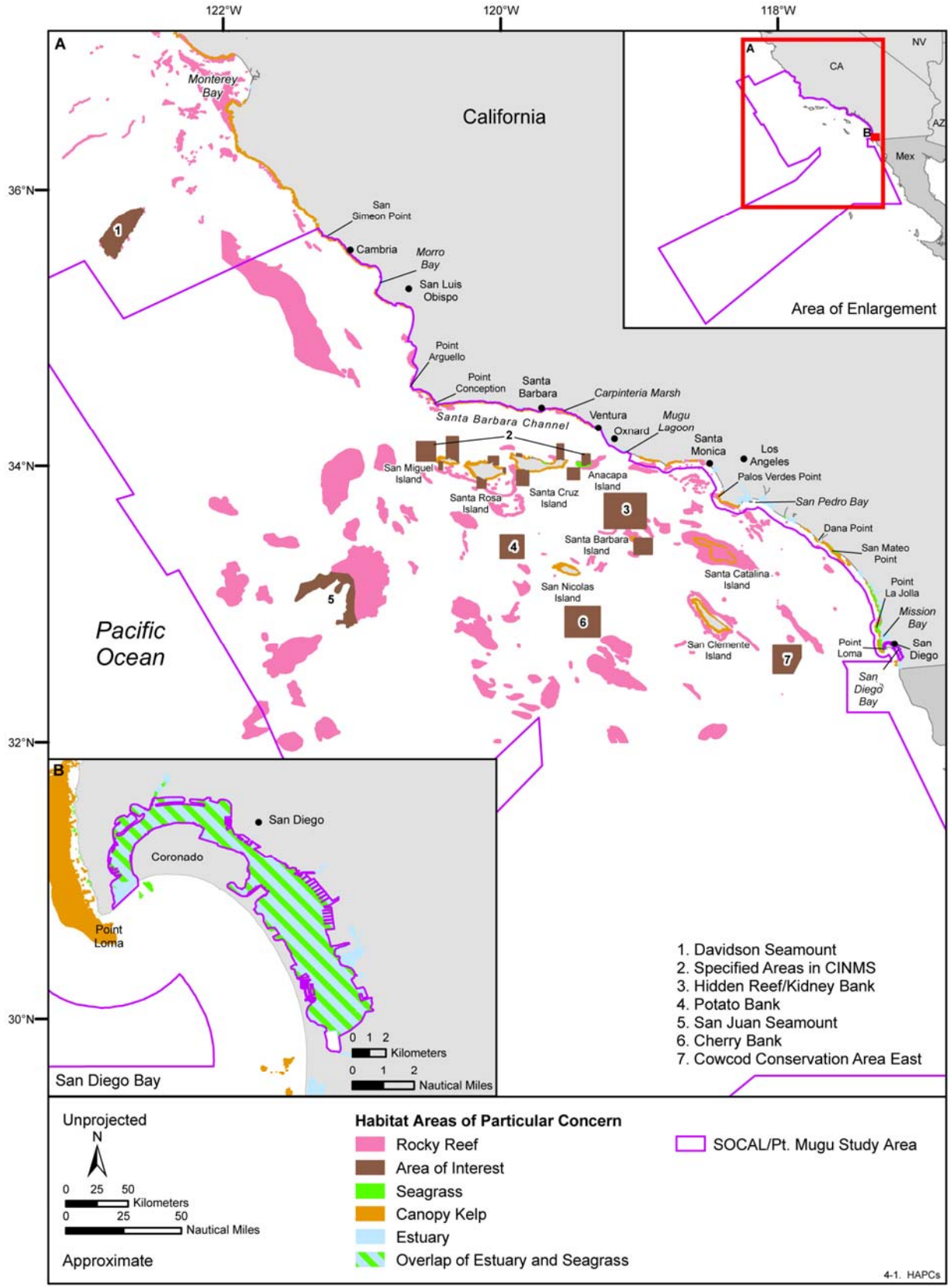

Figure 4-1. Groundfish HAPC in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Terralogic GIS, Inc. (2005a, 2005b, 2005c, 2005d).

midwater from 75 m to over 300 m (Casillas et al. 1998). Arrowtooth flounders typically reside in water temperatures ranging from sub-zero to 9.0°C: adults – 0.0° to 9.0°C, juveniles – sub-zero to 5.0°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 and krill) and fish (gadids, herring, and walleye pollock, *Theragra chalcogramma*) (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. 2005b).

Habitat Associations—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 (McCain et al. 2005). Adults are demersal, whereas the eggs and larvae 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. 2005b).

Habitat Associations—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. 2005b).

Habitat Associations—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 epi-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 50 m to beyond the 200-m isobath where current flows are 10 to 15 cm/s (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 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 Oregon and California to Point Conception 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. 2005b).

Habitat Associations—English sole are very important flatfish in shallow-water, softbottom (i.e., fine sands and mud) marine and estuarine environments (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 outer shelf community off southern California (McCain et al. 2005). Adults and juveniles are demersal, preferring soft substrates and eelgrass habitats (Garrison and Miller 1982; Pearson and Owen 1992). Adults occur from intertidal zone to 550 m, but are most abundant at depths less than 165 m (MBC 1987). Juveniles occur in intertidal zones at depths up to 150 m and in shallow-water coastal bays (e.g., Santa Monica, California) and estuarine areas (e.g., Puget

Sound, Washington State to San Pedro Bay, California) and protected coastlines (Garrison and Miller 1982; Simenstad 1983). Larvae are pelagic and eggs neritic 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., Santa Monica Bay-Santa Barbara Channel: December to April) (Matarese et al. 2003; McCain et al. 2005). This species may also spawn along the entire mainland coast of southern California and Baja California to Punta Eugenia (MBC 1987).

Common Prey Species—English sole preys upon copepods, polychaetes, amphipods, mollusks, cumaceans, ophiuroids, and crustaceans: mysids (Pearson and Owen 1992; Pearson et al. 2001).

- **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. 2005b).

Habitat Associations—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 (Hart 1973), 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 (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 along the Pacific coast (Hart 1973). Four of these breeding stocks spawn in four distinct areas off California: Point Sal in the Study Area and Point Montara, Point Delgada, and Cape Mendocino north of the Study Area (Garrison and Miller 1982; MBC 1987).

Common Prey Species—Petrale sole prey upon shrimp and other decapod crustaceans, as well as euphausiids, pelagic fishes (herring, anchovies, hake, rockfish, and sand lance (*Ammodytes hexapterus*), 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. 2005b). This species is the most widely distributed sole on the continental shelf and upper slope off Oregon (McCain 2003).

Habitat Associations—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 ranging from the surface 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).

- **Rock Sole (*Lepidopsetta bilineata*)**

Distribution—Rock sole (southern species) ranges 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. 2005b).

Habitat Associations—Rock sole prefer sandy or gravel substrata on the coast of the contiguous U.S (Hart 1973; Garrison and Miller 1982; Horton 1989) occurring at water depths from 13 to 339 m (Orr and Matarese 2000). Adults and juveniles are demersal and found primarily in shallow water bays 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 in 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: California – February to April and Puget Sound, Washington State – December to April, peaking in March (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. 2005b).

Habitat Associations—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 estuaries (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). Juveniles, and larvae are found year-round in some estuaries (Hart 1973), whereas adults rarely inhabit estuaries (Pearson and McNally 2005). 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 undergo vertical migration being more abundant near the surface at night (Pearson and McNally 2005).

Sand sole are oviparous with external fertilization. Spawning occurs in late winter through mid spring (Hart 1973) in Puget Sound, Washington State (Pearson and McNally 2005) over sandy and muddy substrates in water 20 to 30 m deep (Garrison and Miller 1982).

Common Prey Species—Sand sole prey mainly on speckled sanddab, Pacific herring (*Clupea harengus*), tomcod (*Microgadus proximus*), northern anchovy, sculpins, crustaceans, mollusks, and worms (Hart 1973; Barry et al. 1996; Pearson and McNally 2005).

- **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 Ocean, they occur from the western Bering Sea and Commander-Aleutian chain to Los Angeles Harbor, southern California (Hart 1973; Garrison and Miller 1982; Kramer et al. 1995; McCain et al. 2005).

Habitat Associations—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 and juveniles are found in estuaries and the lower reaches of major coastal rivers (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 in 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: i.e., Elkhorn Slough, California – November to February peaking in December (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, nemertean worms, brittle stars, and occasionally fish (northern anchovy) (Orcutt 1950; Hart 1973; Haugen 1992; Barry et al. 1996; Haugen and Thomas 2001).

♦ **Sand Flounders (Paralichthyidae)**

- **Pacific Sanddab (*Citharichthys sordidus*)**

Distribution—Pacific sanddab range from Holiday Beach, Kodiak Island, western Gulf of Alaska to Cabo San Lucas, southern Baja California (Garrison and Miller 1982; Mecklenburg et al. 2002; Love et al. 2005b). This species is most abundant along north-central California from Eureka to San Francisco (Rackowski and Pikitch 1989).

Habitat Associations—Pacific sanddab inhabits the inner continental shelf along the western U.S. coast (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). 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° and 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, Washington State – 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 Associations—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) and are most abundant off central and southern California (Love et al. 2002). In the SCB, larvae occur in waters at depths less than 200 m over the continental shelf (Moser et al. 2000).

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 (Love et al. 2002; McCain 2003). Young are released during late winter through late spring

(Casillas et al. 1998). Off California, larvae have been collected from November to August with peak abundances in May and June (Love et al. 2002).

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 Sound, British Columbia, to central Baja California and Isla Guadalupe, but are most common from Fort Bragg southward to at least southern California (Love 1992a; Starr et al. 1998; Love et al. 2002; Love et al. 2005b).

Habitat Associations—Bank rockfish occur offshore (Eschmeyer et al. 1983) at depths from 31 to 454 m (Love et al. 2002; Love et al. 2005b), with adults preferring depths in excess of 210 m (most commonly between 90 and 360 m) (Love et al. 2002) 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 shelves, canyons (i.e., Monterey), 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). In southern California, this species are often found with blackgill and pinkrose rockfishes and cowcod (Love et al. 2002).

Spawning occurs from December to May off California peaking in January (southern California) and February (central and northern California) (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 1992a).

- **Black Rockfish (*Sebastes melanops*)**

Distribution—Black rockfish range from the southern Bering Sea and the Aleutian Islands (Amchitka Island) to northern Baja California but are most common from San Francisco northward to southeast Alaska, occasional into central California, and rare in southern California (Phillips 1957; Miller and Lea 1972; Hart 1973; Stein and Hassler 1989; Kramer and O'Connell 1995; Love et al. 2002; Mecklenburg et al. 2002).

Habitat Associations—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). 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 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 (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, *Sebastes variabilis*;, silvergray, blue, and widow rockfishes), midwater schools near the bottom around kelp forest and high-relief and low-relief rocky terrain, often along steep, drop-offs, and in high-current areas (Hart 1973; Stein and Hassler 1989). Off California, black rockfish make up the kelp-rockfish assemblage along with blue, olive, kelp, black-and-yellow, and gopher rockfishes (Hallacher and Roberts 1985). 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). Recent studies have shown that this species undergoes extensive vertical movements, often in phase with the sunrise or sunset, while its diel vertical migration may be more prevalent a certain times of the year (i.e., October and May) (Parker et al. 2008).

Black rockfish have internal fertilization and annual spawning (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 (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, southern California (Love 1996; Love et al. 2002).

Habitat Associations—Black-and-yellow rockfish are considered a kelp-forest or inshore species (Hallacher and Roberts 1985) 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 1 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). This species releases one brood per season (Love et al. 2002).

Common Prey Species—Black-and-yellow rockfish prey upon crustaceans (shrimp, crabs, and isopods), mollusks, and other juvenile rockfishes (Love 1996; Lea et al. 1999; ODFW 2002).

- **Blackgill Rockfish (*Sebastes melanostomus*)**

Distribution—Blackgill rockfish range from the west coast of the Queen Charlotte Islands, British Columbia to Punta Abreojos, southern Baja California (Love 1996; Love et al. 2002; Love et al. 2005b). They are most abundant in waters off central and southern California (NMFS-NWR 2004).

Habitat Associations—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). Off southern California, mature fish are rarely taken shallower than 275 m (Love 1996). 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 southern California from January to June and off central and northern California from February to April (both peaking in February) (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 Chatham Strait and Kruzof Island, southeastern Alaska to Punta San Tomas, northern Baja California (Miller and Lea 1972; Love et al. 2002; Love et al. 2005b). They are most abundant from Eureka, northern California to the northern Channel Islands, southern California (NMFS-NWR 2004).

Habitat Associations—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). Off central and southern California, they also recruit in large numbers around offshore oil platforms (Love et al. 2002). 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 3 to 5 mo until they recruit to the kelp canopy, shallow rocky areas, and the nearshore sand-rock interface (Casillas et al. 1998). In nearshore areas of central California, post-pelagic newly settled juveniles are associated with crevices, sand-channels among rocks, depressions in the reef, or tide pools at depths of 6 to 20 m (Love 1996). 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 rockfishes, while south of Point Conception, they school with kelp bass, olive rockfish, blacksmith, and halfmoon (*Medialuna californiensis*) (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). In inshore kelp beds, this species may be solitary or form loose-to-compact aggregations (Houk 1992b). Aggregations may be as wide as 4 m and as deep as 25 m under dense kelp canopies or may extend from the surface to bottom in deeper waters, but generally in mid-depth levels from 18 to 36 m (Houk 1992b).

Blue rockfish are ovoviviparous (McCain 2003). In southern California, the blue rockfish begins mating in November and continues through early spring (McCain et al. 2005). They may produce young twice in a breeding season (Casillas et al. 1998).

Common Prey Species—Blue rockfish prey upon algae, pelagic tunicates, hydroids, jellyfishes, salps, crustaceans (i.e., krill and pelagic red crab, *Cancer productus*), and larval and juvenile fishes of many species (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. 2005b) with greatest abundance between Oregon and northern Baja California (Love et al. 2002).

Habitat Associations—Bocaccio is a middle shelf-mesobenthal species (Allen and Smith 1988) that is most abundant at depths ranging from 50 to 250 m, but may occur as deep as 475 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. 2005a; Love et al. 2007). Adults exhibit two primary habitat associations: 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 2 km/d 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 mo (Love et al. 1990). Parturition occurs off southern California from October to March and northern and central California from November to March (MBC 1987) with the production of two or more broods (Hart 1973; Love et al. 1990).

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 Monterey Bay, central California to Punta Colnett, northern Baja California (Love et al. 2002; Love et al. 2005b).

Habitat Associations—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 Prince William Sound, northern Gulf of Alaska to Bahia San Hipolito, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Stein and Hassler 1989; Love et al. 2002; Love et al. 2005b). They are most common from central California to southern California (Love et al. 2002).

Habitat Associations—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. 2005b). 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 shallower oil platforms (central and southern California) 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 2004). 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., 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 (Love et al. 2002).

Brown rockfish are ovoviviparous (Ashcraft and Heisdorf 2001). Off central and northern California, mating takes place more than once per season from December to January and May to June, respectively (Love 1996; NMFS-NWR 2004).

Common Prey Species—Brown rockfish prey upon larger fish, shrimp, isopods, polychaetes, crabs and other crustaceans (Carlisle et al. 1964; Quast 1968a; Feder et al. 1974; Stein and Hassler 1989; Love 1996).

- **Calico Rockfish (*Sebastes dallii*)**

Distribution—Calico rockfish range from San Francisco, northern California to Bahia de Sebastian Viscaino, central Baja California, but is most common south of Point Conception, California (Miller and Lea 1972; Love et al. 2005b; McCain et al. 2005).

Habitat Associations—Calico rockfish is a demersal species that occurs from the intertidal to 305 m (Love et al. 2005b), but prefers waters 60 to 89 m deep (Love et al. 1990). This species rarely swims more than two m above the bottom (Casillas et al. 1998). Adults often live at sand-rock interfaces (McCain 2003), especially rocky shelf areas where there is a mud-rock or sand-mud interface with fine sediments and are associated with areas of high- and low-relief, including artificial reefs and shallow-water oil platforms (Love et al. 1990; Love 1996; Starr et al. 1998; Yoklavich et al. 2000; Love et al. 2002). Juveniles are found in areas of soft sand-silt sediment, at sand-rock interfaces, and on artificial reefs over a wide depth range, including intertidal areas (Mearns et al. 1980; Love et al. 2002). Young-of-the-year settle from the plankton onto either soft substrata, sand-rock interfaces, or low-lying hard substrata starting off central California in June and off southern California in July (Love et al. 2002).

Calico rockfish are a warm-temperate species and are more abundant during warm water years (17°C or warmer) (Mearns et al. 1980) when they enter estuaries (i.e., King Harbor, Redondo Beach, California, only as far as the bottom wedge of cold water penetrates) (Shrode et al. 1982).

Life History— Information is lacking on the migration and movements of the calico rockfish (McCain et al. 2005).

This species is solitary or found in small groups (Love et al. 2002). Calico rockfish are single brooders and release pelagic larvae from January through May, with a peak in February in the SCB (Love et al. 1990).

Common Prey Species—Calico rockfish feed on a wide spectrum of water-column and benthic prey consuming crustaceans (i.e., euphausiids, calanoid copepods, crabs [hermit, spider, cancer, and pelagic red], and shrimp), polychaete worms, ichthyoplankton, gammarid amphipods, bivalves, brittle stars, and cephalopods (Love 1996; Love et al. 2002; ODFW 2002).

- **Canary Rockfish (*Sebastes pinniger*)**

Distribution—Canary rockfish range from the western Gulf of Alaska south of Shelikof Strait to Punta Colnett, northern Baja California (Miller and Lea 1972; Love 1996; Mecklenburg et al. 2002; Love et al. 2005b). A major population concentration of canary rockfish occurs between latitude 44°30’ and 45°00’N off Oregon (McCain et al. 2005).

Habitat Associations—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 and shallow water as young (McCain 2003). Adults have two primary Habitat Associationss: 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, vermilion, and silvergray rockfish and bocaccio (Boehlert and Kappenman 1980; Love 1996; Love et al. 2002). In the southern part of its range, this species appears to be a-reef-associated species (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 (Hart 1973; Love 1996).

Common Prey Species—Canary rockfish prey upon crustaceans, primarily plankton euphausiids and pelagic mysids, cephalopods, and occasionally on mesopelagic fish (Phillips 1964; Love 1996; Lea et al. 1999; PFMC and NMFS 2006). During spring-summer upwelling periods, euphausiids are the dominant prey (McCain 2003).

- **Chilipepper (*Sebastes goodei*)**

Distribution—Chilipepper range from the Pratt and Durgin Seamounts in the Gulf of Alaska to Bahia Magdalena, southern Baja California; 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. 2005b).

Habitat Associations—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 near the surface 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. 2005b). 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/d 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 California, mating occurs from September to April peaking in December through January off southern California and peaking in January through February off central and northern California (Oda 1992; Love 1996; Ralston and Oda 2001). Chilipepper produce multiple broods in a single season in southern California (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, lanternfish, 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 and offshore of San Nicolas Island, southern California (Mecklenburg et al. 2002; McCain

et al. 2005). They are abundant from Prince William Sound, Alaska to Sonoma County, northern California (Love 1996; Love et al. 2002).

Habitat Associations—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). Young-of-the-year settle in shallow water after a probably short pelagic stage (NMFS-NWR 2004).

Life History—China rockfish are territorial and sedentary, traveling less than 1 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. 2005b). They are most abundant from Valdez, Alaska to Punta Banda, northern Baja California (NMFS-NWR 2004).

Habitat Associations—Copper rockfish occur in nearshore waters on natural rocky reefs, boulder fields, artificial reefs, rock piles, and closely associated with reefs or kelp bed areas (within 1 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; M.J. 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 occupy deeper waters (usually 90 m) in the southern part of their range (off southern California) (ODFW 2002). Small juveniles and larvae are pelagic for several months to a year and are frequently associated with waters containing surface-forming kelp (*Macrocystis* sp., *Cystoseira* sp., and *Nereocystis* sp.) before settling in shallow water (Stein and Hassler 1989; Carr 1991; Love 1996). In central California, settlement begins in late April or May (Love et al. 2002). Older young-of-the-year occur with drift algae near the bottom, in and around sand and low rock formations during the summer and winter months (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).

Aggregations numbering 50 to 100 individuals have been observed around oil platforms and depending on habitat and geographic location, they often occur with vermilion, black, brown, dusky, silvergray, yelloweye, quillback, or tiger rockfishes (Love et al. 2002).

Copper rockfish mate once per year and move inshore to release their young (Love et al. 2002). Parturition occurs 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, and 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 Newport, Oregon to Banco Ranger and Isla Guadalupe, central Baja California (Miller and Lea 1972; Love et al. 2005b). This species is common from northern California (south of Cape Mendocino) to at least off Punta Colnett, northern Baja California (Love et al. 2002). Most of their preferred habitat is located in the SCB (Barnes 2001).

Habitat Associations—Cowcod is a parademersal species occurring in water depths of 40 to 491 m (Love et al. 2005b). Adults are commonly found at depths of 72 to 491 m (Orr et al. 1998, 2000) over high-relief rocky areas (Love and Yolkavich 2007), 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 in relatively high densities with submarine platforms (Love and York 2005), shell mound that surround oil and gas platforms, and bottom of platform jackets (Love et al. 2002; Butler et al. 2003; Love et al. 2005a; Love et al. 2007). Love and Yoklavich (2007) reported small juveniles undergo ontogenetic shift at depths ranging from 52 to 330 m. Small fish (5 to 20 cm total length [TL]) live among cobbles or cobbles and small boulders before migrating to boulder fields and rock ridges as they mature. 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). Small juveniles have been found with pygmy and swordspine rockfishes, whereas larger juveniles have been associated with juvenile bocaccio, juvenile widow rockfish, and squarespot rockfish (Love and Yolkavich 2007).

Cowcod are ovoviviparous with large females producing up to three broods per season (Love et al. 1990). In southern California, several broods are produced from November to May peaking in January; whereas in 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 (rockfishes and anchovies), octopus, and squid (Love 1996; McCain 2003)

- **Darkblotched Rockfish (*Sebastes crameri*)**

Distribution—Darkblotched rockfish range from 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) to near Santa Catalina Island and Laguna Beach, southern California (Love et al. 2005b). Darkblotcheds are most common from off British Columbia to central California (Love et al. 2002). Distinct population groups have been found off Oregon coast between latitude 44°30' and 45°20'N (McCain et al. 2005).

Habitat Associations—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 29 to 915 m (Love et al. 2005b) 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) and oil platforms (Love et al. 2002).

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, shortspine thornyhead, and splitnose and redbanded (*Sebastes babcocki*) rockfishes (McCain et al. 2005).

Darkblotched rockfish are ovoviviparous with fertilization and parturition occurring from December to March off Oregon and California (Hart 1973; Nichol and Pikitch 1994).

Common Prey Species—Darkblotched rockfish prey upon macroplanktonic organisms, primarily euphausiids, but also occasionally on crangon shrimp, squid, amphipods, small salps, and octopus, and infrequently on small fish (McCain 2003).

- **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. 2005b). They are most abundant from central California to at least northern Baja California (Love et al. 2002).

Habitat Associations—Flag rockfish occur at depths from 30 to 418 m (Miller and Lea 1972; Love 1996; Orr et al. 2000; Love et al. 2005b), 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, sewer outfalls (southern California), oil platform bottoms, 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, on mussel mounds surrounding oil platforms (Love et al. 2002), and may be associated with rocky reefs (CDFG 2002b). Young-of-the-year are found along the midwater super structure of oil platforms (Love et al. 2002).

Life History—Information is unavailable on the migrations and movements of the flag rockfish (McCain et al. 2005). Flag rockfish are often found in the same habitat with greenspotted, squarespot, canary, starry, rosy, and vermilion rockfishes and cowcod (Love et al. 2002).

Flag rockfish reproduce from March to June off southern California and July to August off northern California (Kendall and Lenarz 1987).

Common Prey Species—Flag rockfish prey upon pelagic red crabs, hermit crabs (including their shell houses), 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. 2005b), but are most common from Sonoma County, northern California to Arrecife Sacramento, central Baja California (NMFS-NWR 2004).

Habitat Associations—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 on rocky reefs or into the kelp colony in shallow water (Casillas et al. 1998). Large juveniles become demersal, preferring low-

relief rocks or sand bottoms closely associated with drift algae and giant kelp (*Macrocystis pyrifera*) (Carr 1991).

Life History—Gopher rockfish are known to move from 1 to 2 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). Kelp, blue, and olive rockfish and treefish occur on the same reefs as the gopher rockfish (Love et al. 2002).

Gopher rockfish are ovoviviparous with eggs carried for 1 to 2 mo 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). This species produces one brood per season (Love et al. 2002).

Common Prey Species—Gopher rockfish prey upon crustaceans (*Cancer* sp., crabs, caridean shrimp, and 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 Westport, Washington State to Playa Maria Bay, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005b), 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 2004).

Habitat Associations—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 in 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 1 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 (crabs and pistol shrimp), juvenile fishes (surfperches, midshipmen, and white croaker, *Genyonemus lineatus*), cephalopods, and gastropods (Love 1996; Lea et al. 1999).

- **Greenblotched Rockfish (*Sebastes rosenblatti*)**

Distribution—Greenblotched rockfish range from Point Delgada, northern California to Ranger Bank, central Baja California, but are most common southward from central California to at least Isla Cedros and around Isla Guadalupe (Miller and Lea 1972; Love et al. 2002).

Habitat Associations—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, and around oil platforms (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, and lanternfish), and squid (McCain 2003).

- **Greenspotted Rockfish (*Sebastes chlorostictus*)**

Distribution—Greenspotted rockfish range from Copalis Head, Washington State to southern Baja California but are abundant from Monterey Bay, northern California to at least Punta Colnett, northern Baja California and Isla Guadalupe and Isla Cedros, central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005b).

Habitat Associations—Greenspotted rockfish are common, benthic inhabitants found in waters 30 to 379 m deep (Miller and Lea 1972; Love et al. 2005b) 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 3 km from their habitat (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 northern and central California from April through September, peaking in May and off southern California from February to July, peaking in April (Love 1996; Love et al. 2002).

Common Prey Species—Greenspotted rockfish prey upon planktonic euphausiids, tunicates, small fishes (juvenile rockfishes and hake, lanternfish, and anchovies), and squid (Love et al. 1990).

- **Greenstriped Rockfish (*Sebastes elongatus*)**

Distribution—Greenstriped rockfish range from Chirikof Island in the western Gulf of Alaska to Cedros Island, central Baja California; 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. 2005b).

Habitat Associations—Greenstriped rockfish are a deep-water, parademersal species inhabiting waters from 12 to 1,145 m deep (Hart 1973; Love et al. 2005b), 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, or 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 (*Ophiacantha*) on deep reefs (Tissot et al. 2007). Juveniles have also been observed at oil platforms, mussel mounds, 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). This species is often found with greenspotted, swordspine, cow, greenblotched, and pygmy rockfishes over rock outcrops off southern California and co-occur with pygmy, halfbanded, greenspotted, and stripetail rockfishes off central California (Love et al. 2002).

Greenstriped rockfish are viviparous and multiple brooders mating two or more times per season (Love et al. 1990). This species reproduces off northern and central California from May to July, peaking in May and off southern California from January to July, peaking in April (Hart 1973; Love et al. 1990).

Common Prey Species—Greenstriped rockfish prey upon various planktonic organisms, such as euphausiids, calanoid copepods, gammarid amphipods, and pelagic tunicates as well as small fishes (hake, anchovies, and lanternfish), shrimp, and squid (Love et al. 2002; McCain 2003).

- **Honeycomb Rockfish (*Sebastes umbrosus*)**

Distribution—Honeycomb rockfish are found from Point Pinos (Monterey County, central California) to Punta San Juanico, southern Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005b) but is most abundant between Point Dume, California to at least Punta San Roque (southern Baja California) (Love et al. 2002).

Habitat Associations—Honeycomb rockfish is a shallow water species, found on or near the bottom most often between 45 to 60 m; however, they can inhabit depth ranges from 18 to 270 m (Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005b). Young recruit to hard substrates and high relief reefs (>1 m) (Casillas et al. 1998) and in some cases to softbottoms at depths between 27 and 54 m (CDFG 2002b). Young-of-the-year honeycomb rockfish have been found settling to the bottom in the La Jolla Submarine Canyon as early as October (Casillas et al. 1998).

Life History—Adult movement is not extensive (Casillas et al. 1998).

Honeycomb rockfish reproduce from March to July, probably peaking in April (McCain 2003).

Common Prey Species—Information is unavailable on the prey of the honeycomb rockfish (McCain et al. 2005).

- **Kelp Rockfish (*Sebastes atrovirens*)**

Distribution—Kelp rockfish range from Albion in northern California to Bahia San Carlos and Islas San Benito, in central Baja California (Love et al. 2002) and are most abundant from northern California to Arrecife Sacramento in central Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996; Love et al. 2005b).

Habitat Associations—Kelp rockfish inhabit shallow waters. Most live at depths of 18 to 24 m (Love et al. 2002) although they occur at depths ranging from inshore (3 m) to 58 m (Eschmeyer et al. 1983; Love et al. 2002; Love et al. 2005b). Adults are primarily residential in kelp (*Macrocystis*) forests (Casillas et al. 1998) frequently occurring on or near the bottom in kelp beds and rocky areas (Eschmeyer et al. 1983; Carr 1991) including artificial reefs (Cailliet et al. 2000).

Juveniles utilize kelp beds in the summer from April to August (earliest in southern California and Baja California) as nursery areas for refuge (McCain 2003). As the fish mature, they shift habitats by gradually migrating down the kelp stipes assuming a parademersal existence in close proximity to benthic algal cover, and in cracks and crevices within the rocky substratum (Casillas et al. 1998). Fronds of kelp beds provide a nursery area and a refuge for the kelp rockfish (McCain et al. 2005).

Life History—Kelp rockfish do not make extensive seasonal movements, except during winter storms, when they migrate into slightly deeper water or rock caves (Love 1996). This species is often solitary, but they occasionally form aggregations of 20 to 25 individuals at oil platforms in the Santa Barbara Channel. Blue, gopher, black-and-yellow, and olive rockfishes inhabit the same habitat as the kelp rockfish (Love et al. 2002).

Kelp rockfish are ovoviviparous with internal fertilization (McCain 2003). Timing of reproduction ranges from late winter through summer (Love 1996) but typically occur from May to June (Carr 1991). Larval release occurs off central California from February through June, peaking in May and off southern California between March and June (Love et al. 2002).

Common Prey Species—Kelp rockfish eat a variety of prey feeding on benthic invertebrates, caridean shrimp, amphipods, tunicates, cephalopods, gastropods, and fishes (e.g., juvenile rockfishes, kelpfishes, pricklebacks, and sculpins) (Love et al. 2002; ODFW 2002; McCain 2003).

- **Mexican Rockfish (*Sebastes macdonaldi*)**

Distribution—Mexican rockfish range from Point Sur, central California to Cape San Lucas, southern Baja California, and eastward into the central Gulf of California (MacGregor 1986; Love et al. 2002; Love et al. 2005b).

Habitat Associations—Mexican rockfish are found at depths ranging from 76 to 350 m (Love et al. 2002; Love et al. 2005b). Adults inhabit rock outcrops, and have been observed near deep oil platforms at depths of 91 to 238 m (Orr et al. 2000; Love et al. 2002). Juveniles and larvae occur at depths of 80 to 100 m (McCain 2003) with larvae collected as far as 185 to 240 km offshore (MacGregor 1986).

Life History—Information is lacking on the migration and movements of the Mexican rockfish (McCain et al. 2005).

Mexican rockfish are ovoviviparous. They reproduce with highest densities occurring in April, with the peak mating time taking place later in the southern parts of its range (MacGregor 1986). Off southern California, larvae are released from November to May (Love et al. 2002).

Common Prey Species—Information is unavailable on the prey of the Mexican 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 Channel Islands off Santa Barbara northward to Cape Mendocino in northern California (Eschmeyer et al. 1983; Love 1996).

Habitat Associations—Olive rockfish occur at depths ranging from surface/intertidal (2 m) 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, and 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 3 m (Carlisle et al. 1964; DeMartini 1981). 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 may occur within the same type of habitat as blue, copper, gopher, black-and-yellow, and kelp rockfishes (Love et al. 2002).

Olive rockfish reproduce once per season (December 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, anchovy, topsmelt, and pipefish), cephalopods, isopods, krill, and polychaete worms (Quast 1968b; 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 La Jolla, southern California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005b) but are common from Oregon northward (Eschmeyer et al. 1983).

Habitat Associations—Pacific ocean perch inhabit the edge of the upper continental slope (Archibald et al. 1983; Dark and Wilkins 1994), occurring from near the surface 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 2 to 3 yr (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).

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 Ocean, 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, amphipods, and fishes (flatfishes, lanternfish, and deepsea 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, but is most abundant from southern California to at least Punta Colnett, northern Baja California (Love et al. 2002; Love et al. 2005b).

Habitat Associations—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 continental shelf and 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 Kodiak Island in the Gulf of Alaska to Anacapa Passage, southern California (Miller and Lea 1972; Love et al. 2005b). They are common from southeastern Alaska to northern California (Hart 1973; Love 1996; Love et al. 2002).

Habitat Associations—Quillback rockfish are a common, shallow-water benthic species that occur from 5 to 274 m (Phillips 1957; 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 estuaries, 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 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). 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. Off northern and central California, this species spawns from April to July with a peak early in the season (Love 1996).

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).

- **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. 2005b). 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 Associations—Redbanded rockfish occurs in waters as shallow as 49 m and as deep as 1,145 m (Love et al. 2005b) 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 northern and central California, parturition occurs from March to September (Love et al. 2002).

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 Pribilof Canyon, southeastern Bering Sea and Amchitka Island, Aleutian Islands to southern Baja California (Hart 1973; Allen and Smith 1988; Love et al. 2002; Love et al. 2005b). This species is most abundant from southeast Alaska to central Oregon (NMFS-NWR 2004).

Habitat Associations—Redstripe rockfish inhabit the outer shelf and upper continental slope (Allen and Smith 1988) in water depths between 12 and 442 m with greatest depth frequency (95%) occurring between 150 and 275 m (Allen and Smith 1988; Love et al. 2002). 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 (Casillas et al. 1998).

Common Prey Species—Redstriped rockfish prey upon krill, small fish (anchovies, herring, and early stages of other rockfishes), and squid (Love et al. 2002; McCain 2003).

- **Rosethorn Rockfish (*Sebastes helvomaculatus*)**

  Distribution—Rosethorn rockfish range from the western Gulf of Alaska east of Sitkinak Island to Banco Range, central Baja California (Phillips 1957; Hart 1973; Love et al. 2005b).

  Habitat Associations—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 (*Ophiacantha*) (Tissot et al. 2007). 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).

  Common Prey Species—Rosethorn rockfish prey upon euphausiids, crustaceans (gammarid amphipods), and fishes (Love et al. 2002; McCain et al. 2005).

- **Rosy Rockfish (*Sebastes rosaceus*)**

  Distribution—Rosy rockfish range from Strait of Juan de Fuca near Puget Sound, Washington State to Bahia Tortugas in southern Baja California (Miller and Lea 1972; Love et al. 2002). This species is most abundant from at least northern California to off Punta Colnett, northern Baja California (Love et al. 2002).

  Habitat Associations—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 and may be found around the bottoms of oil platforms and adjacent mussel mounds (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 and usually occurs with squarespot, blue, starry, pygmy, and speckled rockfishes (Love et al. 2002).
  Rosy rockfish are multiple brooders having one of the longest seasons of larval releases among rockfishes (Love et al. 1990; Love et al. 2002). Reproduction occurs off central California from December to September and off southern California from January to September, peaking in May (Love et al. 1990).

  Common Prey Species—Rosy rockfish prey upon benthic crustaceans such as shrimp, crabs, gammarid amphipods, krill, and 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 Associations—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 or in crevices and caves (Casillas et al. 1998; Love et al. 2002). 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° and 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. 1990). Fishes in the northwest Pacific Ocean 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 Attu Island in the Aleutian Islands, Alaska, to San Diego, southern California (Allen and Smith 1988; Love et al. 2005b). 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 2004) and off Heceta Bank, central Oregon (Love et al. 2002).

Habitat Associations—Sharpchin rockfish is an outer shelf-mesobenthal species that is commonly found at water depths from 25 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*) (Tissot et al. 2007). Pelagic juveniles occur 9 to 148 km offshore and larvae 46 to 148 km offshore over deep water (270 to 2,800 m) (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 La Perouse Bank, southern British Columbia to Punta Baja, southern Baja California (Eschmeyer et al. 1983; Love et al. 2005b) and as far west as the Cobb seamount off the southern Washington State coast (Field et al. 2007). Large concentrations occur along the continental shelf break off the Columbia River, Oregon-Washington State border, between the northern end of Monterey Bay and Point Reyes, California

(particularly in the regions of Ascension Canyon and Farallon Islands), and around the Channel Islands, SCB (Phillips 1964; Moser et al. 2000; Love et al. 2002).

Shortbelly rockfish is one of the most abundant rockfish species in the California Current and a key forage species for many piscivorous fish, birds, and marine mammals. Based on the genetic analysis of specimens collected between San Diego and Cape Mendocino, this species is considered to consist of a single, coastwide stock (Field et al. 2007).

Habitat Associations—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 upper slope (Stull and Tang 1996). Adults are parademersal occurring in waters ranging from 150 to 200 m from central California to southern Vancouver Island and in waters deeper than 200 m off southern California (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 3 to 5 mo 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, 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 Associations—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 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, mollusks, and fish (i.e., lanternfish) (Yang and Nelson 2000; Love et al. 2002).

- **Silvergray Rockfish (*Sebastes brevispinis*)**

Distribution—Silvergray rockfish range from the southeastern Bering Sea to Bahia de Sebastian Vizcaino, central Baja California (Hart 1973; Allen and Smith 1988; Love et al. 2005b) but are most common between the central Gulf of Alaska and Oregon (Love et al. 2002).

Habitat Associations—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 (*Sebastes emphaeus*), and yellowtail rockfishes 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. 2005b) and are common from central California southward to at least Punta Colnett, northern Baja California (Love 1996; Love et al. 2002).

Habitat Associations—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, in crevices, 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 rockfishes (Love et al. 2002).

Speckled rockfish produce multiple broods (two or more times per season) releasing larvae in May off central and northern California and from September to May, peaking in January and February off southern California (Love et al. 1990).

Common Prey Species—Speckled rockfish prey upon plankton (krill and copepods) and occasionally eat small fish (Love 1996).

- **Splitnose Rockfish (*Sebastes diploproa*)**

Distribution—Splitnose rockfish range from Sanak Islands, western Gulf of Alaska to Isla Cedros, central Baja California (Miller and Lea 1972; Allen and Smith 1988; Love et al. 2005b). They are most abundant from British Columbia to southern California (NMFS-NWR 2004).

Habitat Associations—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). Off southern California, juveniles are the dominant rockfish species found under drifting kelp (Love et al. 2002). Larvae are found almost exclusively in waters over the continental shelf at depths less than 2,000 m in the SCB (Moser et al. 2000).

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). This species co-occurs with stripetail and darkblotched rockfishes and shortspine thornyhead off central California (Love et al. 2002).

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. Off southern California, larvae are found in all months, peaking most commonly in summer and fall; while off central California, larvae are release from January to September, primarily in July. Limited year-round larval release may occur coastwide (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 2004). Off southern California, this species feeds on midwater plankton, primarily euphausiids (Love et al. 2002).

- **Squarespot Rockfish (*Sebastes hopkinsi*)**

Distribution—Squarespot rockfish range from the southern Oregon coast to northern Baja California and Isla Guadalupe, central Baja California, most commonly from about central California to at least off Bahia San Quintin, northern Baja California (Love 1996; Casillas et al. 1998; Love et al. 2005b).

Habitat Associations—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 be solitary or 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, peaking in March off central and northern California and from January to April, peaking in January and February off southern California (Love 1996; Love et al. 2002).

Common Prey Species—Squarespot rockfish prey upon plankton primarily copepods, krill, arrow worms, and crab larvae (Love 1996; Love et al. 2002).

- **Starry Rockfish (*Sebastes constellatus*)**

Distribution—Starry rockfish range from Cordell Bank, northern California to Banco Thetis, southern Baja California (Miller and Lea 1972; Love 1996; Love et al. 2005b). This species is abundant from at least central California to off Punta Thurloe, southern Baja California and around Isla Guadalupe, central Baja California (Love et al. 2002).

Habitat Associations—Starry rockfish occur from depths of 15 to 274 m (Orr et al. 1998, 2000; Love et al. 2005b) over hardbottom substrates, usually around large rocks and boulders; in crevices, over cobble and shipwrecks, or inside vase sponges (Love et al. 1990; Love 1996; Love et al. 2002). Off southern California, they are most commonly found at depths from 60 to 150 m (Love et al. 2002). Juveniles are common from depths of 30 to 120 m (Love et al. 2002), and associated with rocks and structures (i.e., shell mounds surrounding oil platforms) (Love et al. 2002).

Life History—Starry rockfish are usually solitary, occasionally forming small aggregations (McCain et al. 2005). It is unlikely that the adults move more than 0.5 m above high-relief rocks (Love 1996). Other species commonly associated with this species include the squarespot, speckled, rosy, juvenile widow, and pygmy rockfishes (Love et al. 2002).

Starry rockfish are multiple brooders. Reproduction in southern California occurs from February to July, with a peak in May and from January to June off central and northern California (Love et al. 1990; Love et al. 2002).

Common Prey Species—Starry rockfish prey include small fishes, benthic crustaceans such as crabs and shrimp, krill, and other small invertebrates (Love 1996; McCain et al. 2005).

- **Stripetail Rockfish (*Sebastes saxicola*)**

Distribution—Stripetail rockfish range from Yakutat Bay, eastern Gulf of Alaska to Punta Rompiente, southern Baja California (Miller and Lea 1972; Hart 1973; Love et al. 2002; Love et al. 2005b). They are most commonly found between British Columbia and southern California (Love et al. 2002).

Habitat Associations—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). This species is the dominant soft-bottom fish off southern California along with Dover sole, slender sole (*Lyopsetta exilis*), Pacific sanddab, plainfin midshipman, yellowchin sculpin (*Icelinus quadriseriatus*), and speckled sanddab (*Citharichthys stigmaeus*) (Stull and Tang 1996). 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). Adults are also quite abundant on shell mounds surrounding the deeper oil platforms and next to pipelines in central and southern California (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 greater than 15 m (central

California) or ranging between 21 to 45 m (southern California) (Johnson et al. 2001; Love et al. 2002). Juvenile habitat consists of sandy substrate in association with macrophytes (kelp beds) (Love et al. 1994), low-relief rocks and sedimentary outcrops bounded by mud and sand, and in some cases oil platforms (Love et al. 2002). Young-of-the-year can be found in bits of drift algae as well as other bottom debris in waters as deep as 224 m (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). This species is commonly associated in the same habitat as splitnose or greenstriped rockfishes, Dover sole, poachers, and thornyheads (Love et al. 2002).

Stripetail rockfish produce one brood per season. Young are released from November through March with peak release occurring in February off central and northern California and in December within the SCB (Love 1996; Casillas et al. 1998; Love et al. 2002).

Common Prey Species—Stripetail rockfish prey upon euphausiids and calanoid copepods (Stull and Tang 1996).

- **Tiger Rockfish (*Sebastes nigrocinctus*)**

Distribution—Tiger rockfish range from Unalaska Island, Aleutian Islands to Tanner and Cortes Banks, southern California (Love et al. 2002; Love et al. 2005b). They are most common between southeast Alaska and northern California (Love et al. 2002).

Habitat Associations—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). 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). This species is often found in the vicinity of quillback, China, and yelloweye rockfishes (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 crabs, and gammarid amphipods) and small fishes like herring and juvenile rockfish (Love et al. 2002; McCain 2003).

- **Treefish (*Sebastes serriceps*)**

Distribution—Treefish range from San Francisco, northern California to Isla Cedros, central Baja California (Miller and Lea 1972; Love et al. 2005b); however, they are common from Santa Barbara, California southward to Arrecife Sacramento, central Baja California (Love 1996; Love et al. 2002; Colton and Larson 2007).

Habitat Associations—Treefish are found from subtidal waters to depths of 97 m (Miller and Lea 1972) but are most common at depths less than 60 m (Love et al. 2002). This species shelters during the day in holes along rocky reefs at Catalina Island off southern California (Casillas et al.

1998). Adults are found on shallow rocky reefs, frequently in caves and crevices ((Hart 1973; Feder et al. 1974; Love 1996; Starr 1998), and on artificial reefs (Cailliet et al. 2000). Pelagic juveniles are often associated with drifting kelp mats and recruit to hard substrate with high relief (>1 m) (Love 1996) at shallow, subtidal depths to 30 m (Love et al. 2002). Recent information suggests that larvae and juveniles spend at least three months in the plankton before recruiting to the benthos (Colton and Larson 2007).

Life History—Treefish are solitary and highly territorial, defending their shelter against intruders (Love 1996). Translocated adults consistently return to the same shelter (Casillas et al. 1998). This species often occurs with other shallow-outcrop fishes including kelp, gopher, and black-and-yellow rockfishes (Love et al. 2002).

Treefish are viviparous reproducing in late winter (February and March) (Love 1996) with larvae being released during May, June, and July (Love et al. 2002; Colton and Larson 2007).

Common Prey Species—Treefish feed on bottom invertebrates such as shrimp, mollusks, spider and cancer crabs, and small fishes (Love 1996; Love et al. 2002).

- **Vermilion 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. 2005b). They are most abundant from northern California to at least Isla San Martin, northern Baja California and Isla Guadalupe, central Baja California (Love et al. 2002).

Habitat Associations—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. 2005b). 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 oil 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). They live on relatively low-relief rocky outcrops, bottom of oil platforms and their shell mounds, and pipelines (Love et al. 2002). Larvae are pelagic and remain near the surface for 3 to 4 mo 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., *Pterygophora*, rocky strata, worm tubes, eelgrass, and pier 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 (2 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 such as wastewater discharge pipes and oil drilling platforms (MBC 1987). Other rockfishes found with the vermilion rockfish include bocaccio, brown, copper, yellowtail, blue, and canary (Love et al. 2002).

Vermilion rockfish are ovoviviparous with internal fertilization and single broods (Love et al. 1990). Larval release occurs in September, December, and April to June off central and northern California and from July through March, peaking in November off southern 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, and flatfishes), octopus, squids, pyrosomes, copepods, mysids, amphipods, isopods, polychaetes, pelagic red crab (*Pleuroncodes planipes*), and krill (Phillips 1964; Love 1996; Love et al. 2002; ODFW 2002).

- **Widow Rockfish (*Sebastes entomelas*)**

Distribution—Widow rockfish range from Albatross Bank, western Gulf of Alaska to Bahia de Todos Santos, 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).

Habitat Associations—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). Post-pelagic newly settled widow rockfish are associated with crevices, sand channels among rocks, or depressions in the reef at depths of 6 to 20 m (McCain et al. 2005). 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 adult widow rockfishes occur off headlands (e.g., Cape Mendocino, Point Reyes, and Point Sur, 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). Large aggregations of juveniles have been reported around San Miguel and San Nicolas islands, southern California (Love et al. 2002). Adults school with yellowtail rockfish; whereas juveniles school with squarespot, pygmy, and speckled rockfishes. Off central California, pelagic larvae and juveniles co-occur with the following rockfishes: yellowtail, chilipepper, shortbelly, and bocaccio larvae and juveniles (Love et al. 2002).

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 and from December through March off southern California, both peaking in February (Hart 1973; Love et al. 2002).

Common Prey Species—Widow rockfish prey upon small pelagic crustaceans (hyperiid and gammarid amphipods), euphausiids, myctophids, midwater fishes (northern anchovy, juvenile Pacific hake, and lanternfish), salps (including pyrosomes), caridean shrimp, sergestid shrimp [*Sergestes similis*], 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 at least occasional around San Miguel Island, southern California (Love et al. 2002).

Habitat Associations—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 550 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 piles (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). All life stages have been seen around the oil platforms between Point Arguello and Point Conception, California (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 (Love et al. 2002).

Common Prey Species—Yelloweye rockfish prey upon fish (rockfish, cods, sand lances, herrings, and lumpsuckers), crustaceans (caridean shrimp and lithodid crab), green sea urchin (*Strongylocentrotus droebachiensis*), and gastropods (Love 1996; McCain 2003).

- **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. 2005b). Their abundance center is from southeast Alaska to central California and around San Miguel Island, southern California (Ralston 2001; Love et al. 2002).

Habitat Associations—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).

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). They also inhabit ridges and boulders, vase sponges (*Scypha* and *Iophon*), and basket stars (*Gorgonocephalus*) (Tissot et al. 2007). 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). Young-of-the-year may be extremely abundant in midwaters around oil platforms north of Point Conception, California (Love et al. 2002).

Life History—Yellowtail rockfish form large mid-water schools (>1,000 fish), singly or in association with canary and vermilion rockfishes 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 February and January to July off northern and central California with February or March peaks throughout California (Love et al. 2002).

Common Prey Species—Yellowtail rockfish prey upon fish (small hake, Pacific herring, smelt, anchovies, and lanternfish), squid, mysids, and other planktonic organisms (euphausiids, salps, and pyrosomes) (Love 1996; McCain 2003).

Scorpionfish

- **California Scorpionfish (*Scorpaena guttata*)**

Distribution—California scorpionfish range from Santa Cruz, central California into Gulf of California (Love et al. 2005b).

Habitat Associations—Scorpionfish occur from tidepools and surf zone to a depth of 183 m (Miller and Lea 1972) in both sandy and rocky areas often lodged in crevices (Casillas et al. 1998). This species also aggregates near prominent features, such as rocks and boulders as well as, kelp beds, sewer pipes, and wrecks (Casillas et al. 1998). Older juveniles settle on rocky bottoms, including artificial reefs, whereas very young fish live in shallow water, hidden away in habitats with dense algae and bottom-encrusting organisms (Love 1992b).

Life History—California scorpionfish make extensive spawning migrations in late spring and early summer with adults moving from depths of 4 to 110 m, forming large aggregations (called "explosive breeding assemblages") on or near the bottom (PFMC and NMFS 2006). During spawning, these aggregations rise up off the bottom, sometimes approaching the surface (Love 1992b). Spawning occurs in the same areas year after year with the same fish returning repeatedly to the same spawning ground (Love 1992b; Casillas et al. 1998).

Scorpionfish are oviparous producing eggs that are laid as a single layer in a floating gelatinous mass (Casillas et al. 1998). Spawning occurs from May to September, peaking in July (McCain 2003).

Common Prey Species—California scorpionfish prey on crustaceans (i.e., juvenile cancer crabs, ridgeback prawn, and shrimp), small fishes (e.g., northern anchovy), octopus, and isopods (McCain 2003; McCain et al. 2005).

Thornyhead

- **Longspine Thornyhead (*Sebastolobus altrivelis*)**

Distribution—Longspine thornyhead range from the Shumagin Islands, western Gulf of Alaska to Cabo San Lucas, southern Baja California (Miller and Lea 1972; Eschmeyer et al. 1983; Love 1996; Love et al. 2005b) but are abundant from southern California northward (Love 1996).

Habitat Associations—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). Off central California, longspine thornyheads are the dominant fish species of the soft substrata habitat (Love et al. 2002). 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 mo 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 not more than 32 km offshore (Cross 1987).

Life History—Longspine thornyhead neither schools, aggregates, nor exhibits any ontogenetic migration pattern (McCain 2003). Wakefield and Smith (1990) reported that this species does display 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 2 to 4 batches per seasons (Wakefield and Smith 1990; Love 1996). Off California, longspine thornyhead spawn from about January to 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. 2005b) and to Navarin Canyon and Aleutian Islands to Boca de Santo Domingo, southern Baja California (Love 1996; Casillas et al. 1998; Mecklenburg et al. 2002). They are abundant from the northern Kuril Islands to a least southern California (NMFS-NWR 2004).

Habitat Associations—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 (Love et al. 2002; Tissot et al. 2007). 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 mo 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 mo and have been collected up to 560 km off the California coast with the majority being in the range of 32 km (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, and 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 above and below Point Conception, California (Cope and Punt 2005).

Habitat Associations—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). 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 1968a). 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 southern California, spawning takes place from late October to March, peaking in January and February (Wilson-Vandenberg and Hardy 2001; NMFS-NWR 2004). 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 exhibiting nest-guarding behavior (Garrison and Miller 1982).

Common Prey Species—Cabezon prey upon crabs, small lobsters, mollusks (abalone, squid, and octopus), small fish (including rockfishes), and fish eggs (Quast 1968a; 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, south-central California (Mecklenburg et al. 2002).

    Habitat Associations—Kelp greenling are abundant in coastal waters and inland seas (i.e., Puget Sound, Washington State) (Hart 1973) from the intertidal zone to 130 m (Love et al. 2005b). 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). 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 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 the Shumagin Islands, southeastern Gulf of Alaska to Punta San Carlos, northern Baja California (Love et al. 2005b). 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 Associations—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 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). Tissot et al. (2007) found adults in habitats consisting of ridge and boulders, vase sponges (*Scypha* and *Iophon*), and basket stars (*Gorgonocephalus*) in areas near the top of banks at water depths less than 100 m. 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 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 MLLW (lowest tide) over rocky reefs in areas of swift current (Adams and Hardwick 1992). For the Humboldt Bay California stock, peak spawning occurs from January through February (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 6 wk (Shaw and Hassler 1989).

Common Prey Species—Lingcod prey upon demersal fishes (spiny dogfish, Pacific herring, walleye pollock, 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).

Habitat Associations—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 along the West Coast (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). 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). Larvae may be transported by tidal currents to nursery areas (Casillas et al. 1998).

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).

- **Merlucciid Hakes (Merlucciidae)**

  - **Pacific Hake (*Merluccius productus*)**

Distribution—Pacific hake or Pacific whiting, of the migratory coastal stock, range from Attu Island in the Aleutian Islands and Gulf of Alaska to Bahia Magdalena, southern Baja California and Gulf of California to Mexcaltitan, southern Mexico (Miller and Lea 1972; Mecklenburg et al. 2002) but are most abundant in the CCS between British Columbia and Baja California (Hart 1973; Love 1996). This stock annually migrates between southern California (latitude 25°N) and Queen Charlotte Island (latitude 55°N) (Ressler et al. 2007). In addition to the migratory 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). This dwarf stock is now considered a separate species (Ressler et al. 2007).

Habitat Associations—The migratory 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 km^2 feeding habitat near the shelf break of British Columbia, Washington State, Oregon and California populated 6 to 8 mo 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 4 to 6 mo a year; and (3) a continental shelf area of unknown size off California and Baja California, where juveniles brood (Smith 1995). This species represents the largest fish biomass of any groundfish in the California Current Large Marine Ecosystem (CCLME) (Phillips 2007) and is considered the most abundant groundfish off the North American west coast, south of Alaska (Ressler et al. 2007). This species also supports a substantial fishery and exerts a wide influence as both predator (zooplankton and forage fish) and prey (larger finfish/invertebrates, seabirds, and marine mammals) (Ressler et al. 2007).

Adults, juveniles, larvae, and eggs are pelagic (MBC 1987) ranging in depths from 12 to 1,400 m (Love et al. 2005b). Adults are epipelagic-mesopelagic (Sumida and Moser 1980) occurring from 12 to 1,400 m (Love et al. 2005b) 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; 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 (Vetter and Dayton 1999). Larvae of 8 to 12 mm are found at 100 to 300 m, whereas those larvae greater than 12 mm occur primarily below 200 m (Bailey et al. 1982) and have been reported as close as 4 km from shore (Phillips 2007). 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). Eggs are neritic and float to neutral buoyancy (Bailey et al. 1982). 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 continental shelf, shelf break, and slope (McCain et al. 2005). From April to May, the migratory coastal stocks undertake extensive annual migrations from offshore spawning areas in Baja California and southern California (Saunders and McFarlane 1997; Lo 2007), moving inshore, following food supply and Davidson currents to summer feeding grounds off northern California, Oregon, and Washington State, and Vancouver Island, British Columbia (Quirollo 1992). By late summer or fall (September to October), 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; Smith 1995). Dorn (1995) reported that the cross-shelf-shelf distributions extends from the inner shelf out to waters more than 2,000 m deep, perhaps 40 km or more beyond the shelf break. Stocks in the Strait of Georgia, British Columbia and Puget Sound, Washington State 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) in regions of steeply sloping bathymetry along the shelf break and near the edges of mid-shelf banks and basins, sometimes extending well offshore (Bailey et al. 1982; Dorn 1995)). The highest densities of these midwater aggregations are located over bottom depths of 200 to 300 m (Quirollo 1992). Pacific hake also form well-defined pelagic schools during the day, mostly between depths of 50 m and 500 m, disperse and undertake a diel vertical migration toward the surface at dusk to feed (Sumida and Moser 1984), then migrate back to mid-depths during the daytime (Best 1963; Alverson and Larkins 1969; Bailey et al. 1982).

Pacific hake are oviparous, pelagic spawners with external fertilization, spawning at least once per season (Casillas et al. 1998). The coastal stock (Cape Mendocino, California to Magdalena Bay, Baja California) spawns from January through March, peaking in late January (Smith 1995; Lo 2007; Phillips 2007). Spawning aggregations begin a month prior to gamete release, with spawning occurring at depths between 130 and 500 m (Bailey et al. 1982; Smith 1995). Juvenile Pacific hake nursery areas have been identified to be principally located along the coastal shelf and slope of California (Phillips 2007). During spawning, the Pacific hake neither feeds nor migrates (Ressler et al. 2007).

Common Prey Species—Pacific hake prey upon euphausiids (*Euphasia pacifica* and *Thysanoessa spinifera*), amphipods, squid, pandalid shrimp (*Pandalus jordani*), smelt, crabs, and occasionally on Pacific hake and pelagic schooling fish (eulachon, *Thaleichthys pacificus*, and Pacific 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 or blackcod range from off central Honshu, Japan, to Aleutian Islands and Bower Banks to Bering Sea, south of St Lawrence Island, Alaska, and to Islas San Benito and Isla Cedros, central Baja California. This species is uncommon south of Point Conception, California (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, Canada and Gulf of Alaska characterized by fast growth rates and larger sizes. Only the south of Monterey Bay stock occurs within the SOCAL/Pt. Mugu Study Area (Schirripa and Colbert 2005).

    Habitat Associations—Sablefish is an inner shelf-bathybenthal species that is found over soft substrates in deep marine waters (Love 1996). Adults and large 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 consisting of mud and sea urchins (*Allocentrotus*) (Tissot et al. 2007). 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 and a preferred salinity range for spawning adults between 33.7 psu and 34.5 psu (Mason et al. 1983; MBC 1987).

    Life History—Sablefish are a non-migratory species, although some long migrations have been documented such as individuals moving up to 2,735 km to mid-ocean seamounts (Love 1996; Schirripa 2007). 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 (i.e., 1,500 m off southern California) (MBC 1987) 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 500 m along the continental slope (Hart 1973; Schirripa 2007) from late fall through winter but varies with latitude (e.g., Monterey Bay in central California: November to 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, and Pacific herring, shrimp), crabs, and octopus, but their predominant prey organism is euphausiids (Hart 1973; McFarlane and Beamish 1983a; McCain 2003).

Skates and Sharks

- **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. 2005b). 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 2004; FLMNH[6]).

    Habitat Associations—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, Oregon) consisting of mud and sea urchins (*Allocentrotus*) (Tissot et al. 2007). 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 (e.g., cancrid crabs, crangonid shrimp), small benthic fishes, polychaete worms, and mollusks (Hart 1973; Eschmeyer et al. 1983; Ebert 2003; Bizzarro et al. 2007).

  - **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 Associations—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 bottom sediments (Roedel and Ripley 1950; CDFG 2002b) and deepwater habitats consisting of mud and sea urchins (*Allocentrotus*) (Tissot et al. 2007).

    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, crabs, and fishes (Ebert 2003; Bizzarro et al. 2007).

- **Longnose Skate (*Raja rhina*)**

  Distribution—Longnose skate range from southeastern Bering Sea to just below Punta San Juanico, southern Baja California and Gulf of California (Allen and Smith 1988; Ebert 2003).

  Habitat Associations—Longnose skate is one of the more common skates (Roedel and Ripley 1950) occurring on the bottom of the inner and outer continental 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.[3] Eggs are laid in an enclosed rough, leathery shell with a loose covering of fibers and short horns (Eschmeyer et al. 1983). Typically, an egg case houses 4 to 5 embryos, although the numbers may range from as low as 1 egg to as high as 7 eggs per case (Roedel and Ripley 1950; Hart 1973; Gertseva and Schirripa 2007). 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 and cephalopods (Ebert 2003; Robinson et al. 2007).

♦ **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[6]). This species is most abundant in northern California bays and estuaries and along southern California beaches (Ebert 2003).

  Habitat Associations—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 1984a; Emmett et al. 1991; Smith 2001; Love et al. 2005b). This species also inhabits littoral waters (Castro 1983; Eschmeyer et al. 1983; Compagno 1984a; 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, central California) (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, southern California (Smith 2001) and near eel grass beds in other bays (i.e., San Francisco and Humboldt bays; central California) (Ebert 2003). This species occurs in polyhaline to euhaline waters (NMFS-NWR 2004).

  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 1984a; Emmett et al. 1991; Love 1996; Ebert 2003; FLMNH[6]). Adult female leopard sharks are known to aggregate in large numbers in shallow bays and estuaries,

particularly in summer months and have been reported to travel at least seven km between aggregation sites (Hight 2007).

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 mo (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 1984a; Love 1996).

Common Prey Species—Leopard shark prey upon cancrid crabs, clam siphons, small fishes, polychaetes, echiuroid worm (*Urechis caupo*), and fish eggs (i.e., herring, topsmelt, jacksmelt, and midshipmen) (Compagno 1984a; 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 1984a).

Habitat Associations—Soupfin shark is an abundant coastal-pelagic species of temperate continental and insular waters that is often associated with bottom habitats (Compagno 1984a) 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 1984a).

Male and female soupfin sharks segregate by sex (Casillas et al. 1998), with adult males favoring deep waters and females, shallow waters (Compagno 1984a). 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/d, with sustained speeds of 16 km/d for 1,600 km (Hart 1973; Eschmeyer et al. 1983; Compagno 1984a).

Soupfins are ovoviviparous with mating occurring during the spring (Ebert 2003). After a gestation period of approximately 1 yr, 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 1984a) averaging 35 pups (Ebert 2003). The primary nursery grounds are inshore areas south of Point Conception, California. In central California, San Francisco and Tomales bays are utilized to a certain extent as pupping grounds (Compagno 1984a).

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 1984a; 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[6]). This species is common in inlands seas (i.e., San Francisco Bay) (Castro 1983; Allen and Smith 1988) and in shallow bays from Alaska to central California (Eschmeyer et al. 1983).

    Habitat Associations—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. 2005b) 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 mo, 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).

<u>Other Species</u>

- **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 Associations—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 Associations—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. 2005b). 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 for 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).

- **Shortnose Chimaeras (Chimaeridae)**

  - **Spotted Ratfish (*Hydrolagus colliei*)**

Distribution—Spotted ratfish (formerly known as ratfish) 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 Associations—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 (Tissot et al. 2007). 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 water temperatures 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 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 in polyhaline to euhaline waters (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, opisthobranchs, annelids, and small crustaceans such as 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-SWR (NMFS 2004b). The U.S. west coast HMS are composed of 13 species (**Table 4-1**) which occur within the SOCAL/Pt. Mugu Study Area. Fishes under the FMP for HMS with EFH designation include oceanic sharks, tuna, billfish, swordfish, and dorado, which are distributed over wide areas of the open ocean, neritic waters of the continental shelf, and coastal waters (PFMC 2003a). In addition to the EFH species, great white shark (*Carcharodon carcharias*), basking shark (*Cetorhinus maximus*), megamouth shark (*Megachasma pelagio*), Pacific halibut (*Hippoglossus stenolepis*), and five Pacific salmon species (*Oncorhynchus* spp.) are designated for prohibited status under the HMS FMP (NMFS 2004b). For help in the identification of the HMS refer to Collette and Nauen (1983), Compagno (1984b; 1984a), Nakamura (1985), Compagno and Niem (1998), Compagno (2002), Pacific Shark Research Center[5], and Froese and Pauly[3].

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 2003a).

EFH species are discussed in the following subsection and listed in **Table 4-1**. The status, distribution, Habitat Associations (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 2003a). 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 2002; PFMC 2003a).

Five shark species found in the SOCAL/Pt. Mugu Study Area have EFH described for their three lifestages (neonate/early juvenile, late juvenile/subadult, and adult) by the PFMC (2003a). All five 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 2003a).

- **Thresher Sharks (Alopiidae)**

  - **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 2003a; NMFS 2005d; NMFS 2007). In 2007, the IUCN Red List of Threatened Species listed the bigeye thresher shark as vulnerable due to its potential extinction on a global scale.[2] 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 Ocean. In the eastern Pacific Ocean (EPO), 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 1984a, 2002; PFMC 2003a).

    Habitat Associations—Bigeye thresher sharks are found in oceanic and neritic waters over continental and insular shelves, occasionally in shallow areas (Compagno 1984a). 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 2003a). Bigeye threshers can reportedly stay in cooler water for longer periods of time than other pelagic sharks (PFMC 2003a). 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 2003a). 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 2003a). In the EPO 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 2003a). In the Atlantic Ocean, bigeye threshers have been reported traveling 1,000 to 2,000 miles from the continental shelf off New Jersey eastward into the central Atlantic Ocean and southward into the Gulf of Mexico, and from North Carolina south to off Cuba (PFMC 2003a).

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 mo (PFMC 2003a).

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 2003a; FLMNH[6]).

EFH Designations—(PFMC 2003a; **Figure D-5**)

- Neonate/early juveniles (~90 to 115 cm fork length [FL], 0 to 2 and 3 yr 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 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.

- **Common Thresher Shark (*Alopias vulpinus*)**

Status—Common thresher shark is not managed internationally and there are no quotas. In 2007, the IUCN Red List of Threatened Species listed the common thresher shark as vulnerable due to its potential extinction on a global scale.[2] 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 2003a; NMFS 2005d; NMFS 2007).

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 Ocean. In the EPO, 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 1984a, 2002).

Habitat Associations—Common thresher sharks are most abundant over continental and insular shelves in neritic and oceanic waters out to 161 km (Compagno 1984a, 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 2004). These effects create habitats conducive to the production and maintenance of schooling pelagic prey (PFMC 2003a). 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, California and Baja California, Mexico to Oregon and Washington State following warm water masses and schools of prey (Ebert 2003; PFMC 2003a). In early spring, adults remain in offshore southern California waters (366 to 549 m) from 1 to 2 mo during which time pupping occurs followed by the pups moving to inshore nursery areas (PFMC 2003a). 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 2003a). 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 2003a).

Reproduction in the common thresher shark is ovoviviparous and oophagous with a normal brood size of 3 to 4 (predominately 4) per litter in the EPO (Bedford 1992; Smith and Aseltine-Neilson 2001; Fowler et al. 2005). Mating presumably takes place in mid-summer (July to August) along the U.S. west coast EEZ, with a gestation period of about 9 mo, with parturition occurring most likely in the spring months (March to June) off California (PFMC 2003a). Young common thresher sharks remain close to shore after parturition and during their first few years (Bedford 1992).

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.), lanternfish (Myctophidae), and Pacific salmon (*Oncorhynchus* spp.), market squid, octopus, pelagic red crab, shrimp, and seabirds (Hart 1973; Preti et al. 2001; FLMNH[6]; Fowler et al. 2005).

EFH Designations—(PFMC 2003a; **Figure D-6**)

- Neonate/early juveniles (<102 cm 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°10'N 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. 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.

- **Pelagic Thresher Shark (*Alopias pelagicus*)**

Status—The pelagic 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. Little is known of the pelagic thresher shark's abundance and stock structure (PFMC 2003a; NMFS 2007). In 2007, the IUCN Red List of Threatened Species listed the pelagic thresher shark as vulnerable due to its potential extinction on a global scale.[2] The FAO lists this species as category 3 (exploited species), due to its very limited reproductive potential and the effect of fisheries (Castro et al. 1999).

Distribution—The pelagic thresher shark is an epipelagic species in neritic and oceanic waters throughout the tropical Indo-Pacific Ocean, occurring during exceptionally strong El Niño years in the EPO, although rarely as far north as Cape Blanco, Oregon. More commonly, it is distributed from southern California to Panama including the southern tip of Baja California and Islas Galapagos (Compagno 1984a; Hanan et al. 1993; Holts et al. 1998; Love et al. 2005b).

Habitat Associations—Within the water column, this species ranges in depth from the surface to at least 700 m (PFMC 2003a; Weng and Block 2004). Tracking studies in the ETP have indicated a water column temperature tolerance range of 14° to 28°C, with a night depth preference of 60

to 70 m (17° to 21°C water) and a slightly deeper daytime range of 70 to 100 m in slightly cooler water temperatures (14° to 17°C) (PFMC 2003a). Suitable nursery habitat is largely unknown within the EEZ and likely exists to the south of Mexico, closer to the center of this species distribution. The SCB may serve as a pupping area on a sporadic basis (PFMC 2003a).

Life History—During remarkably warm years, there is a pronounced shift northward of what appears to be largely a Mexican stock (Compagno 1984a). With the exception of this observation, movements and migration are poorly understood (PFMC 2003a).

Reproduction in the pelagic thresher shark is ovoviviparous and oophagous with a litter size of two (one embryo developing in each uterus) pups. The gestation period is unknown for this species (Compagno 1984a; Ebert 2003).

Common Prey Species—Pelagic thresher sharks prey almost exclusively on small pelagic schooling fish including herring, flyingfish, and mackerel and occasionally pelagic squid (PFMC 2003a; FLMNH[6]).

EFH Designations—(PFMC 2003a; **Figure D-7**)

- Neonate/early juveniles (<137 cm FL)—There is no evidence of a successful nursery within the EEZ. Pupping presumably takes place to the south of Mexico, close to the center of this species' distribution.
- Late juveniles/subadults (>135 cm FL and <162 cm FL)—EFH consists of epipelagic and predominantly oceanic waters along the coast of California from the U.S./Mexico border. The habitat extends as far north as 34°N latitude, from the 183 m isobaths out to the Santa Rosa-Cortes Ridge, particularly between San Diego and Long Beach, California. (Line extends from the Ridge to a point on the EEZ boundary at 31°36'N latitude and 127°30'W longitude). Late juveniles/subadults associate with SSTs of 21°C or warmer.
- Adults (>161 cm FL, predominantly adult females)—EFH includes epipelagic and predominantly oceanic waters along the coast of California from the U.S./Mexico border. The habitat extends as far north as 34°N latitude, from the 183 m isobaths out to the Santa Rosa Ridge, particularly between San Diego and Long Beach, California. (Line extends from the Ridge to a point on the EEZ boundary at 31°36'N latitude and 127°30'W longitude). Adults associate with SSTs of 21°C or warmer.

♦ **Mackerel Sharks (Lamnidae)**

- **Shortfin Mako Shark (*Isurus oxyrhinchus*)**

Status—Shortfin mako or bonito shark 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 2003a; NMFS 2005d; NMFS 2007). Information is unavailable on the population structure of the shortfin mako in the eastern North Pacific Ocean (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). In 2007, the IUCN Red List of Threatened Species listed the shortfin mako as vulnerable due to its potential extinction on a global scale.[2]

Distribution—Shortfin mako is circumglobal occurring in warm-temperate and tropical seas. In the EPO, it ranges 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 Associations—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 2003a). 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). Recent information reports that this species has the highest aerobic metabolic rate for any pelagic shark (Sepulveda et al. 2007). 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 2003a).

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 2003a).

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 3-yr reproductive cycle, which includes a 15- to 18-mo gestation period, a late winter to mid-spring pupping season, followed by an 18-mo 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, lancetfish, rockfishes, lingcod, yellowtail, seabass, swordfish, and juvenile blue, requiem, and hammerhead sharks, cephalopods, dolphins, and sea turtles (Strasburg 1958; Taylor and Bedford 2001; Compagno 2002; Ebert 2003; FLMNH[6]).

EFH Designation—(PFMC 2003a; **Figure D-8**)

- 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 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 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 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 yr (PFMC 2003a). This species is not undergoing overfishing, nor is it considered overfished on the west coast (PFMC

2003a; NMFS 2005d; FLMNH[6]; NMFS 2007). 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.[2]

Distribution—Blue shark is primarily circumglobal in its distribution occurring in temperate and tropical waters from 60°N to 50°S latitude (Compagno 1984b). In the EPO, 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 1984b; Holts 1992).

Habitat Associations—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 1984b; Ebert 2003). In the Pacific Ocean, blue sharks are present in greatest abundance between 20°N to 50°N with females more abundant at higher latitudes than males (PFMC 2003a). 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 (1984b) 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 Ocean, 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 Ocean, where birth occurs in early summer in nursery areas located at 35° to 45°N, with 1- to 5-yr-old females moving north of these latitudes and 2- to 4-yr-old males moving south. Upon reaching maturity, this species apparently migrates to the subtropics and tropics to join a reproductively active population (PFMC 2003a). Within the U.S. west coast EEZ, a larger nursery area extends from 31° to 47°N (PFMC 2003a). 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 placentally, viviparous with 4 to 135 young per litter (average 20 to 40) and a gestation period lasting 9 to 12 mo (Compagno 1984b; Ebert 2003; Fowler et al. 2005). Reproduction for blue sharks has been reported as seasonal in most areas, with birth often occurring in spring or summer (Nakano 1994; PFMC 2003a). 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 2003a).

Common Prey Species—Blue sharks prey upon relatively small bony fishes such as Pacific herring, sardines, northern anchovy, blacksmith, salmon, lancetfish, flying fishes, pipefishes, hake, lingcod, jack mackerel, tunas, sea bass, flatfishes, and spiny dogfish and invertebrates including squid (Histioteuthid and market squid), red crab, and euphasuiid swarms (*Thysanoessa spinifera*) (Compagno 1984b; Love 1996; Ebert 2003; PFMC 2003a; FLMNH[6]).

EFH Designations—(PFMC 2003a; **Figure D-9**)

- Neonate/early juveniles (<83 cm FL)—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 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, extending inshore to the 366-m isobath south of 37°N latitude off Santa Cruz.

Tuna

The family Scombridae, (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 thermoregulation and endothermy. They are predaceous, swift-swimming, and powerful fishes that occur in tropical and temperate waters. Five EFH designated tuna species occur in the SOCAL/Pt. Mugu Study Area (PFMC 2003a).

♦ Mackerels (Scombridae)

• Albacore Tuna (*Thunnus alalunga*)

Status—Albacore tuna stock is healthy and it is unknown if overfishing is occurring or it is overfished (PFMC 2003a; PFMC 2007b). No quotas are being considered and no regional harvest guidelines have been recommended at the present time (NMFS 2005d; NMFS 2007). 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.[2] Currently, the FAO lists the status of the albacore tuna in the North Pacific Ocean as fully exploited (Majkowski 2007).

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 Ocean, 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, North Pacific Transition Zone (NPTZ), and California Current (IATTC 2001a).

Habitat Associations—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 2003a). 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 2003a). 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 (2 to 4 years old). A given year class migrates west to east in a band between 30° to 45°N, leaving the northwest Pacific Ocean 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 EPO 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 to 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 SOCAL/Pt. Mugu Study Area, instead taking place in the North Pacific Ocean between latitudes 10° and 30°N from Japan to Hawaii between April and September in oceanic waters (MBC 1987; Weber 1997). 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 anchovy, Pacific saury, rockfish spp., myctophids, barracudina, *Magnisudis atlanica*), squids (e.g., opalescent inshore, armhook [*Gonatus anonychus*], boreoatlantic armhook [*G. fabracil*], and clubhook [*Onychoteuthis* spp.]), octopus, crustaceans (sergestid shrimp, pelagic red crab, amphipods [*Phronima sedentaria*], and euphausiids [*Euphausia pacifica*]) (Hart 1973; Collette and Nauen 1983; Bernard et al. 1985; Weber 1997; PFMC 2003a).

EFH Designations—(PFMC 2003a; **Figure D-10**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.
- Juveniles (<85 cm FL)/Adults (>84 cm FL)—EFH is identified 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. Juveniles and adults associate with SSTs between 10° and 20°C and between 14° and 25°C, respectively in waters of the NPTZ in dissolved oxygen levels greater that 60%.

- **Bigeye Tuna (*Thunnus obesus*)**

Status—Although subject to overfishing in the western central Pacific Ocean (WCPO), the bigeye tuna is probably overexploited and that overfishing is taking place in the EPO (Aires-da-Silva and Maunder 2008). Currently, no regional harvest guidelines are recommended (NMFS 2007; PFMC 2007b). This species is listed as vulnerable according to the IUCN Red List, due to an observed

20% reduction over the last 10 yr or 3 generations, based on an index of abundance and actual or potential levels of exploitation.[2] Currently, the FAO lists the status of the bigeye tuna in the EPO as over exploited (Majkowski 2007).

Distribution—Bigeye tuna are trans-Pacific in their distribution stretching between northern Japan and the north island of New Zealand in the western Pacific Ocean and 40°N to 30°S in the EPO (PFMC 2003a). Along the U.S. west coast, they range from Iron Springs, central Washington State to Chile including Islas Galapagos (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005b). This species also occurs in the Atlantic and Indian oceans.

Habitat Associations—Bigeye tuna are epipelagic and mesopelagic ranging from the surface to as deep as 1,500 m (Schaefer and Fuller 2002) in areas of suitable temperatures (between 10°C and 15°C) and available dissolved oxygen (remain above one milliliter per liter [mL/L]) (PFMC 2003a). Adult bigeye tuna also aggregate to drifting flotsam and anchored buoys, although to a lesser degree than juveniles. Bigeye tuna also aggregate over deep seamount and ridge features. Water temperature, thermocline depth, and season appear to strongly influence the distribution of large bigeye tuna (PFMC 2003a). Bigeye tuna are generally associated with particular water masses or current systems during different life stages (PFMC 2003a).

Juveniles greater than 35 cm FL aggregate strongly to drifting or anchored objects, large marine animals (e.g., whales), and regions of elevated productivity (i.e., near seamounts and upwelling areas). Distribution of juvenile bigeye tuna less than 35 cm FL is not known but assumed to be similar to the larvae which occupy warm surface waters (Blackburn 1969; Hampton and Bailey 1993; PFMC 2003a).

The larvae of the bigeye tuna are most common in warm surface waters between 30°N and 20°S in the Pacific Ocean, being relatively more abundant in the western and eastern Pacific Ocean compared to the central Pacific Ocean, and most common in the western Pacific Ocean between 10°N and 15°S. Bigeye larvae appear to be restricted to the mixed layer well above the thermocline and at depths less than 50 to 60 m (PFMC 2003a).

Life History—Bigeye tuna are capable of large-scale movements, moving freely within broad regions of favorable water temperatures and dissolved oxygen values (PFMC 2003a). Juvenile bigeye tuna form mono-specific schools with similar-sized fishes (e.g., skipjack and/or juvenile yellowfin tunas) at or near the surface. Larger juveniles and pre-adult bigeye tuna appear in higher latitude fisheries, which suggest that this species moves away from tropical spawning areas as they increase in size preferring more subsurface habitats (PFMC 2003a).

There is no clear evidence of diurnal preference by depth or patterns of vertical migration for bigeye tuna larvae (PFMC 2003a). Schaffer and Fuller (2002) reported that adult bigeye tuna undergoes diel vertical migration based on the distributions of their preferred prey and not on temperature, depth, or light preferences. They also observed changes in the average nighttime depth distributions in relation to moon phase.

Spawning spans broad areas of the Pacific Ocean throughout the year in tropical waters and seasonally at higher latitudes at water temperatures above 23° or 24°C (PFMC 2003a). Bigeye tuna are serial spawners, capable of repeated spawning at near daily intervals with batch fecundities of millions of ova per spawning event. Spawning normally takes place during the afternoon or evening hours at or near the surface producing epipelagic eggs (PFMC 2003a).

Common Prey Species—Bigeye tuna are opportunistic, feeding on crustaceans, cephalopods, and mesopelagic fishes (PFMC 2003a).

EFH Designations—(PFMC 2003a; **Figure D-11**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.

- Juveniles (<100 cm FL) and Adults (>100 cm FL)—EFH includes oceanic, epipelagic and mesopelagic waters generally beyond the 366-m isobath out to the EEZ boundary from the U.S./Mexico EEZ border north to Point Conception, California. Some years have noted habitats extending northward to Monterey Bay, California (37°N latitude). Juveniles and adults associate with SSTs between 13° and 29°C and with optimum temperatures between 17° and 22°C. Habitat is concentrated in the SCB primarily south of 34°N latitude, from the 183- to 1,829-m isobath.

- **Northern Bluefin Tuna (*Thunnus orientalis*)**

Status—Evidence for overfishing or approaching an overfished condition in the stock of the northern bluefin tuna is unknown (PFMC 2007b). According to the IUCN Red List, the northern 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.[2] 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 Ocean, 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 2003a; PFMC 2007b). Currently, the FAO lists the status of the northern bluefin tuna in the Pacific Ocean as fully exploited (Majkowski 2007).

Distribution—Northern bluefin tuna originates in the western Pacific Ocean, 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 EPO, 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. 2005b) 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 Associations—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 (between 17°C and 23°C) tend to prevail in those areas (PFMC 2003a). 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 EPO 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 to the eastern Pacific Ocean. Tagged individuals off Japan made the trans-Pacific migration in about two months, then resided in the EPO for about 8 mo before being recaptured (Itoh et al. 2003b). 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 kg) school by size with other tunas such as albacore, yellowfin, bigeye, skipjack, frigate (*Auxis rochei*), eastern Pacific bonito, and yellowtail (Collette and Nauen 1983). Itoh et al. (2003a) reported a diurnal and seasonal change in swimming depth and vertical swimming behavior at dawn and dusk. For the northern bluefin tuna, Kitagawa et al. (2007)

reported that there was a significant correlation between average nighttime depth distributions and the visible disk area of the moon all year round to be consistent with similar behavior found in the southern bluefin (*Thunnus maccoyi*) and bigeye tunas.

The majority of northern bluefin tuna spawn in the northwest Pacific Ocean in areas 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. 2003b). 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 (sardines), sanddabs, white croakers, pompanos, mackerel, Pacific saury, Pacific hake, and other tuna, squid (Humboldt, *Dosidicus gigas*), as well as red crabs (*Pleuroncodes planipes*) (Collette and Nauen 1983; Bayliff 1993; Love 1996; FLMNH[6]).

EFH Designations—(PFMC 2003a; **Figure D-12**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.
- Juveniles (<150 cm FL and 60 kg)—EFH is identified 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.

- **Skipjack Tuna (*Katsuwonus pelamis*)**

Status—The EPO skipjack tuna stock appears healthy, with no indication of approaching the upper limit of sustainable catches. Currently, no regional harvest guidelines have been recommended because overfishing or approaching an overfished condition is unlikely (PFMC 2007b). Currently, the FAO lists the status of the skipjack tuna in the EPO as moderately exploited (Majkowski 2007).

Distribution—Skipjack tuna are distributed in well-mixed surface waters of tropical, subtropical, and warm temperate waters of all oceans. In the western Pacific Ocean, it is bounded by the 15°C isotherm or roughly between 45°N and 45°S latitude. This range is more restricted in the EPO. East of 150°W longitude, their distribution ranges between 40°N and 40°S latitude and off the coastlines of the U.S., Mexico, Central America, and South America. During El Niño events, skipjack tuna may inhabit areas as far north as 50°N, along the U.S. west coast (IATTC 2001b; PFMC 2003a). Within the U.S. west coast EEZ, the skipjack tuna occurs from Yakutat Bay, southeastern Alaska to Chile including southern Gulf of California and Islas Galapagos (Collette and Nauen 1983; Mecklenburg et al. 2002; Love et al. 2005b).

Habitat Associations—Skipjack tuna are epipelagic and oceanic occurring from the surface to a depth of 260 m (Love et al. 2005b). Habitat of the skipjack tuna is based on temperature and salinity with the lower temperature limit around 18°C, a lower dissolved oxygen level of around 3.5%, and a speculative upper temperature limit ranging from 33°C for the smallest individual to 20°C or less for the largest individual (Matsumoto et al. 1984). Skipjack tuna can be found around floating objects (Schaefer and Fuller 2007). No information on small juvenile habitat is available, although the range is probably similar to that of the larvae (PFMC 2003a). Larvae are concentrated in, though not exclusively restricted to, tropical equatorial waters. Like adults, larvae have a wider latitudinal distribution in the western Pacific Ocean (35°N to 35°S) than in the EPO (between 10°N and 5°S) (Matsumoto et al. 1984).

Life History—Skipjack tuna are genetically heterogeneous across the Pacific Ocean. Migrants to the EPO split into northern and southern groups off Mexico and Central and South America,

respectively. Large-scale current patterns in the region might account for this north-south distribution (PFMC 2003a).

Schaefer and Fuller (2007) reported that the vertical movement patterns of the skipjack tuna when associated with floating objects were similar for bigeye tuna associated with floating objects in the equatorial EPO. This species predominately inhabits the mixed water layer but make occasional brief dives below the thermocline (Schaefer and Fuller 2007).

Skipjack tuna spawn more than once in a season, and possibly as often as every 1.18 d (PFMC 2003a). They spawn year-round in tropical waters and seasonally (spring to early fall) in subtropical waters (PFMC 2003a).

Common Prey Species—Skipjack tuna opportunistically feed on fishes (herring, northern anchovy, Pacific saury, and sardines), crustaceans (euphausiids, pelagic red crab), and mollusks (squid) (PFMC 2003a; FLMNH[6])

EFH Designations—(PFMC 2003a; **Figure D-13**)

- Eggs/Larvae and Juveniles—No habitat within the U.S. west coast EEZ.
- Adults—EFH consists of oceanic, epipelagic waters beyond the 732-m isobath, out to the EEZ boundary from the U.S./Mexico border, northward to Point Conception, California, and northward beyond the 1,829-m isobath (north to 40°N latitude). Adults associate with SSTs between 18°C and 20°C and dissolved oxygen levels less than 3.5 ppm. Habitats in the SCB primarily occur south of 33°N latitude, especially in warm years.

- **Yellowfin Tuna (*Thunnus albacares*)**

Status—Yellowfin tuna is actively managed through quotas and other measures. Although subject to overfishing in the WCPO, the yellowfin tuna is not currently overfished or approaching an overfished condition and no regional harvest guidelines are recommended in the EPO (NMFS 2007; PFMC 2007b; Maunder and Aires-da-Silva 2008). According to the IUCN Red List, the yellowfin tuna is treated as a lower risk/least concern.[2] Currently, the FAO lists the status of the yellowfin tuna in the EPO as fully exploited (Majkowski 2007).

Distribution—Yellowfin tuna are trans-Pacific in distribution, occupying the surface waters of all warm oceans. Their distribution in the Pacific Ocean lies roughly within latitudes 40°N to 40°S and water temperatures between 18° and 31°C (PFMC 2003a). In the EPO, they range from 50°00'N, 150°02'W and Morro Bay, south-central California to Chile including Islas Galapagos (Miller and Lea 1972; Squire 1987; Mecklenburg et al. 2002; Love et al. 2005b).

Habitat Associations—This epipelagic, oceanic species occurs from the surface to 464 m (Love et al. 2005b) and is known to aggregate with drifting flotsam (kelp mats), FADs, anchored buoys, dolphins, and other large marine animals (Hampton and Bailey 1993; Weber 1997). Adult yellowfin also aggregate in regions of elevated productivity and high zooplankton density, such as near seamounts and regions of upwelling and convergence of surface waters of different densities (Blackburn 1969).

Juvenile fish (>35 cm FL) are distributed in warm oceanic surface waters, above the thermocline, and are found throughout the year in tropical waters (i.e., western Pacific Ocean: between 31°N near the east coast of Japan to 23°S and central Pacific Ocean: from 23°N near the Hawaiian Islands to 23°S). Like adults, juveniles are known to aggregate beneath drifting objects or large, slow moving animals, such as whale sharks and manta rays, (Hampton and Bailey 1993) and near seamounts and submarine ridges (PFMC 2003a). Juvenile yellowfin tuna form single-species schools of similar-sized fish at or near the surface or may be mixed with other tuna species, such as skipjack or juvenile bigeye tuna. Within the U.S. Pacific coast EEZ, most fish taken by fisheries are juveniles (<95 cm FL) that are generally distributed seasonally in epipelagic

oceanic waters from the U.S./Mexico EEZ border north to Point Conception, California, extending in some warm-water years northward to Monterey Bay, central California (in SSTs >18°C) (PFMC 2003a).

The larvae of the yellowfin tuna are trans-Pacific in distribution and are found throughout the year in tropical waters but are restricted in summer months to subtropical regions (i.e., Kuroshio Current: May and June, and East Australian Current: austral summer [November to December]). Their basic environment can be characterized as warm, oceanic surface waters, in mixed layer above the thermocline, with preference toward upper range of temperatures (SSTs above 26°C) (Boehlert and Mundy 1994). The distribution of early juveniles, less than 35 cm FL, has not been well documented but is assumed to be similar to that of larval stages (PFMC 2003a).

Life History—Eastern Pacific yellowfin tuna are clearly capable of large-scale movements. They appear to move freely within broad regions of favorable water temperatures and are known to make seasonal excursions to higher latitudes, as water temperatures increase. However, the extent of these movements is unknown and the nature of the yellowfin tuna migration in the central and western Pacific Ocean remains unclear (Wild 1993).

Schaefer et al. (2007) reported that vertical distributions of the yellowfin tuna indicate greater daytime depths in relation to a seasonally deeper mixed water layer in February, whereas from March through September this species exhibits a greater proportion of daytime at shallower depths in relation to a shallower mixed water layer.

Yellowfin tuna have a high spawning frequency and fecundity. Being a broadcast spawner, they are capable of repeated spawning at near daily intervals with batch fecundities of millions of ova per spawning event. Spawning spans broad areas of the Pacific Ocean and occurs over protracted time periods throughout the year in tropical waters and seasonally at higher latitudes, at water temperatures ranging from 23.3° to 29.7°C (Marguiles et al. 2007). In the EPO, this species spawns south of California, peaking in January and February off Central America (Weber 1997).

Common Prey Species—Yellowfin tuna are opportunistic feeders on fishes (northern anchovy), krill, cephalopods, and crustaceans (red crab) (PFMC Weber 1997; 2003a).

EFH Designations—(PFMC 2003a; **Figure D-14**)

- Eggs and Larvae—No habitat within the U.S. west coast EEZ.
- Juvenile-females (<92 cm FL; males: <69 cm FL)—EFH includes oceanic, epipelagic waters from the U.S./Mexico EEZ border north to Point Conception, California, (with some years extending northward to Monterey Bay, California [37°N latitude]) south of Point Conception from the 183-m isobath out to the EEZ boundary, and north of Point Conception from 549-m isobath out to the EEZ boundary. Juveniles associate with SSTs between 18°C and 31°C.
- Adults (>92 cm FL; males and 60 kg)—Adult yellowfin tuna do not regularly occupy habitat within the U.S. west coast EEZ.

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 (striped marlin) has EFH designated within the SOCAL/Pt. Mugu Study Area (PFMC 2003a).

- **Billfishes (Istiophoridae)**

  - **Striped Marlin (*Tetrapturus audax*)**

    Status—Commercial harvest of striped marlin is presently prohibited by California and no west coast harvest guideline is recommended for the seasonal influx of fish, which occurs in the U.S. EEZ at the edge of the species' range (PFMC 2003a). Currently, this species is not overfished nor approaching an overfished condition in the EPO (PFMC 2007b).

    Distribution—Striped marlin are widely distributed in oceanic, epipelagic waters throughout most tropical, subtropical, and temperate waters of the Pacific and Indian oceans. The species is apparently more abundant in the eastern and north-central Pacific Ocean than elsewhere, and associated with SSTs of 20° to 25°C (Nakamura 1985). Pacific striped marlin have a U-shaped distribution, occurring in the greatest numbers in two supra-equatorial bands (Northern Pacific Group: west of 140°W and north of 15°N and Eastern Pacific Group: east of 120°W and south of 15°S) that join at the eastern tropical margin (Nakamura 1985). Elevated water temperatures as a result of El Niño events apparently lead to a northerly shift in the striped marlin range (Squire 1987). Striped marlins are found in greater numbers in the north Pacific Ocean, with higher catch rates found in the north-central, northeast, and southeast Pacific Ocean (PFMC 2003a). Within the U.S. EEZ, they range from near Westport, Washington State to Chile including central and southern Gulf of California and Islas Galapagos (Love et al. 2005b). This species is most common south of Point Conception, California (Weber 1997).

    Habitat Associations—Striped marlin occur from near the surface to 289 m (Bedford and Hagerman 1983; Eschmeyer et al. 1983). Subadult fish occur in high abundance around the tip of the Baja Peninsula. Adult fish with some subadults occur seasonally within the SCB during most years and north to San Francisco, central California and beyond in warm water years (D.B. Holts 2001). Striped marlins also occur just west of the U.S. EEZ in moderate concentrations, from about 22° to 37°N latitude and west of 125°W longitude (PFMC 2003a). Very little information is known about juvenile marlin's habitat and egg (presumably epipelagic) distribution is unknown (PFMC 2003a).

    Life History—Striped marlin make long-term migrations between spawning and feeding areas. The spawning areas are in the northwest and to a lesser extent the southwest Pacific Ocean. Young fish migrate eastward to feeding areas off the Central American coast and return westward as adults. Seasonal patterns generally conform to water temperature-related changes (PFMC 2003a).

    Larvae may make diurnal vertical migrations in the top 50 m of the water column. Research suggests that depth preference is governed by temperature stratification (between 25°C and 27°C), with the striped marlins preferring to remain in the mixed layer above the thermocline (PFMC 2003a).

    Spawning does not occur within the U.S. west coast EEZ but rather to the south, far offshore Mexico (July and August) and westward in a band across the central equatorial Pacific Ocean (Weber 1997). In the northwestern Pacific Ocean, peak abundance occurs in May to June. Spawning is probably seasonal and confined to the early summer months in both hemispheres (PFMC 2003a).

    Common Prey Species—Striped marlins consume saury, anchovy, sardine, jack mackerel, tuna, squid, shrimp, and red crab (Nakamura 1985; Weber 1997; D.B. Holts 2001).

EFH Designations—(PFMC 2003a; **Figure D-15**)

- Eggs/Larvae and Juveniles—No habitat within the U.S. west coast EEZ.
- Adults (>150 cm "eye-to-fork" length [EFL] or 171 "tip of jaw to fork" length [JFL])—EFH consists of oceanic, epipelagic waters of the SCB, above the thermocline, from the 366-m isobath from the U.S./Mexico EEZ border to about 34°09'N latitude (Point Hueneme, California), east of the Santa-Cortes Ridge (a line from South Point, Santa Rosa Island, southeast to EEZ boundary at approximately 31°36'N latitude and 118°45'W longitude). Adults prefer water temperatures bounded by 20° to 25°C.

Swordfish

Swordfish are the sole member of the family Xiphiidae. This large scrombid recreational fish occurs in worldwide seas and has EFH designated within the SOCAL/Pt. Mugu Study Area (PFMC 2003a).

♦ **Swordfishes (Xiphiidae)**

- **Broadbill Swordfish (*Xiphias gladius*)**

Status—Recent studies indicate that the broadbill swordfish population is healthy and currently no regional harvest guideline is recommended (PFMC 2003a; NMFS 2007). The swordfish is listed as data deficient by the IUCN Red List 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.[2]

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 2003a). In the EPO, 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. 2005b). Broadbill swordfish are most abundant off northwestern Mexico (south of Baja California), common off southern California between the mainland and Channel Islands but uncommon north of Point Conception, California (Miller and Lea 1972; Squire and Smith 1977; Palko et al. 1981; Weber 1997).

Habitat Associations—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. 2005b). 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 Ocean (PFMC 2003a).

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 2003a). 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 Ocean, 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 2003a).

Life History—Little is known about migration in Pacific Ocean swordfish, although limited tagging data support a general west-to-east movement from Hawai'i toward continental North America (PFMC 2003a). 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; D. Holts 2001).

Research suggests that swordfish do not seem to have a discrete spawning ground or spawning season (PFMC 2003a). 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 EPO, the distribution narrows, probably because of lower water temperatures associated with the Peru Current and upwelling in that region (PFMC 2003a). 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 Ocean between May and August, from December to January in the south Pacific Ocean, and from March to July in the central Pacific Ocean (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°C and 29°C (PFMC 2003a).

Common Prey Species—Swordfish prey upon squid and pelagic fishes including dorado, barracuda, flying fish, clupeids, sauries, Pacific hake, gadids, anchovies, jack mackerel, shortbelly rockfish, lanterfishes, and small scrombids (Squire and Smith 1977; Palko et al. 1981; Nakamura 1985; FLMNH[6]; Weber 1997).

EFH Designations—(PFMC 2003a; **Figure D-16**)

- 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.
- 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 beyond the 1,829-m isobath northward to 46°40'N latitude.

Dolphinfish

Dolphinfish are members of the family Coryphaenidae. Two species (*Coryphaena hippurus* and Pompano dolphinfish [*C. equiselis*]) are found in this family with both species apparently occurring worldwide in tropical and subtropical seas. Only *C. hippurus* has EFH designated within the SOCAL/Pt. Mugu Study Area (PFMC 2003a).

- **Dolphinfishes (Coryphaenidae)**

  - **Dorado or Mahi Mahi (*Coryphaena hippurus*)**

    Status—The dorado population is presumed to be healthy and no regional harvest guideline is recommended, considering that recreationally, west coast fishermen are accessing only the northern fringe of an extensive regional population primarily during warm water years. This population should be able to rebound quickly from exploitation even if it becomes significantly reduced (PFMC 2003a; PFMC 2007b).

    Distribution—Dolphinfish are epipelagic and oceanic in tropical and subtropical waters worldwide. They are distributed in seas warmer than 19° to 20°C and usually greater than 24°C (Palko et al. 1982; PFMC 2003a). In the EPO, dorados are most abundant off Mexico, Panama, Ecuador, Peru, and around the Galapagos (PFMC 2003a). They range from Grays Harbor, Washington State to Chile including Gulf of California and Islas Galapagos (Miller and Lea 1972; Love et al. 2005b).

    Habitat Associations—Dorado occurs from the surface to about 200 m (Eschmeyer et al. 1983; Love et al. 2005b). This species moves into U.S. west coast waters generally during warm water years, as far north as Grays Harbor, Washington State, although usually remaining south of Point Conception, California. Largest concentrations of dorado have occurred in late summer and early fall within the Southern California Eddy System. These concentrations are correlated with oceanic intrusions, where temperatures exceed 20°C and northern geotropic flow is the greatest (PFMC 2003a). During warm water incursions the dolphin-fish usually inhabit water around the 11-m isobath, along coastal California from the U.S./Mexico border generally as far north as Point Conception, California (34°34'N), primarily east of the 2,560-m isobath. This species generally occurs inshore of the cooler, southerly flowing plume of water that usually persists west of offshore banks and islands. Its high metabolic rate vertically limits its habitat to the oxygen-rich near-surface layers above 30 m depth (Kraul 1999). Small-sized males and all sizes of females may spend more time associated with floating and drifting objects than large sized males, which tend to spend more time in open water, possibly traveling between female-dominated schools below rafts (PFMC 2003a).

    Life History—Little information is known about the dorado's Pacific Ocean migrations. They are thought to migrate relatively long distances in the western Atlantic Ocean and Mediterranean Sea (Oxenford and Hunte 1986). In the EPO, temperature seems to be an important factor in defining the range and possibly the movements of this species which is bounded to the north by the California current and to the south by the Peru Current (Lasso and Zapata 1999). Research suggests that the habitat of dorado has been expanding northward over the past 30 yr in response to an oceanic and atmospheric regime shift that has brought periods of warmer water and enhanced northerly current flow to California (Norton 1999). It has also brought less cold water upwellings off northern Mexico, which had formerly inhibited northward dispersal.
    Uchiyama and Boggs (2006) suggested two possible migration scenarios: a similar nearshore (<93 km)-offshore spawning movement as reviewed by Arocha et al. (1999) and a similar migration northward in summer up to 1,100 km from the main Hawaiian Islands to southern boundary of the subtropical front where productivity is high and then southward back to the Hawaiian archipelago to reproduce nearshore as reviewed by Oxenford and Hunte (1986).

    Dorados are oviparous with pelagic eggs and larvae. Spawning is thought to occur year-round in waters greater than 24°C (Smith and Crooke 2001). Spawning of the California-Mexico dorado population occurs in waters south of the west coast EEZ. Larvae have been collected off central and southern Baja California, Mexico and only occasionally off southern California in warm years, with peak abundance occurring in August and September (PFMC 2003a).

    Common Prey Species—Dorado are opportunistic feeding on small oceanic fishes (flyingfish, man-o-war fish, *Nomeus gronovii*;, sargassum fish, and triggerfish), juveniles of large pelagic fish

(tunas, billfishes, jacks, mackerels, and dolphinfish), pelagic larvae of benthic fish (flying gunards, triggerfish, pufferfish, and grunts), and invertebrates (cephalopods, crabs, and schyphozoans) (Lasso and Zapata 1999; Oxenford and Hunte 1999).

EFH Designations—(PFMC 2003a; **Figure D-17**)

- Spawning, eggs and larvae (<13.7 cm FL)—Primarily outside of the U.S. west coast EEZ. Spawning restricted to water >24°C off southern Baja California, Mexico, with peak larval production in August and September.
- Juveniles-and subadults (>13.6 cm FL and <35 cm FL) and Adults (>34 cm FL /)—EFH includes epipelagic (<30 m deep) and oceanic waters offshore the 11-m isobath along coastal California, from the U.S./Mexico border generally as far north as Point Conception, California (34°34'N latitude) and within the U.S. west coast EEZ primarily east of the Santa Rosa-Cortes Ridge. (Line extends from Point Conception south-southeast to a point on the EEZ boundary at 31°36'N latitude and 118°45'W longitude). This life history stage prefers SSTs of 20°C and higher during warm water incursions.

4.5 FISHERY RESOURCES

The commercial and recreational fishing industries are valuable economic resources in the SOCAL/Pt. Mugu Study Area. There are numerous commercial fisheries that are operating throughout the Study Area from central California to southern California. Historically, fisheries, both commercial and recreational, have been important to the State of California. Early records indicate that commercial fisheries were documented as early as the 1850s (Allen et al. 2006a). Today, many California commercial fisheries significantly impact economic markets both domestic and foreign. During 2005 and 2006, total commercial landings in the Pacific were 3,152,793 and 2,994,782 mt, respectively (NMFS 2007b). California comprised 6% of the total commercial landings in 2005 and 5% of the total commercial landings in 2006.

Organized recreational fisheries have existed in California since the 1870s (Allen et al. 2006a); thus, California recreational fisheries have always been an important component. Today, based on angler expenditures, recreational fishing continues to be economically important to the Study Area (Thomson 2001). In the Pacific, excluding Hawaii and Alaska, approximately 1.5 million marine recreational fishing participants took 6 million trips and caught 24 million fish in 2006 (NMFS 2007b). Most (95%) of the trips were in California waters, followed by Oregon and Washington, respectively. California ranked fifth in the nation for the total number of angler trips in 2005 and fourth in 2006 (NMFS 2007b). In southern California (south of Point Conception), there were more than twice the number of resident and non-resident saltwater anglers than in northern California, Oregon, and Washington State combined.

During 2005 and 2006, California ranked ninth in the nation for the total pounds of finfish harvested, commercial and recreational landings combined (NMFS 2007b). For this reason, there is much emphasis on protecting, conserving, and managing these marine resources to maintain viability to both these industries in California waters. Evaluating commercial and recreational fisheries is important for assessing any potential impacts posed by activities within those areas.

4.5.1 Overview of Fisheries in the Study Area

Because of the varied topography and oceanic conditions resulting from the mixing of the southward-flowing California current and northerly flowing Davidson countercurrent within the Study Area, there are numerous diverse habitats for marine resources (Schiff et al. 2000). Within the SOCAL/Pt. Mugu Study Area, fish species utilize various spawning, nursery, and feeding grounds, some on a seasonal basis, consisting of bays, estuaries, nearshore, and offshore waters (Allen et al. 2006b).

Commercial and recreational fishing effort is based on the occurrence and distribution of target species (i.e., fish and invertebrates) and historically successful fishing areas (i.e. the ability of fishermen to locate and land these species) (NMFS (National Marine Fisheries Service) 2006e). For most commercial and

recreational fishing endeavors, successful fishing is attributed to the ability to anticipate the occurrence of target species at a given place and time and the ability to capture these species using a specific gear. The distribution and abundance of fishery species in the SOCAL/Pt. Mugu Study Area is dependent upon fluctuations in physical and biological factors 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; Allen et al. 2006a). Fluctuations in fish distribution and abundance are influenced by natural (El Niño and La Niña events) as well as anthropogenic activities (Waite et al. 1994; Allen 2006a). Overall, spatial and temporal fish distributions are primarily influenced by environmental factors and the availability of prey items. Distribution and movements of fishes can be variable throughout a species' life stages and with seasonal environmental fluctuations (e.g., salinity and temperature), which usually influence Habitat Associations and fish abundance (Helfman et al. 1999; Allen et al. 2006a).

4.5.1.1 Fishery Problems

Although natural patterns of variation are expected in marine fishery stocks, anthropogenic activities are known to have definite effects on fish distribution and abundance. The primary anthropogenic impacts to marine fishery stocks are overfishing, habitat loss or alteration, and water quality degradation (Saila and Pratt 1973; Malakoff 1997; NMFS 1999). These anthropogenic activities have the ability to affect nearly all estuarine species and the viability of coastal fisheries. In addition, overfishing and habitat destruction or alteration due to fishing methods (e.g., dragging nets and dredges on the seafloor) impact offshore fish populations as well (Auster and Langston 1998).

Over the past two centuries, and especially within the last 50 yr, the overall intensity of fishery effort (commercial and recreational) has significantly increased. 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 overall fishery landings for many species because of declining populations (Waite et al. 1994; Parker and Dixon 1998; Hobday and Tegner 2000). Advances in technology and available oceanographic information have made target fish species easier to locate (SeaWeb 2002). While improvements in fishing gear and methods continue, overall catch rates in relation to effort expended are decreasing (NMFS 1999). Fishery declines are directly and indirectly attributed to several factors: habitat loss, physical habitat damage, natural events (e.g. disease, competition) and cycles, fishing pressure, stream flow alteration, and degradation of water quality; however, overfishing and bycatch are considered the main causes of recent declining catch rates (Waite et al. 1994; NMFS 1999). As fishery landings decrease for target species, often bycatch or discarded species become new target species once techniques and markets have been established. Because of changes in target species (e.g. pollock and menhaden) with commercial fisheries, trophic level changes are occurring (Caddy et al. 1998; Pauly et al. 1998). Since most fisheries are already fully exploited (NMFS 1999), commercial and recreational industries show a trend of transitioning toward targeting lower trophic level species following the removal of larger predatory fishes (Pauly et al. 1998; Baum et al. 2003; Baum and Myers 2004).

4.5.1.2 Fishery Management

Public involvement, including the assistance from academia, research institutes, non-governmental organizations, and recreational and commercial participants, are essential for implementing appropriate fishery management measures. Fisheries are managed at the state, interstate, federal, and, depending on the species (e.g. HMS), at the international level. At the federal level, various statutes, environmental opinions (EOs), proclamations, and regulations have been created to aid in the conservation and management of marine resources. One of the primary mandates of the MSFCMA was the creation of a number of interstate management agencies, called FMCs. There are various FMCs throughout the country, with each having jurisdiction over a designated area. Each FMC manages the various fishery stocks located in their region in federal waters, which consists, in most cases, of waters from 3 to 200 nm from shore (EEZ). FMCs are responsible for producing and implementing FMPs with pubic input and involvement. FMPs describe the fishery, stock status, and any regulatory recommendations that are needed to conserve and manage the fishery. Once the FMPs have been approved by the Secretary of

Commerce through a cooperative effort with the NMFS, the NMFS is then responsible for developing, implementing, and enforcing regulations according to the FMP. In addition, the NMFS participates in fishery management efforts by providing fisheries data and analysis.

Since HMS transit throughout the Pacific and are targeted by many nations and gear types, management by the U.S. alone is not sufficient to ensure that harvests are sustainable in the long term. Therefore, the U.S. is a member of the Inter-American Tropical Tuna Commission (IATTC), which is responsible for the conservation and management of fisheries for tunas and other species taken by tuna-fishing vessels in the EPO. In addition, a new intergovernmental organization, the Central and Western Pacific Fisheries Commission, tasked with coordinating HMS management in the western and central Pacific was established in 2004. Although the U.S. is a signatory to the convention establishing the Central and Western Pacific Fisheries Commission, U.S. participation is limited until the convention is ratified. At this time, west coast HMS domestic management is primarily based upon the HMS FMP; Amendment 1 was approved on June 2007 (PFMC 2007b). In general, the HMS FMP was designed as a framework in order to provide a mechanism for the U.S. to meet its responsibilities under the United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and High Migratory Fish Stocks (known as the UNIA). The UNIA interprets the duties of nations that assist in conserving and managing fisheries resources and dictates that coastal states may not adopt measures that undermine the effectiveness of regional measures to achieve conservation of the fishery stocks. The U.S. is also a member of the FAO, which has implications for HMS management. In 1995, the FAO's Committee on Fisheries developed a Code of Conduct for Responsible Fisheries (FAO 1995), which more than 170 member countries, including the U.S., have adopted. Pursuant to this Code of Conduct, the U.S. has adopted the agreement for various species to promote compliance with the FAO's International Plan of Action (IPOA) for fishing vessels operating and fishing on the High Seas (FAO 2000; NMFS 2001b; Swan 2005). Within the SOCAL/Pt. Mugu Study Area there are various HMS species that are found, including various species of sharks, tuna, swordfish, dorado, and billfish (NMFS 2004a).

Of the eight FMCs in the U.S, the PFMC manages fisheries off the coast of California, Oregon, and Washington State within the EEZ (3-200 nm). The PFMC, in conjunction with the CDFG, manages the majority of the fishery resources in the SOCAL/Pt. Mugu Study Area within state waters (out to 3 nm offshore). In managing state fisheries, the CDFG management practices must remain consistent with federal laws. Under the requirements of NEPA and other environmental statues (ESA, MMPA, and MSFCMA), the PFMC recommends fishery management measures, through public involvement process, to the NMFS. Presently, the PFMC oversees four major FMPs which include salmon, CPS (Pacific sardine, mackerels, northern anchovy, squid, and krill), Pacific coast groundfish (flatfish, rockfish, scorpionfish, thornyhead, roundfish, skates and sharks, and other species), and HMS (sharks, tunas, billfish, swordfish, and dorado). More than 110 species are managed by these 4 FMPs combined (Witherell 2004).

4.5.1.3 Fishery Closures

In the U.S., there are various fishery management approaches. One method used is a fishery closure. For the purpose of protecting and rebuilding localized commercial and recreational fishery populations to harvestable levels, temporary, seasonal, or permanent fishery closures are sometimes implemented as a management approach. Through fishery management efforts of the NMFS, PFMC, and CDFG, permanent (i.e., year-round) closures remain in place for specified gear types (e.g., limited entry trawl and fixed gears, open access gears) in specific areas until the managing bodies (i.e., NMFS) modify, amend the regulations, or fishery closure time-periods expire (sunset regulations). Modifications to fishery regulations and/or involving area closures are published in the Federal Register. In response to the fishery stock status, fishery closures or closed areas may remain in affect or alter over years. In addition to permanent fishery closures, seasonal and rolling closures are implemented to protect stocks within spatial or temporal areas. Rolling closures are effective for a specified time period only and are implemented across various geographical areas to fulfill similar conservation or management goals as permanent closures (NMFS 2005a; 2006c; 2006d).

On March 8, 2006, the NMFS approved the regulatory provisions of Amendment 19 to the Pacific Coast Groundfish FMP. Amendment 19 provided for a comprehensive program to describe and protect EFH for Pacific coast groundfish. The management measures to implement Amendment 19 (which were authorized by the FMP and MSFCMA), were intended to minimize, to the extent practicable, adverse effects to EFH from fishing. These measures included fishing gear restrictions and prohibitions, closed bottom trawling (e.g., two types of bottom trawl roller gear: dredge gear and beam trawl gear) areas, and areas that were closed to all groundfish fishing within the west coast EEZ west of a line approximating the 1,280 m depth contour for gears that contacted the bottom. In addition to the 1,280 m closure (NMFS 2006; **Figure 4-2**), 12 areas within or near the SOCAL/Pt. Mugu Study Area off California have been closed (NMFS 2006d; **Figure 4-2**). In conjunction with protective measures to minimize bycatch and protect EFH, the NMFS published a new requirement for groundfish vessels. On December 7, 2007 (NMFS 2008a), the NMFS required all trawl vessels to provide declaration reports and to activate and use a vessel monitoring system transceiver while fishing off the coasts of Washington State, Oregon, and California. The goal of this management measure was to ensure compliance with those closed groundfish areas. The NMFS in conjunction with the PFMC has implemented various fishery closures within the SOCAL/Pt. Mugu Study Area (**Figure 4-2**). In total, there are 23 areas encompassing 12,045.1 km^2 which are closed to various gears. Nine areas (Point Sur Deep, TNC/ED Areas 1 (East San Lucia Bank), 2 (Big Sur Coast/Port San Luis), and 3 (Point Conception), Potato Bank, Cherry Bank and Hidden Reef/Kidney Bank (CCA West), Catalina Island, and CCA East) are closed to bottom trawl gear, one area (Davidson Seamount) is closed to all bottom contact gear, and 13 areas (Anacapa Island SMCA, Anacapa Island State Marine Reserve [SMR], Carrington Point, Footprint, Gull Island, Harris Point, Judith Rock, Painted Cove, Richardson Rock, Santa Barbara, Scorpion, Skunk Point, and South Point) are closed to fishing off California, with the exceptions (federal waters around the Channel Islands) (Sound GIS et al. 2005a, 2005b; MPAC 2008).

4.5.2 Commercial Fisheries

The total commercial fishery landings and value for the entire state of California from 1998 to 2006 was 1,906,298 mt, worth an estimated 1.1 billion dollars. Total California landings decreased from 294,926 mt in 2000 to 154,943 mt in 2006 (**Figure 4-3**) and the mean landing per year during this period was 211,811 mt (SE ± 18,432). The total California ex-vessel value (the value of the seafood at the dock as it is offloaded from the fishing vessel) ranged from 107 million dollars in 2001 to 148.9 million dollars in 1999 and the mean value per year was 126.6 million (SE ± 5.2 million) (NMFS 2007b); however, the actual economic value to the region is far greater, in terms of jobs, goods, and services associated with these fisheries. Total commercial landings and value fluctuate seasonally. Generally, mean total California landings (1998-2006) decreased during the spring and summer months and peak landings occurred during October through March (**Figure 4-4**). Total California ex-vessel values (1998 to 2006) remained relatively stable during February through October with a slight increase during November through January (**Figure 4-5**).

The market squid (also known as the opalescent inshore squid (Roper et al. 1984; Roper et al. 1998) is currently the largest revenue fishery in California (CDFG 2001; Yaremko 2001) and the primary fishery within SOCAL/Pt. Mugu Study Area. Market squid generated 6.4 million dollars in southern California and ranked second in metric tons landed at 28,117 in 2002 (CDFG 2003). During April 1, 2005 through March 31, 2006, market squid landing ranged from 426 mt in April to 25,574 mt in March (CDFG 2006; CDFG 2007). Total landings during this period were 90,639 mt (CDFG 2006; CDFG 2007).

In 2002, Pacific sardine ranked third in landings revenue behind market squid and swordfish, grossing almost 4 million dollars (CDFG 2003). In 2004, the Pacific sardine fishery became the primary fishery (total landings) in the SOCAL/Pt. Mugu Study Area at 44,261.6 mt. In 2005 and 2006, Pacific sardine total west coast landings were 86,346.4 and 86,573.2 mt, respectively. The total ex-vessel value during 2005 was 10.1 million dollars and the estimated ex-vessel value in 2006 was 9.4 million dollars (CDFG 2006; CDFG 2007). In terms of revenue, other significant fisheries in southern California include northern anchovy, groundfish (all groundfish species combined), yellowfin tuna, swordfish, California spiny lobster, albacore, sablefish, and spot prawn. In general, fishery activities occur at varying degrees throughout the year in virtually every part of the SOCAL/Pt. Mugu Study Area.

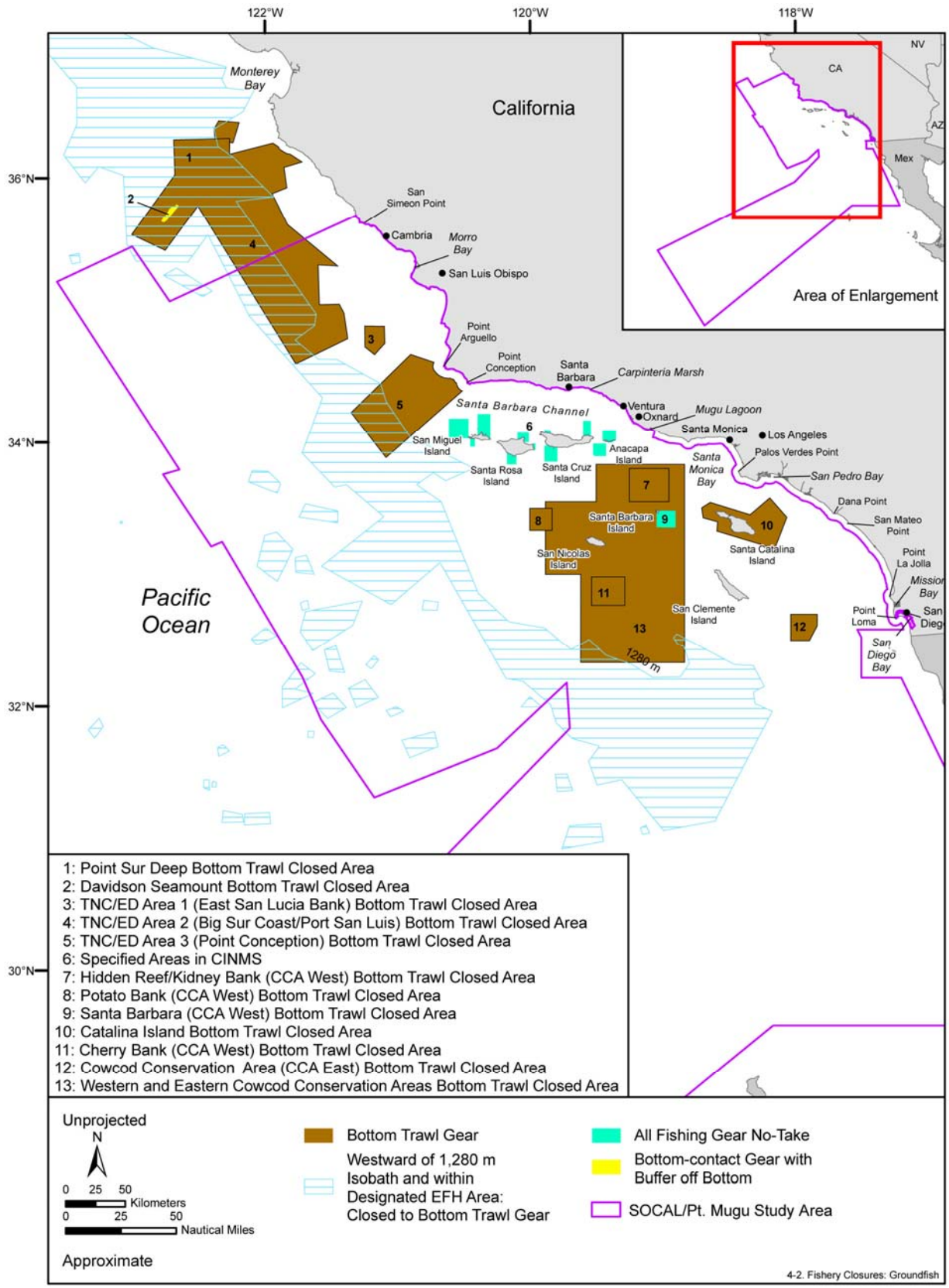

Figure 4-2. Groundfish fishery closures in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Sound GIS et al. (2005a, 2005b) and MPAC (2008).

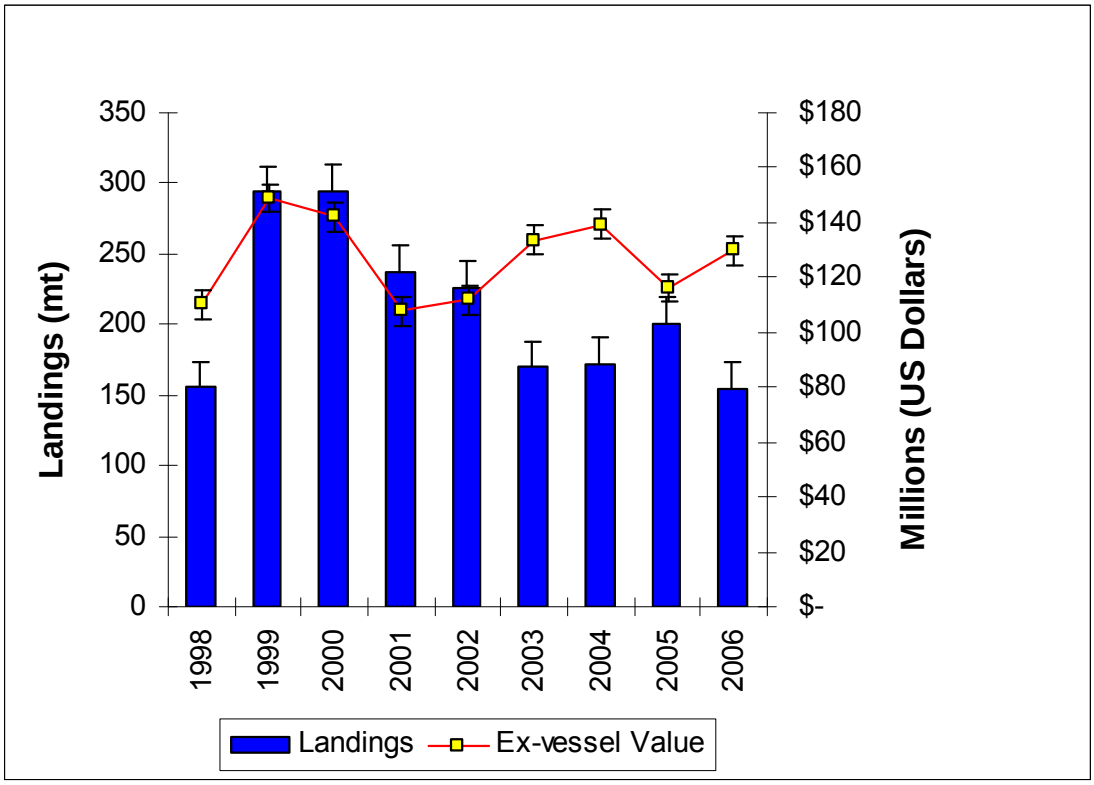

Figure 4-3. California commercial landings during 1998 to 2006. Vertical bars depict ± 1 SE. Source data: (NMFS 2007b).

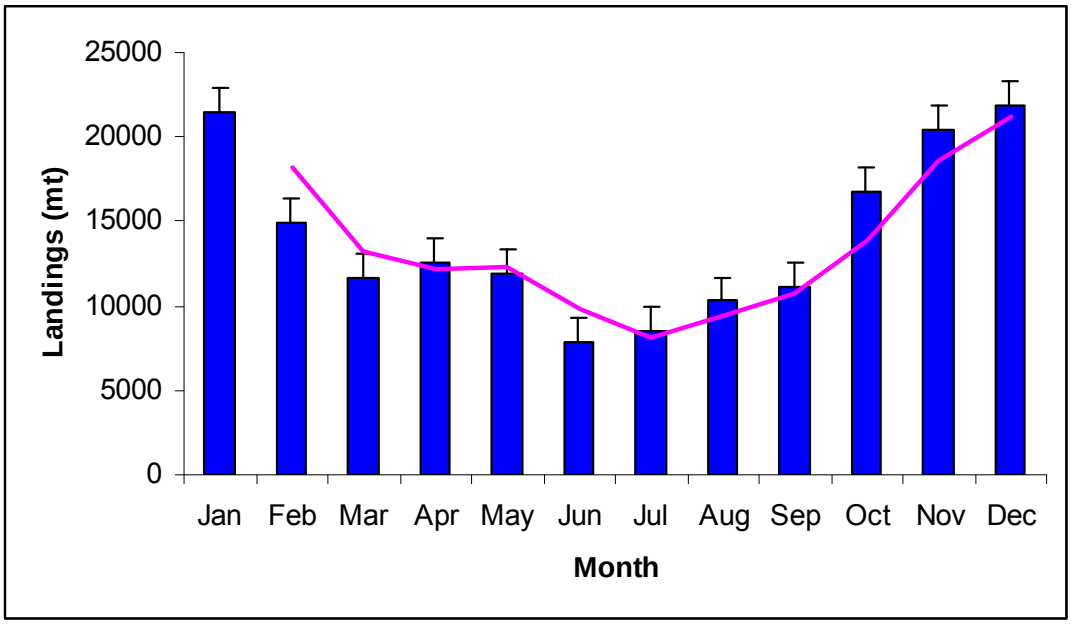

Figure 4-4. Mean California commercial landings during 1998 to 2006. Vertical bars depict ± 1 SE and trend line depicts moving average. Source data: (NMFS 2007b).

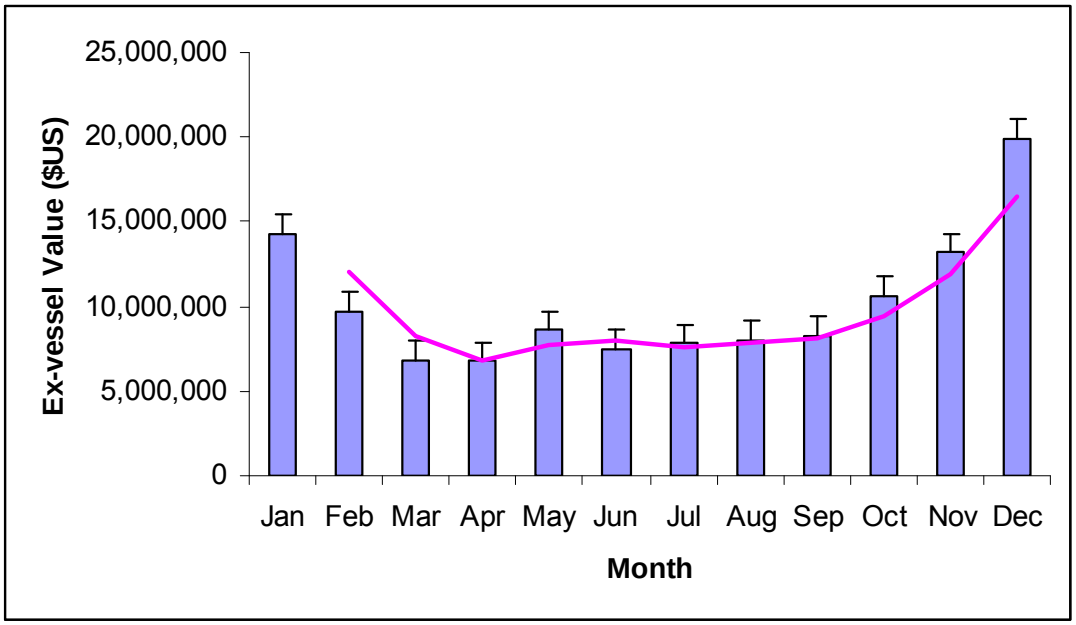

Figure 4-5. Mean California commercial ex-vessel value during 1998 to 2006. Vertical bars depict ± 1 SE and trend line depicts moving average. Source data: (NMFS 2007b).

Various commercial fishing gears and techniques are used within the SOCAL/Pt. Mugu Study Area depending on the specific fishery, as well as state and federal regulations (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) (PFMC 1999). A brief description of the primary fisheries, gear types, and fishing seasons (**Table 4-4**) within the SOCAL/Pt. Mugu Study Area is included below.

The primary commercial fisheries in the SOCAL/Pt. Mugu Study Area are coastal pelagic, groundfish, highly migratory, other major specific finfish, and invertebrate fisheries. The leopard shark, soupfin shark, and spiny dogfish are also targeted in the Study Area and are associated with the groundfish fishery, while the common thresher shark, pelagic thresher shark, bigeye thresher shark, shortfin mako shark, and blue shark are associated with the HMS fishery. Commercial fisheries are generally referred by the species targeted, the gear type used, and/or the location and season. **Table 4-5** contains a list of common fishing gear types used off the coast of southern California **(NMFS 2007b; NMFS 2007a)**.

- Set Gillnet Gear: Set gillnet gear are gillnets that are anchored to the seafloor or float above the bottom. In southern California, set gillnets are used to target California halibut, sharks, white seabass, barracuda, white croaker, flying fish, and rockfish.

- Drift Gillnet and Trammel Net Gear: Gillnets and trammel nets consist of panels of netting (monofilament or nylon) suspended vertically in the water by floats at the top and weights along the bottom. Trammel nets are typically constructed with a secondary panel of netting. After the gear is deployed, the gear is usually anchored to a vessel and drifts along with the current. Sharks and swordfish are among some of the species targeted using drift gillnets. Because of bycatch concerns, these nets are prohibited within California coastal waters.

Table 4-4. Major commercial fisheries of the SOCAL/Pt. Mugu Study Area including their seasons and gear used (peak months/seasons given in parenthesis).

FISHERY	SEASON	GEAR
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
Market Squid	April through March of following year	Round Haul Gear, Purse Seine, Drum Seine, Lampara Nets, Brail Gear, Dip and Scoop Nets, Artificial Lights
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		
Swordfish	Year Round (August through December)	Longline, Harpoons, Drift Gill Net Troll, Gillnet, Longline
Sharks	Year Round (Seasonal by species and region)	Drift Gillnet, Set Gillnet
Tunas	Year Round (Seasonal by species and region)	Longline, Purse Seine, Hook-and-Line
Other Significant Fisheries		
Pacific Bonito	Year Round (Seasonal by species and region)	Purse Seine, Troll Gear, Gillnet, Hook-and-Line
Whte Seabass	Year Round (Seasonal by species and region). Seaonal Closure: March-June	Gillnet Gear, Hook-and-Line
Shortspine Thornyhead	Year Round (Seasonal by species and region)	Trawl, Trap, Troll, Gillnet, 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
Warty Sea Cucumber	Year Round (Closed March 14 through June 16 in Halibut Trawl Grounds)	Diver, Trawl, Hand Rake
Dungeness Crab	November through June	Pot, Trap
Spiny Lobster	October-March	Pot, Trap, SCUBA
Spot Prawn	February-October	Traps, Trawls

Sources: Weber (1997), PFMC (1998b; 2003a), NMFS (1999), Leet et al. (2001), CDFG (2004a), Recht (2003), and Witherell (2004).

Table 4-5. Top fishing gears (combined) used in California and the associated landings in metric tons and ex-vessel dollar value during 2002 through 2006 (NMFS 2007b; NMFS 2007a).

Gear	Metric Tons	Ex-vessel Value
Nets, excluding trawls	563,231.0	$177,089,321
Unspecified Gear	227,544.8	$73,470,839
Trawls, Unspecified	49,168.7	$47,913,144
Lines Hand, Other	15,286.7	$51,499,140
Pots And Traps, Other	48,882.3	$211,046,718
Lines Troll, Other	14,060.5	$59,242,363
Otter Trawl Bottom, Shrimp	5,937.2	$10,318,379
Dredge Other	1.1	$2,130
Total:	**924,112.3**	**$630,582,034**

- Longline Gear: Longlines are composed of monofilament lines (mainline) that are deployed horizontally in the water column. Along the mainline, ganglions (monofilament leaders) with hooks on the terminal end and sometimes floats (buoys) are attached. Longlines can be deployed at various depths depending on the number of floats or polyballs used. Longlines can either be anchored to the bottom or drift along with the current. Longline gear may be hauled manually, electrically, or hydraulically. Pelagic longline gear is most often used to catch swordfish, sharks, and tunas, whereas bottom longline gear targets demersal or semi-demersal species (rockfish, sablefish).

- Troll Gear: Troll gear is made up of stainless steel lines that are attached from hydraulic spools to outrigger poles. The lines are spread and/or suspended from the stern of the boat on outrigger poles that are deployed at about a 45° angle from the sea surface. Baited hooks are then attached to the stainless steel mainlines at regular intervals using monofilament leaders. Leaders can either be attached to baited hooks or artificial lures. The lines are then pulled slowly through the water by a moving vessel, which is referred to as trolling. Trolling gear is typically used to target salmon and albacore tuna.

- Trawl Gear: Trawls are sock-shaped nylon nets having a wide mouth that tapers into a narrow tail, called a cod end. Trawls can be used to target species found on or near the ocean floor (bottom) or higher in the water column (mid-water). Trawl gear is commonly used to target California halibut, sea cucumbers, and both spot (*Pandalus platycerus*) and ridgeback (*Sicyonia ingentis*) prawns.

- Purse Seine Gear: Purse seines are composed of long, large panels of heavy nylon netting used to encircle a school of fish at the surface, while the bottom of the net is cinched closed. Depending on scale, purse seine operations can involve various vessels, equipment (planes) and personnel. Purse seine gear is commonly used to target sardines, Pacific herring, squid, bonito mackerel, northern bluefin tuna, and salmon.

- Drum Seine Gear: Drum seines are smaller versions of purse seines that are hauled into drums, requiring fewer personnel to operate. Drum seine fisheries commonly target bait fish, sardines, anchovy, and mackerel.

- Lampara Net Gear: Lampara net gear is another type of purse seine net. This gear is shorter and shallower than the purse seine and can be hauled in less time and with less power. Lampara nets are used to target sardines, anchovies, and mackerels.

- Trap or Pot Gear: Trap or pot gear are baited boxes that can be circular, rectangular or conical in shape. These gears are set on the ocean floor to catch various fish and shellfish. They are generally constructed of galvanized wire that may or may not be vinyl coated. In California, trap and pot gear is usually distributed throughout shallow water in the spring and summer and is moved into deeper waters as winter arrives. Traps and pots are used to target spot prawns, spiny lobster, and rock crabs (*Cancer antennarius*).

- Dredge Gear: Dredges are generally 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. Dredge gear is dragged along the seafloor to target various species of demersal groundfish or shellfish.

- Hook-and-line Gear: Hook-and-line gear are monofilament lines attached to a fiberglass or graphite pole and reel. Hook-and-line gear can be used in various ways including trolling, stationary-fishing the bottom or mid-water column, and/or casting to specific surface fish species. In addition, hook-and-line gear can be used to target demersal species, coastal pelagics, and HMS. They can also include pelagic longlines used to target tuna and swordfish.

- Brail Net Gear: Brail net gear are small nets used to scoop and haul out portions of catch from the main net. Brail nets are often used in association with the market squid fishery in southern California.

- Dive Gear: Dive gear is either SCUBA or snorkel gear used to take various fish and shellfish such as urchins, lobsters, and sea cucumbers. Divers use either self-contained air tanks, breath off "hookah" systems consisting of a long air hose connected to an air compressor on the deck of a boat, or a snorkel if in shallow waters. Specimens are collected by hand utilizing rakes, hoes, hand carried implements (harpoons, spears, spearguns, or sticks), or hand-held, manually operated water jet or suction devices (e.g., geoducks).

- Dipnet Gear: Dipnets are small nets attached to the end of a long shaft. They are used in the harvest of coastal pelagic species, such as chub mackerel.

- Trammel Net Gear: Trammel nets are similar to gillnet. Trammel net gear consists of panels of netting (monofilament or nylon) suspended vertically in the water by floats at the top and weights along the bottom. Unlike gillnet gear, trammel nets are typically constructed with a secondary panel of netting. After the gear is deployed, the gear is usually anchored to a vessel and drifts along with the current.

- Jigs: Jigs are artificial lures attached to hook-and-line gear used to actively target a variety of species found on the surface, mid-water, and bottom species.

4.5.2.1 Salmon Fisheries

Unlike in the Pacific Northwest Region, Pacific salmon support only a small offshore commercial fishery in the Pacific Southwest 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 2003c). Overall, salmon fisheries extend from the Washington State/Canadian border south to the Mexican border; however, almost all of the salmon fisheries are located north of Point Conception, California (NMFS-NWR 2003). In California waters, the coho salmon has been a prohibited species since 1993. There are virtually no salmon fisheries within the SOCAL/Pt. Mugu Study Area; however, Chinook salmon are landed in minimal quantities in Morro Bay during May through October. In 2006, commercial landings for Chinook salmon at Morro Bay ranged from 0.11 mt in August to 1.95 mt in June. The total Chinook landings in 2006 were 5.1 mt (CDFG 2006; CDFG 2007).

4.5.2.2 Coastal Pelagic Fisheries

Several CPS stocks support fisheries along the U.S. west coast from southern California to Alaska. CPS stocks include the Pacific sardine, jack mackerel, Pacific mackerel (commonly known as chub mackerel), northern anchovy, 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 2006c). 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 applied. CPS are either harvested directly or as bycatch in other fisheries. In 2005, combined commercial landings of CPS finfish totaled 44,641 mt with an ex-vessel value of 4.8 million dollars (CalCOFI 2007). Among these four fish species, the Pacific sardine fishery is the most valuable CPS fishery within the SOCAL/Pt. Mugu Study Area (**Figure 4-6**), contributing 70% of the total landings and about 65% of the total ex-vessel value (CalCOFI 2007). Overall, market squid is the most valuable fishery in terms of landings and revenue. Most squid landings for the ports within the SOCAL/Pt. Mugu Study Area occurred in Los Angeles (**Figure 4-6**). Generally, CPS are targeted with "round-haul" gear which includes purse seines, drum seines, lampara nets, and dip nets. CPS are also taken incidentally with midwater trawls, pelagic trawls, gillnets, trammel nets, trap pots, and hook-and-line using artificial jigs (PFMC 2005g). The fishery management area is divided into subareas for the regulation of fishing for CPS, with the following boundaries: 1) the CPS Limited Entry Zone covers that portion of the EEZ between 39°00'00"N (off California) and the U.S. Mexico-International Boundary; 2) Subarea A covers that portion of the EEZ between the U.S.-Canada Provisional International Boundary and Pt. Piedras Blancas, California (35°40'00"N); and 3) Subarea B covers that portion of the EEZ between Pt. Piedras Blancas, California, and the U.S.-Mexico International Boundary. The SOCAL/Pt. Mugu Study Area is located in Subarea B. Generally, fisheries for CPS can be divided into two areas: north and south of Pigeon Point, California (~37°10'N). To date, nearly the entire commercial fishery for CPS finfish and market squid has been prosecuted south of Pigeon Point, California. Presently, the CPS limited entry fleet consists of 63 permits and 61 vessels (The Research Group 2006). The capacity goal and transferability provisions established under Amendment 10 of the CPS FMP were based on calculated gross tonnage of individual vessels.

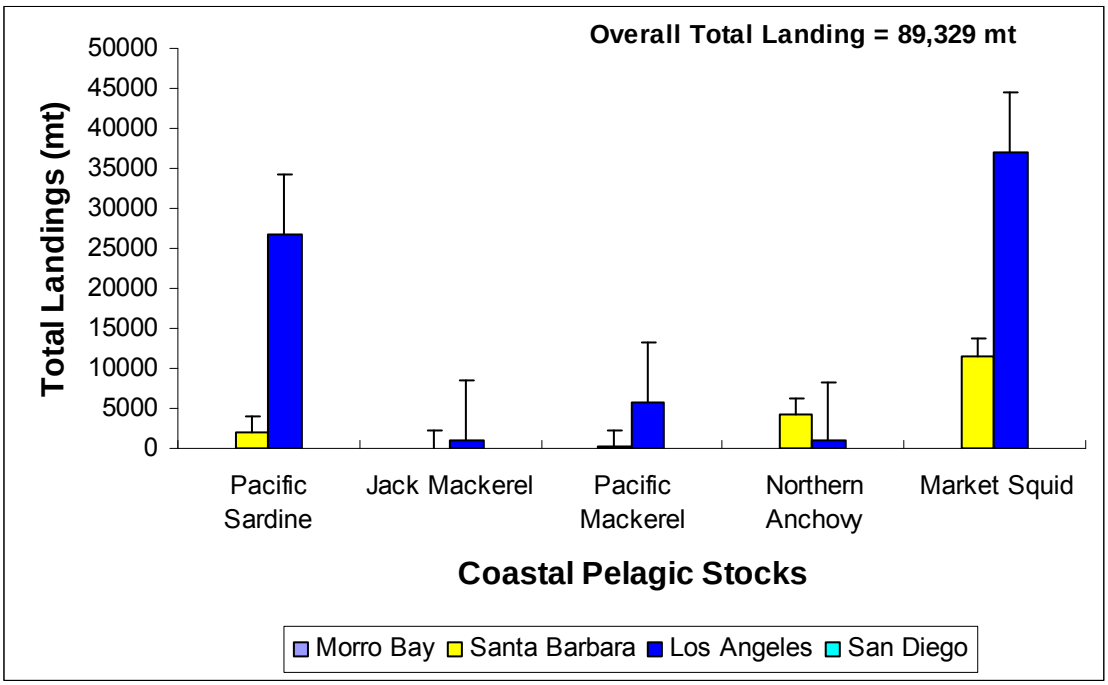

Figure 4-6. Total coastal pelagic stock landings in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

Krill are not only a critical component of the ecosystem off the U.S. west coast, but are a principal food source for many fish species that are subject to management under the PMFC FMPs. Although Washington State, Oregon, and California already prohibit their vessels from fishing for krill and prohibit landings of krill into west coast ports, there were no prohibitions that prevent a vessel from another state to target and land krill in another area. Therefore, in June 2006, the PFMC amended the CPS FMP in order to prohibit the potential harvest of krill in federal waters (NMFS 2006). On May 20, 2008, NMFS proposed to add all eight krill species as a management unit under a newly established category called prohibited harvested species in Amendment 12 of the CPS FMP. Unilike the current prohibited species category, the new category would not allow for the harvest of krill species by any fishery or gear type in the U.S. EEZ, including incidental catch and would deny the use of exempted fishing permits to allow krill fishing (NMFS 2008b).

4.5.2.2.1 Pacific sardine

Pacific sardine are jointly managed by the states of California, Oregon, and Washington, along with the PFMC. Under the PFMC FMP, the biomass of Pacific sardine is estimated each year and a coast-wide harvest guideline is established and allocated by the NMFS (ODFW 2005). Except for the coast-wide harvest guideline, management of Pacific sardine north of 39°N (approximately Point Arena, California) continues under jurisdiction of the states as long as the management measures are consistent with the 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 transitioned from a state limited entry system to federal limited system managed by the NMFS under Amendment 8 to the CPS FMP (PFMC 1998b). Commercial sardine landings averaged 40,974.6 mt during 1995 through 2005 and, as in previous years, most (93.4%) of California's 2005 catch was landed in the Los Angeles (69.9%) and Monterey (23.5%) port areas (CDFG 2006; CDFG 2007) During 2001 through 2006, annual California Pacific sardine commercial total landings ranged from 34,632.6 mt in 2005 to 58,352.8 mt in 2002 (CDFG 2006; CDFG 2007). During this period, the fishery was the second largest fishery in the state of California (CDFG 2007). California Pacific sardine total revenue ranged from 3,150,095 dollars in 2005 to 6,288,144 dollars in 2001 (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, total Pacific sardine landings in 2006 were 0.05; 1,935.8; 26,789.5; and 17.7 mt, respectively (**Figure 4-6)** (CDFG 2006; CDFG 2007).

4.5.2.2.2 Jack mackerel

Jack mackerel distribution extends from the Gulf of Alaska to Cape San Lucas, Baja California, Mexico with spawning occurring in southern California waters during March through July. Similar to other species of bait fish, jack mackerel have been exploited in California waters since the 1930s. Currently, most landings of jack mackerel are an incidental bycatch of Pacific sardine and Pacific mackerel fisheries in California; however, directed landings do occur sporadically. During the 1980s, California landings ranged from 9,210 mt in 1982 to 25,984 mt in 1985. Landings of jack mackerel in California during the 1990s reached 5,878 mt in 1992 and averaged around 1,900 mt. More recently, jack mackerel landings have ranged from 253 mt in 2005 to 3,624 mt in 2001. In 2006, total California jack mackerel landings were 1,167 mt and the ex-vessel value was 165,914 dollars within the SOCAL/Pt. Mugu Study Area (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, total jack mackerel landings in 2006 were 0.0; 0.0; 1,025.6; and 0.0 mt, respectively (**Figure 4-6**) (CDFG 2006; CDFG 2007).

4.5.2.2.3 Pacific mackerel

Since the late 1970s population collapse, Pacific mackerel populations have extensively been assessed (Dorval et al. 2007). Pacific mackerel have traditionally been targeted in southern California waters between Monterey and the U.S./Mexican border with 93% of the landings occurring at San Pedro and Terminal Island (CDFG 1999). Similar to other commercial fisheries, monthly landings were dependent on fishermen's participation in other fisheries, economic markets, and weather conditions (daily or climatic [El Niño and La Niña events]); however, generally most landings occurred in spring and fall months (CDFG

1999). Over the last 10 yr annual landings have averaged 9,193.4 mt, but have declined in recent time. In 2005, 2941.4 mt of Pacific mackerel were landed in California with an ex-vessel value of 535,259 dollars (CDFG 2006; CDFG 2007). Most of the Pacific mackerel (97%) were landed in the Los Angeles port areas. During 2001 through 2006, annual California Pacific mackerel commercial total landings ranged from 3,244.3 mt in 2005 to 6,924.4 mt in 2001 (CDFG 2006; CDFG 2007). California Pacific mackerel total revenue ranged from 487,625 dollars in 2002 to 1,095,664 dollars in 2001. In 2006, total California Pacific mackerel landings were 5,892.9 mt and the ex-vessel value was 809,694 dollars within the SOCAL/Pt. Mugu Study Area (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, total Pacific mackerel landings in 2006 were 0.0; 146.1; 5,714.4; and 0.55 mt, respectively (**Figure 4-6**) (CDFG 2006; CDFG 2007).

4.5.2.2.4 Northern anchovy

Northern anchovy have been exploited since the early 1900s. Over the years, commercial landings have drastically fluctuated. The most recent complete assessment for northern anchovy was described in (PFMC 2004a). Historical information indicates that landings peaked in the 1950's and then declined. By the early 1960s, California landings of northern anchovy began to increase slightly and landings peaked in 1975 at 143,799 mt; however, after 1975, landings declined. During 1983 through 1999, landings did not exceed 6,000 mt per year until 2000 when landings reached a high of 11,753.4 mt (PFMC 2004a). California total landings of northern anchovy reported by Pacific Coast Fisheries Information Network (PacFIN) ranged from 68 mt in 2005 and 1,676 mt in 2003 to 12,788 mt in 2006, which were mostly caught in the Monterey area. In 2006, total California northern anchovy landings were 12,794.1 mt and the ex-vessel value was 728,251 dollars within the SOCAL/Pt. Mugu Study Area (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, total northern anchovy landings in 2006 were 0.0; 4,182; 878.6; and 26.1 mt, respectively (**Figure 4-6**) (CDFG 2006; CDFG 2007).

4.5.2.2.5 Market squid

Market squid is domestically consumed or used for bait. The fishing permit season for market squid runs from April 1 through March 31 the following year. The fishery is typically prosecuted on squid spawning grounds in the SCB and Monterey Bay areas (Maxwell 2004). In northern waters, the fishery is prosecuted around Monterey Bay, while in southern waters the fishing effort is often associated with the 100-m contour around Santa Rosa, Santa Cruz, Anacapa, and Santa Catalina islands (Maxwell 2004). In southern waters, the fishery is associated with the squid spawning season, which is during the fall and winter months (October to December and January to March). Conversely, in northern waters, the squid spawning season and associated commercial fishery is during the summer months. Usually, more market squid are landed in southern waters than in northern waters (Zeidberg 2006). Similar to many of the CPS, the market squid fishery has drastically fluctuated depending on environmental conditions and the occurrence of El Niño events. The total squid fishery landings were 20% greater in 2005 than in 2004, increasing from 42,014.9 mt to 50,434.6 mt (CDFG 2006; CDFG 2007). In 2005 and 2006, the market squid fishery was the largest fishery in the state, with landings estimated at 54,976 mt and 49,145 mt, respectively. The ex-vessel value in 2006 was 26,686,559 dollars within the SOCAL/Pt. Mugu Study Area (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, market squid was the primary CPS landed. In 2006, the total market squid landings within the SOCAL/Pt. Mugu Study Area were 0.0; 11,536.7; 37,117.2; and 1.4 mt, respectively (**Figure 4-6**) (CDFG 2006; CDFG 2007).

4.5.2.2.6 Other coastal pelagic species

In addition to the directed CPS commercial fisheries, there is also a bait fishery associated for some of the CPS found within the SOCAL/Pt. Mugu Study Area. Although tonnage of CPS and squid landed in the live bait fishery is minimal in comparison to the directed commercial landings, estimates have shown that the revenue of the live bait fishery for sardine equaled that of the commercial catch (PFMC 2007a). The live bait fishery is primarily prosecuted in southern California and the market is mostly for the recreational

fishing industry. In 2006, the estimated number of vessels in the live bait fishery in southern California was around 18. Pacific sardine and northern anchovy are the main species comprising the live bait fishery. Besides logbooks, live bait sales do not have any requirements such as mandatory sales reporting; thus, landing estimates are unreliable (PFMC 2007a). Nonetheless, recent estimated annual California landings ranged between 5,000 mt and 8,000 mt, with effort usually increasing during summer months (PFMC 2007a).

4.5.2.3 Groundfish Fisheries

Groundfish are one of the most diverse groups of fishes found on the U.S. west coast. Groundfish include more than 90 species of demersal fish that inhabit or are associated with the sea bottom. The groundfish fishery includes 12 species of flatfish (soles, flounder, and sanddab), 64 species of rockfish (e.g., widow, yellowtail, canary, shortbelly, vermilion, cowcod, and Pacific ocean perch, etc.); 6 species of roundfish (lingcod, cabezon, kelp greenling, Pacific cod, Pacific whiting, and sablefish); 6 shark and skate species (leopard shark, soupfin shark, spiny dogfish, big skate, California skate, and longnose skate); and 3 other species which include Pacific flatnose, spotted ratfish, and Pacific grenadier. 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. Most groundfish are targeted with trawl gear; however, other gear types include gillnets, longline, troll, jig, hook-and-line, pots/traps, and other gear (e.g., spears, throw nets) (Witherell 2004).

On January 4, 1982, the Pacific Coast Groundfish FMP was approved by the NMFS, and implemented on October 5, 1982. Prior to FMP implementation, management of domestic groundfish fisheries was under the jurisdiction of the states of Washington, Oregon, and California. To date, the PFMC has revised the FMP through 19 different amendments. The PFMC develops and recommends harvest specifications and management measures to the NMFS, and if approved by the NMFS, these specifications and management measures usually become effective on January 1 of any given year (the beginning of the management cycle). The FMP divides the U.S. west coast groundfish fishery into 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 foot rope requirements for landing shelf rockfish) (PFMC 1998a). Groundfish specifications and management measures are developed by the PFMC and are usually implemented annually by the NMFS (NMFS 2006d).

Groundfish landings peaked in the early 1980s, but have declined and leveled off since then. Much of the decline of groundfish species in the 1980s was due to the transition from a lightly exploited, highly abundant stock level to a fully exploited, moderately abundant stock level (PFMC 2004b). The overall groundfish complex has drastically declined for reasons unknown, but speculated to have been from overfishing, incidental bycatch, unavailable life history knowledge on specific species, and oceanic climatic changes caused by El Niño and La Niña events (CDFG 1999). As with many U.S fisheries, the likely cause of stock declines is growth and overexpansion, which often causes the overfishing of stocks (McGovern et al. 1998). For some species, such as the sablefish and lingcod, the PFMC and the NMFS have imposed restrictive measures. For others, such as the cowcod, management measures have included closed areas. For example, in the SCB, south of Pt. Conception, there are two large areas that have been closed to bottom fishing since 2000 in order to minimize mortality of cowcod, a severely depleted groundfish stock under rebuilding. Termed the CCAs, these areas are designated with regular, rectangular lines to ease enforcement of fishing prohibition zones (NMFS 2006d).

In 2005, the overall California commercial groundfish harvest was around 9,070 mt, which was 16% less than 2004 landings (CDFG 2006; CDFG 2007). The groundfish harvest mainly consisted of four species: Pacific whiting, Dover sole, sablefish, and rockfishes. For 2004 and 2005 fishing seasons, the ex-vessel value of groundfish landings remained unchanged at around 13.8 million dollars (CalCOFI 2007).

4.5.2.3.1 Flatfish

Flatfish species harvested in California include various sole species, flounders, and sanddabs. Flatfish are almost exclusively harvested using trawl gear. In California, Dover sole is the most economically important flatfish followed by arrowtooth flounder, petrale sole, and English sole ranking second, third, and fourth, respectively. The Dover sole fishery started as an undesirable bycatch of the bottom trawl fishery in the 1940s, but has evolved into the most abundant flatfish landed in the states of California and Oregon. This increase was attributed to the market demand during WWII and to the 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 dollars in 2004 (CDFG 2006; CDFG 2007). 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. 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) and from 2001 to 2004 at 6,934 mt; whereas the arrowtooth flounder has averaged 4,298 mt per year from 1995 through 2004, peaking in 1999 at 6,453 mt. In 2006, Dover sole landings were 1,760.4 mt, arrowtooth flounder were 31.8 mt, petrale sole were 752.9 mt, and English sole were 299.4 mt (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, California halibut (*Paralichthys californicus*) was the primary flat fish landed in 2006. In 2006, the total California halibut landings within the SOCAL/Pt. Mugu Study Area were 7.6, 66.3, 26.8, and 8.9 mt, respectively (**Figure 4-7**) (CDFG 2006; CDFG 2007). Total landings within the SOCAL/Pt. Mugu Study Area for Dover sole, English sole, Petrale sole, and starry founder were 11.5, 0.7, 1.0, and 0.47 mt, respectively (**Figure 4-7**) (CDFG 2006; CDFG 2007).

4.5.2.3.2 Rockfish

Rockfish (*Sebaste*s and *Sebastolobus* spp.) are an important group of commercial fish, generating about 1.2 million dollars in revenue in 2006. During 2002 through 2006, California rockfish landings ranged from 759.2 mt in 2005 to 1,521.8 mt in 2002. California rockfish revenue ranged from 996,985 dollars in 2005 to 2.9 million dollars in 2002 (CDFG 2006; CDFG 2007). Life history parameters (long-lived, slow to mature) make rockfish susceptible to overfishing. In addition, climatic changes (El Niño and La Niña events) have impacted populations by lowering juvenile rockfish survival rates (Stephens 2006). The majority of rockfish are harvested using bottom trawl gear (89%), but other gears include hook-and-line (9%), and traps, trolling, and gillnets (2%) (Parker et al. 2000). Rockfish landings have declined dramatically over the past 10 yr from 32,832 mt in 1995 to a projected low of 2,689 mt in 2005. Some of the more economically important rockfish in the SOCAL/Pt. Mugu Study Area include brown rockfish, gopher rockfish, grass rockfish, black-and-yellow rockfish, blackgill rockfish, group red rockfish, group shelf rockfish, group slope rockfish, and vermilion rockfish (NMFS 2006d). Total landings for these rockfish were 17.3; 7.6; 14.3; 4.8; 43.5; 3.5; 6.4; 7.1; and 7.1 mt, respectively. Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, blackgill rockfish was the primary rockfish landed in 2006 (CDFG 2006; CDFG 2007). In 2006, the total blackgill rockfish landings within the SOCAL/Pt. Mugu Study Area were 5.7, 7.3; 3.3; and 3.4 mt, respectively (**Figure 4-8**) (CDFG 2006; CDFG 2007).

4.5.2.3.3 Roundfish

The main roundfish species commonly landed in California include lingcod, cabezon, Pacific whiting (hake), and sablefish (CDFG 2006; CDFG 2007). Lingcod are caught commercially using bottom trolling, longline gears, trawls, and set gillnets, whereas cabezon are mainly harvested as incidental catch from fisheries utilizing trap, gillnet, and hook-and-line gears (NMFS-NWR 2004). 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 (CDFG 2006; CDFG 2007). The Pacific whiting trawl fishery extends from northern California (about 40°30'N) 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)

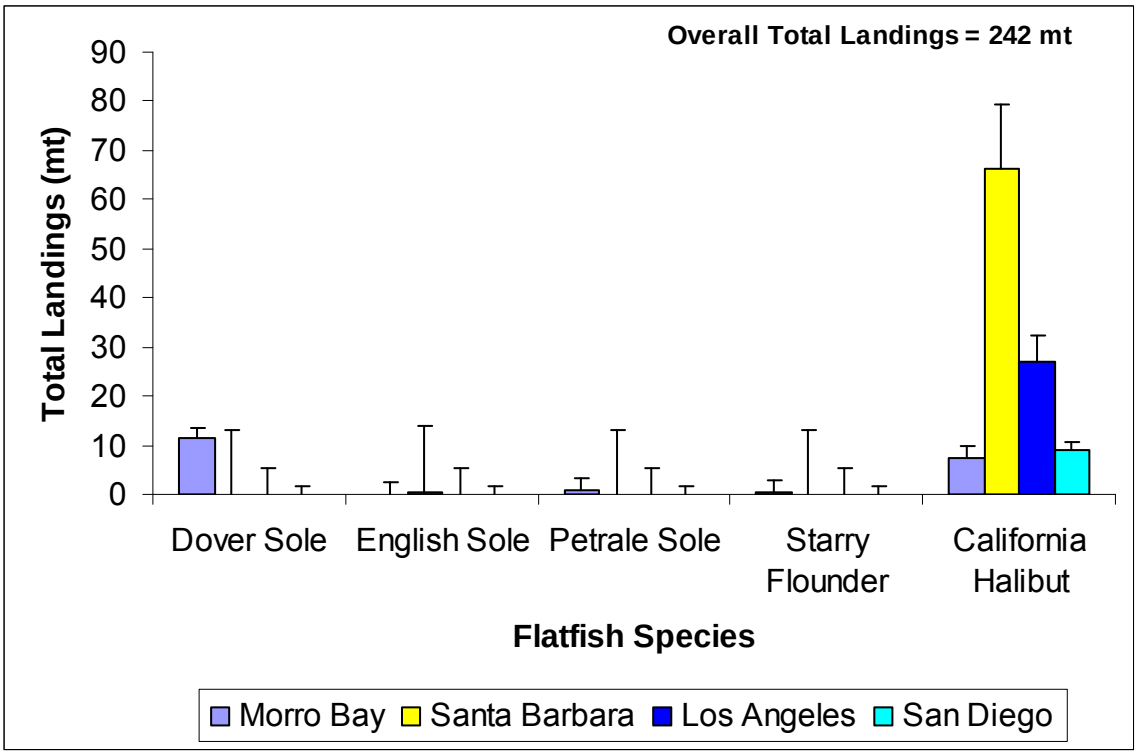

Figure 4-7. Total landings of flatfish in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

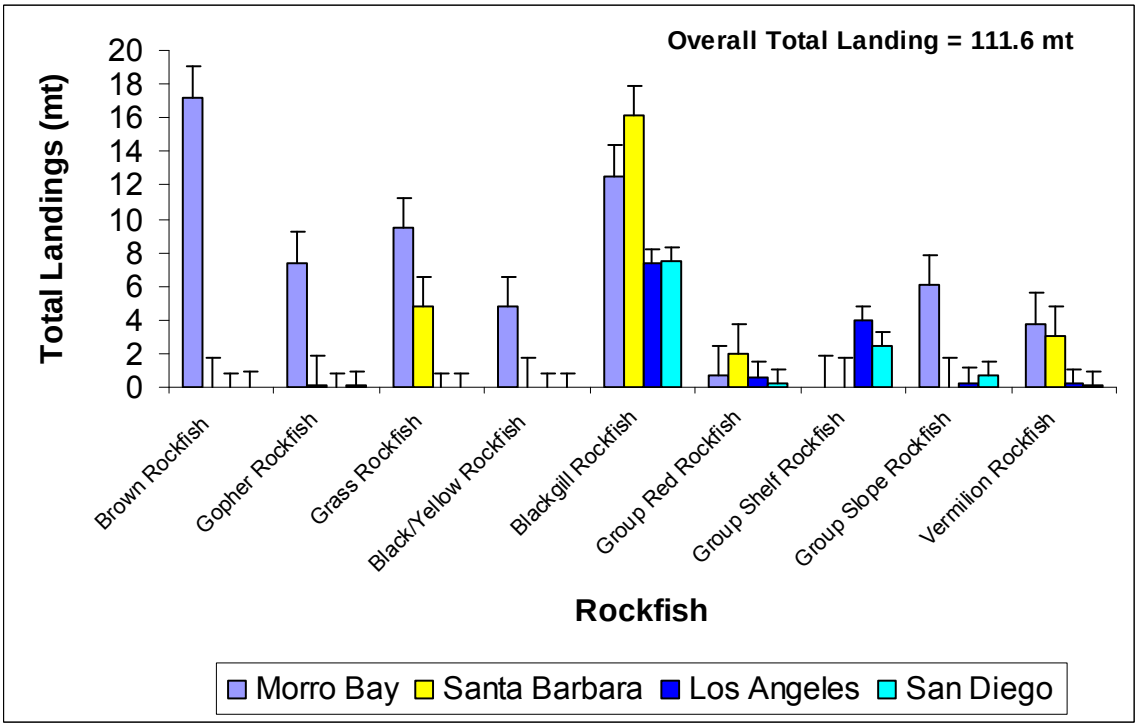

Figure 4-8. Total landings of rockfish in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

beginning on April 1, the fishery south of 40°30'N opening April 15, and the fishery north of 42°N on June 15. This fishery is annually accessed and jointly managed through federal regulations by the PFMC under the groundfish FMP (Carretta et al. 2005a) and the Canadian Department of Fisheries and Oceans (NMFS-NWR 2004). Over the past decade, 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 (CDFG (California Department of Fish and Game) 2006, 2007). Sablefish are harvested commercially using longline, trap, bottom trawl, and gillnet gears. Over the past decade, sablefish landings averaged 8,412 mt and 27 million dollars in revenue from 1995 through 1997, then declined and leveled off from 1998 to 2004 averaging 5,559 mt and 16 million dollars in revenue (CDFG 2006; CDFG 2007). The overall total landings for the entire SOCAL/Pt. Mugu Study Area for lingcod, cabezon, Pacific whiting, and sablefish were 9.6; 17.2; 0.56; and 188.4 mt, respectively. Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) that are found within the SOCAL/Pt. Mugu Study Area, sablefish was the primary roundfish landed in 2006 (CDFG 2006; CDFG 2007). In 2006, the total sablefish landings within the SOCAL/Pt. Mugu Study Area were 120.8, 15.8, 24.6, and 27.1 mt, respectively (**Figure 4-9**) (CDFG 2006; CDFG 2007).

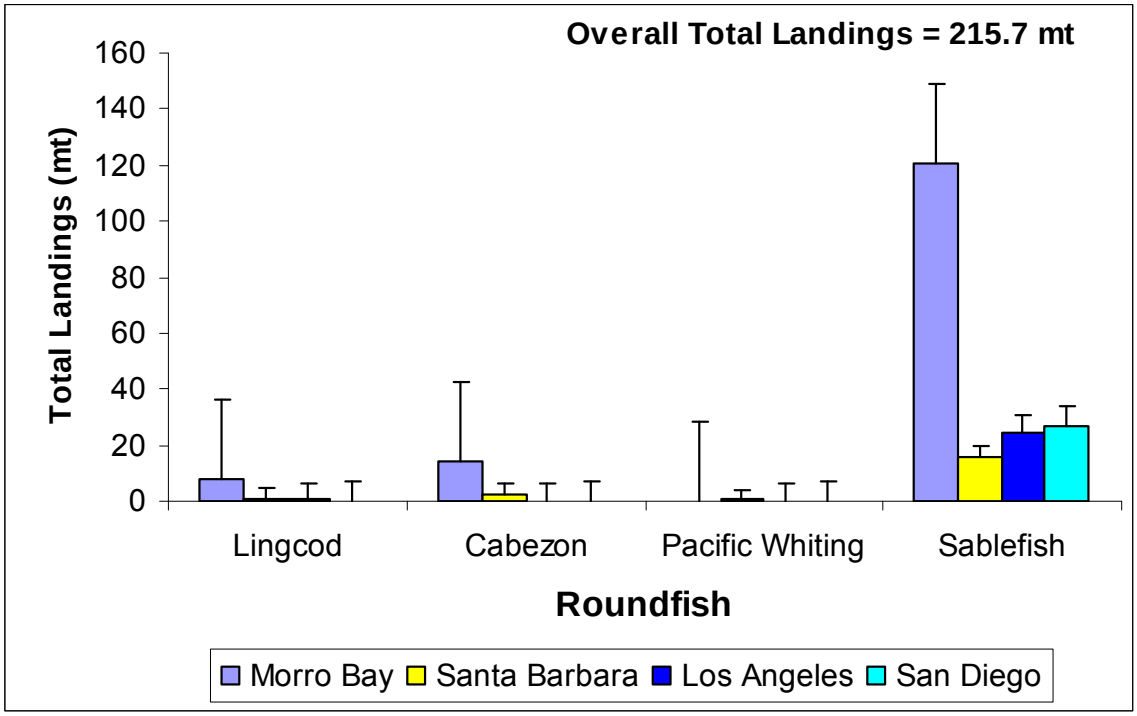

Figure 4-9. Total landings of roundfish in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

4.5.2.4 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 demersal sharks within the SOCAL/Pt. Mugu Study Area, the soupfin shark is the most abundant and economically important shark, followed by the spiny dogfish shark (Hanson 1999). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, soupfin shark was the primary shark landed in 2006 (CDFG 2006; CDFG 2007). The ex-vessel value for soupfin shark was 37,527 dollars within the SOCAL/Pt. Mugu Study Area

(CDFG 2006; CDFG 2007). In 2006, the total soupfin shark landings within the SOCAL/Pt. Mugu Study Area were 1.5; 2.9; 4.7; and 7.6 mt, respectively (**Figure 4-10**) (CDFG 2006; CDFG 2007). Within the SOCAL/Pt. Mugu Study Area; spiny dogfish were only landed in Los Angeles in 2006. The ex-vessel value for spiny dogfish was 14,667 dollars within the SOCAL/Pt. Mugu Study Area. Spiny dogfish landings in Los Angeles were 6.1 mt which represented 43% of the total California landings (**Figure 4-10**) (CDFG 2006; CDFG 2007).

Coastal trawl fleets account for the majority of all skate landings off the west coast, although some are caught by trammel nets in California (NMFS-NWR 2004). Skates are usually caught incidentally in the sole and rockfish fisheries (PFMC 2004b). Typically, only the wings of skates are marketed, which are primarily sold in the Asian fish markets in southern California (NMFS-NWR 2004). Both California and Oregon dominate the skate fisheries, comprising 81% of the total landings over the past decade (1995 to 2004). Most skate landings occur in northern and central California areas (Eureka, San Francisco, and Monterey), with limited landings occurring in southern California waters. Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, skate (unspecified) was primarily landed in the Los Angeles area. The ex-vessel value for skate was 4,215 dollars within the SOCAL/Pt.Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) (CDFG 2006; CDFG 2007). In 2006, the total skate landings within the SOCAL/Pt. Mugu Study Area were 0.43; 0.59; 3.9; and 0.0 mt, respectively (**Figure 4-10**) (CDFG 2006; CDFG 2007).

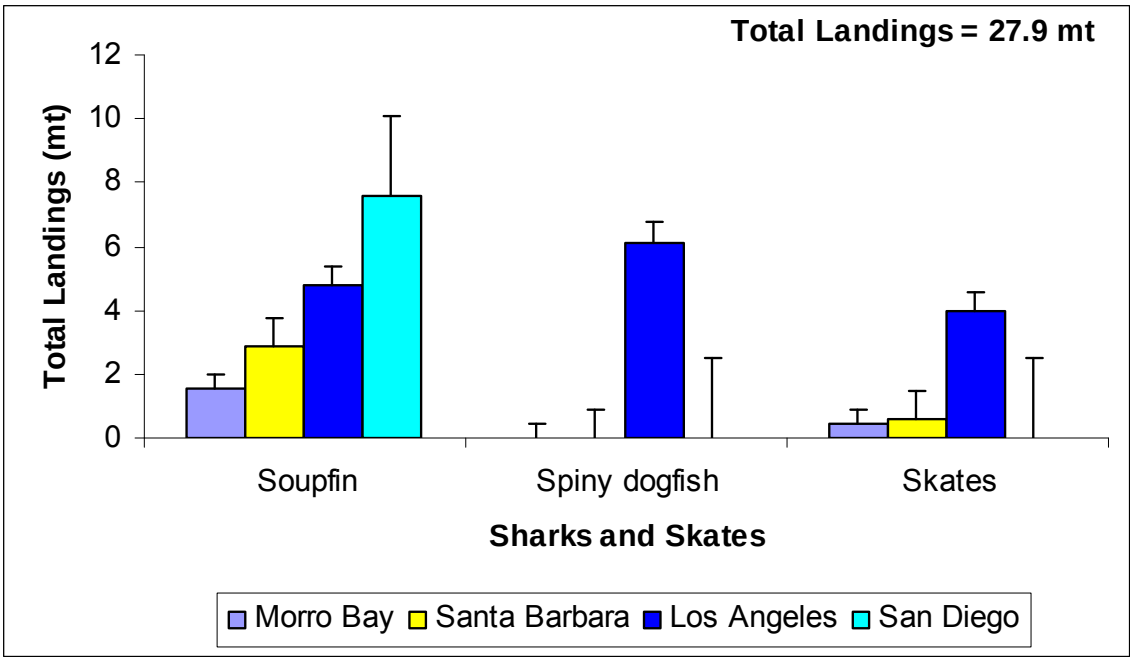

Figure 4-10. Total landings of sharks and skates in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

4.5.2.5 Highly Migratory Species Fisheries

HMS have wide ranging migration patterns in the open ocean environment which often occur outside the EEZ in international waters. The HMS FMP final rule implements regulations necessary for federal management of U.S. fishing vessels targeting HMS within the U.S. west coast EEZ and on the high seas (seaward of the EEZ) (PFMC 2005d). In addition to U.S. management, effective HMS management requires international cooperation because many of these species are targeted by other countries.

In the U.S., HMS are managed under several authorities including the U.S.-Canada albacore treaty, Western and Central Pacific Fishery Commission (WCPFC), UNIA under the Law of the Sea Treaty, U.N. Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, IATTC, and western Pacific FMP. The MSFCMA defines HMS as tuna species, billfish, oceanic sharks, dorado, and swordfish. The term "tuna species" includes albacore, bigeye, northern bluefin, skipjack, and yellowfin tunas. Most of these species are highly valued by both commercial and recreational fisheries (PFMC 2003a). HMS are primarily landed in the SOCAL/Pt. Mugu Study Area with swordfish and yellowfin tuna being the main species landed by commercial and recreational fisheries (**Figure 4-11**) (CDFG 2006; CDFG 2007).

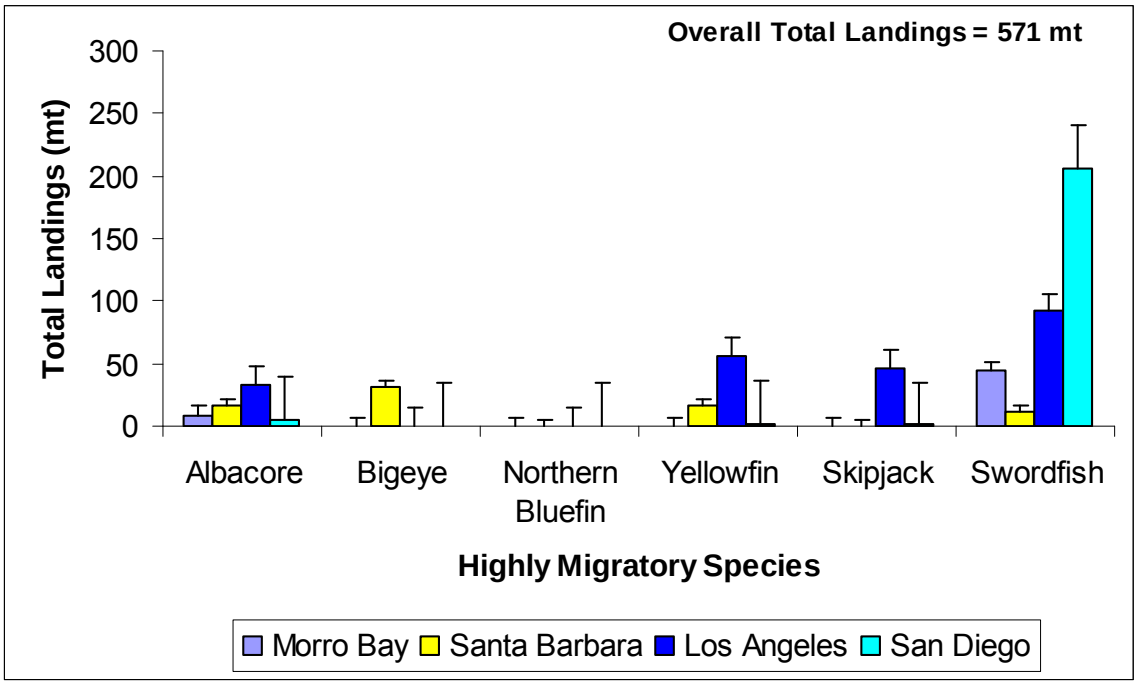

Figure 4-11. Total landings of highly migratory species in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

4.5.2.5.1 Swordfish

Swordfish are primarily harvested using drift gillnet and pelagic longline gears. Pelagic longline gear within the west coast EEZ and shallow-set longline gear in the high seas is prohibited. In 2006, swordfish were landed throughout the year; however, 60% (223.7 mt) of the landings occurred in November and December. As a result, peak landings occurred in the third quarter (September to December) and the lowest landings (5%) occurred in the second quarter (May to August). Overall, swordfish landings in California steadily decreased during 2003 through 2005 with landings in 2006 at 45% higher than in 2006. During 2002 through 2006, ex-vessel value decreased from a high of 7,849,250 dollars in 2003 to low of 1,990,682 dollars in 2005. Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, swordfish was primarily landed in the San Diego area. In 2006, the total swordfish landings within the SOCAL/Pt. Mugu Study Area were 43.8; 11.1; 91.5; and 206.4 mt, respectively (**Figure 4-11**) (CDFG 2006; CDFG 2007).

4.5.2.5.2 Yellowfin tuna

Yellowfin tuna are harvested by a variety of commercial fishing gear including harpoons, surface hook-and-line gears, purse seines, drift gillnets, and longlines. Pelagic longline gear within the west coast EEZ

and shallow-set longline gear in the high seas is prohibited. In 2006, yellowfin tuna were landed throughout the year; however, 75% (55.8 mt) of the landings occurred in the month of November (CDFG 2006; CDFG 2007). As a result, peak landings occurred in the third quarter (September to December) and the lowest landings (5%) occurred in the second quarter (May to August). Overall, yellowfin tuna landings in California remained stable during 2002 through 2005; however, landings decreased 40% from 478 mt in 2005 to 285 mt in 2006. Ex-vessel value, however, has steadily decreased from a high of 588,677 dollars in 2002 to a low of 163,771 dollars in 2006. Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, yellowfin tuna was primarily landed in the Los Angeles area (CDFG 2006; CDFG 2007). In 2006, the total yellowfin landings within the SOCAL/Pt. Mugu Study Area were 0.0; 16.5; 56.1; and 1.7 mt, respectively (**Figure 4-11**) (CDFG 2006; CDFG 2007).

4.5.2.5.3 Albacore tuna

Another important HMS species is the albacore tuna. The U.S./Canada Albacore Treaty, a treaty between the U.S. and Canadian governments, was originally implemented in 1981, amended in 2002, and codified in 2004 (NMFS 2004c). The treaty was primarily enacted to allow U.S. and Canadian vessels to target albacore tuna seaward of 12 nm from within each other's countries. In addition, the treaty allows Canadian and U.S. vessels to use specific ports, the ability to obtain supplies and services, and to land fish within each other's country (PFMC 2005d).

Generally, albacore tuna are harvested by trollers (hook-and-line) and live bait methods, but may also be caught with longlines, purse seines, drift gillnets, and other hook-and-line gears. Fishing efforts for albacore tuna along the U.S. west coast extends from July through September and occasionally, weather permitting, into November. Overall, albacore tuna landings along the U.S. west coast have steadily increased from 1995 through 2004; however, albacore landings have continued to decrease in California as a result of a shift in fishing effort by California-based vessels into waters off Oregon and Washington State (PFMC 2005d). In 2005, commercial albacore California landings were 435 mt, which was a 35% decrease from that of 2004. The ex-vessel value for albacore was 1.1 million dollars in 2005, which was a 55% decrease from that of 2004. In 2006, the commercial albacore California landings declined 48% to 207.6 mt for a value of 523,459 dollars or a 48% decrease from that of 2005. Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, albacore tuna was primarily landed in the Los Angeles area (CDFG 2006; CDFG 2007). In 2006, the total albacore landings within the SOCAL/Pt. Mugu Study Area were 8.7; 16.8; 33.2; and 5.6 mt, respectively (**Figure 4-11**) (CDFG 2006; CDFG 2007).

4.5.2.5.4 Other highly migratory species

Northern bluefin, skipjack, and bigeye tunas comprising the HMS category also support important fisheries in the SOCAL/Pt. Mugu Study Area. Although skipjack tuna and bigeye tuna comprise a significant portion of the total HMS catch in limited areas, northern bluefin tuna landings are low. In 2006, the overall annual total landings of northern bluefin, bigeye, and skipjack tuna for the entire SOCAL/Pt. Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) were 0.64; 31.2; and 47.6 mt, respectively (**Figure 4-11**) (CDFG 2006; CDFG 2007).

Pelagic sharks are also a common group associated with HMS gear. The two primary pelagic shark species captured are the common thresher shark and the shortfin mako shark, with the common thresher being the most common and valuable. Typically, these sharks are captured incidentally in the drift gillnet and pelagic longline fisheries and both species are captured throughout the year, with peak landing for the common thresher shark occurring in September and peak landing for the shortfin mako shark occurring in November. The drift-net fishery is a limited entry fishery with seasonal closures and gear restrictions. 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. 2005b). The fishery is managed under the FMP administered by PFMC (Carretta et al. 2005b). Both species are landed throughout the Study Area, but most of the landings occur in the San Diego area. In 2006, the overall annual total landings of common thresher and shortfin mako sharks for the entire SOCAL/Pt.

Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) were 92.5 and 30.5 mt, respectively (**Figure 4-12**) (CDFG 2006; CDFG 2007). Of the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, common thresher and shortfin mako were primarily landed in the San Diego area (CDFG 2006; CDFG 2007). In 2006, the total common thresher landings within the SOCAL/Pt. Mugu Study Area were 5.7; 15.9; 22.3; and 48.6 mt, respectively (**Figure 4-12**) (CDFG 2006; CDFG 2007). Shortfin mako landings within the SOCAL/Pt. Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) were 3.9; 3.5; 6.7; and 16.5 mt, respectively (**Figure 4-12**) (CDFG 2006; CDFG 2007).

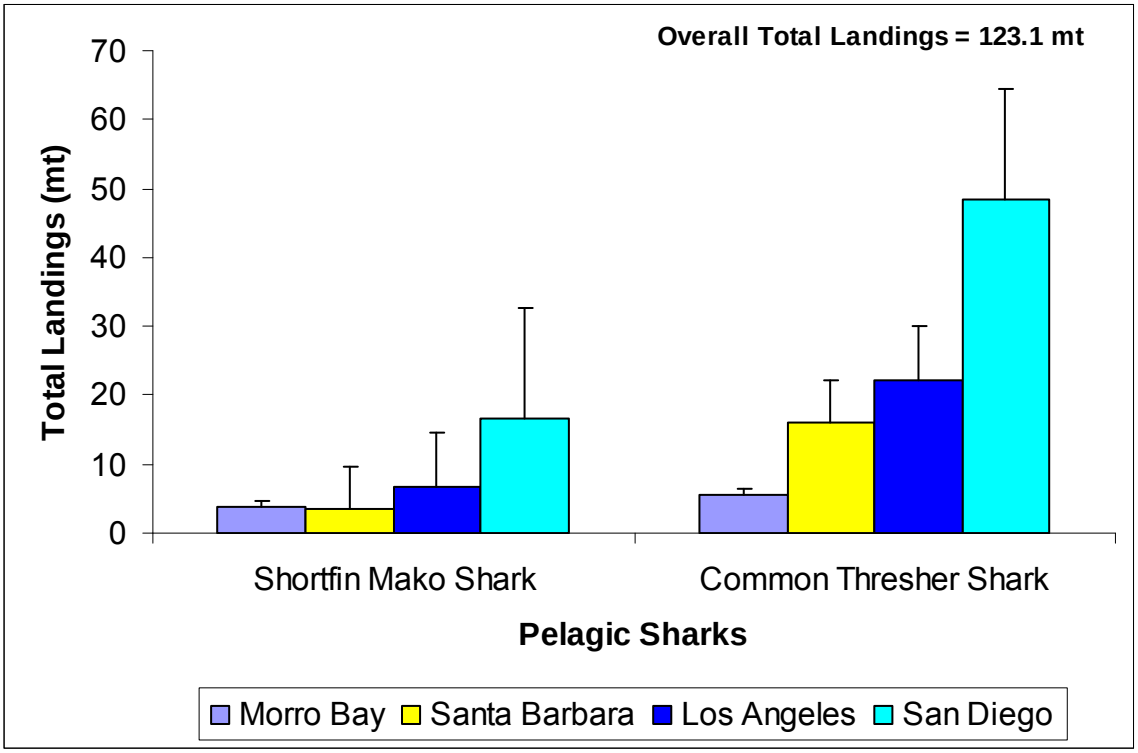

Figure 4-12. Total pelagic shark landings in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

4.5.2.6 Other Significant Finfish Fisheries

There are various other fish species that are economically important (>0.5 million dollars in ex-value) to the SOCAL/Pt. Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) which include the Pacific bonito, white seabass, and rockfish-shortspine thornyhead. In 2006, the overall annual total landings of white seabass and shortspine thornyhead for the entire SOCAL/Pt. Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) were 171.5 and 443.6 mt, respectively. Pacific bonito are taken commercially by trolling gear, gillnets, and hook-and-line gear, but the primary commercial fishing gear for bonito is the purse seine. The purse seine fleet consists of two general groups: the local "wetfish" vessels (veesels that store fish in fresh/wet condition) with fish load capacities of 30 to 100 tons, and the larger tuna seiners capable of carrying 150 to 500 tons (Leet et al. 2001). Vessels usually alternate between harvesting mackerel and sardines, to seasonally targeting Pacific bonito, squid, and northern bluefin tuna. Most of the wetfish fleet is based in San Pedro with effort primarily in the Santa Barbara and San Pedro channels (Leet et al. 2001). Off the California coast, commercial fishing for Pacific bonito occurs year round south of Point Conception with the largest catches in late summer and early fall. Similar to most commercial fisheries, annual Pacific bonito landings are impacted by the species availability, the availability of other desirable species, market demand, and price (Leet et al. 2001).

Likewise, the availability of Pacific bonito can vary considerably between seasons and years depending on migratory movements in relation to oceanic changes such as during El Niño and La Niña events. Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings in 2006 were 0.16; 265.4; 2,215.7; and 3.2 mt, respectively (**Figure 4-13**) (CDFG 2006; CDFG 2007).

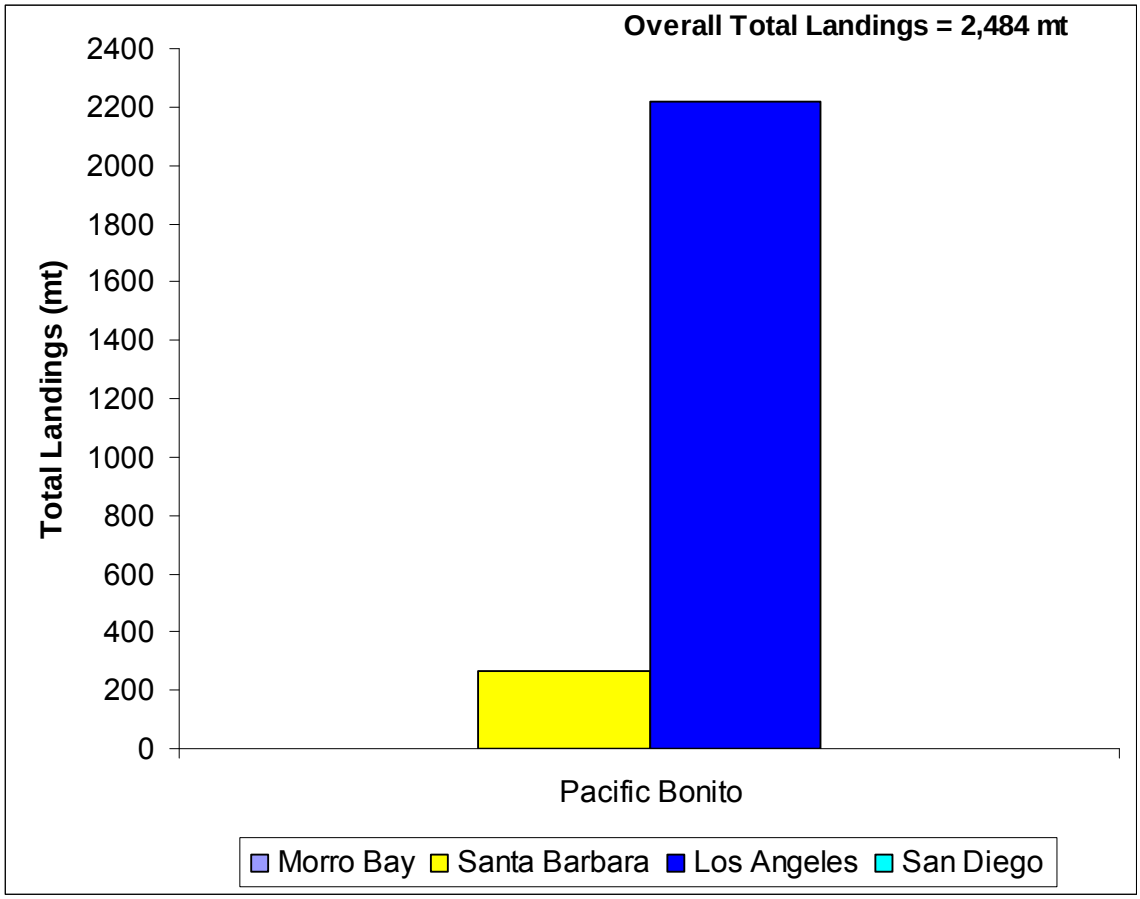

Figure 4-13. Total Pacific bonito landings in south-central and southern California in 2006. Source data: (CDFG 2006; CDFG 2007).

4.5.2.7 Invertebrate Fisheries

The invertebrate fisheries off the southern coast of California are comprised of various crustaceans (crabs, lobster, and prawns), echinoderms (sea cucumbers and sea urchins), and mollusks (whelk, sea hare) species. The primary fisheries are California spiny lobster, red sea urchin, spot prawn, rock crab, Dungeness crab, and warty sea cucumber. Although insignificant in terms of total landings and revenue, total landings in 2006, of Kellet's whelk (*Kelletia kelleti*) and sea hare (*Aplysia* spp.) for the entire SOCAL/Pt. Mugu Study Area (Morro Bay, Santa Barbara, Los Angeles, and San Diego) were 86.4 and 4.4 mt, respectively. Harvest methods include a variety of gears and methods: trawls, traps, modified hand rakes, ring nets (a circular frame holding a bag of web), bare hands, and SCUBA. Most species are only harvested by the commercial fishing industry, with the exception of the spiny lobster which supports a substantial recreational fishery. In general, invertebrate species within the SOCAL/Pt. Mugu Study Area comprise some of the U.S. west coast's most valuable marine resources (Kalvass 2001a, 2001b).

4.5.2.7.1 California spiny lobster

California spiny lobster are primarily found between Point Conception, California and Magdalena Bay, Baja California. Adult lobsters usually inhabit rocky areas from the intertidal zone to depths of 73 m or more (Leet et al. 2001). The commercial lobster fishery is conducted in shallow, rocky areas from Point Conception to the Mexican border and off the islands and banks (such as Cortes and Tanner banks) of southern California using traps (Leet et al. 2001). Traps are rectangular in form and are constructed of heavy wire mesh or plastic. Typically, fishermen set between 100 and 300 traps, but some fishermen set as many as 500 traps during the peak of the season (Leet et al. 2001). Traps are baited with whole or cut fish and weighted with bricks, cement, or steel. Traps are set in waters less than 30.5 m, which are clustered around rocky outcrops on the bottom. Usually traps are set close to shore at the beginning of the season and by the end of the season traps are further offshore in deep waters (31 to 94 m). The commercial and recreational harvest is primarily landed during the beginning of the fishing season with 43% of the catch occurring in October. The months of October through December comprise 82% of the total landings. The effort and catch drop off sharply in January through the middle of March (the season's end). In regards to economic value, California spiny lobster are usually the most valuable invertebrate species within the SOCAL/Pt. Mugu Study area. In 2006, spiny lobster ranked first in revenue and third in overall invertebrate landings (CDFG 2006; CDFG 2007). In 2006, total revenue was 8,058,066 dollars and total landings were 403 mt. Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings were 0.016.7; 130.1; 120.7; and 15.1 mt, respectively (**Figure 4-14**) (CDFG 2006; CDFG 2007).

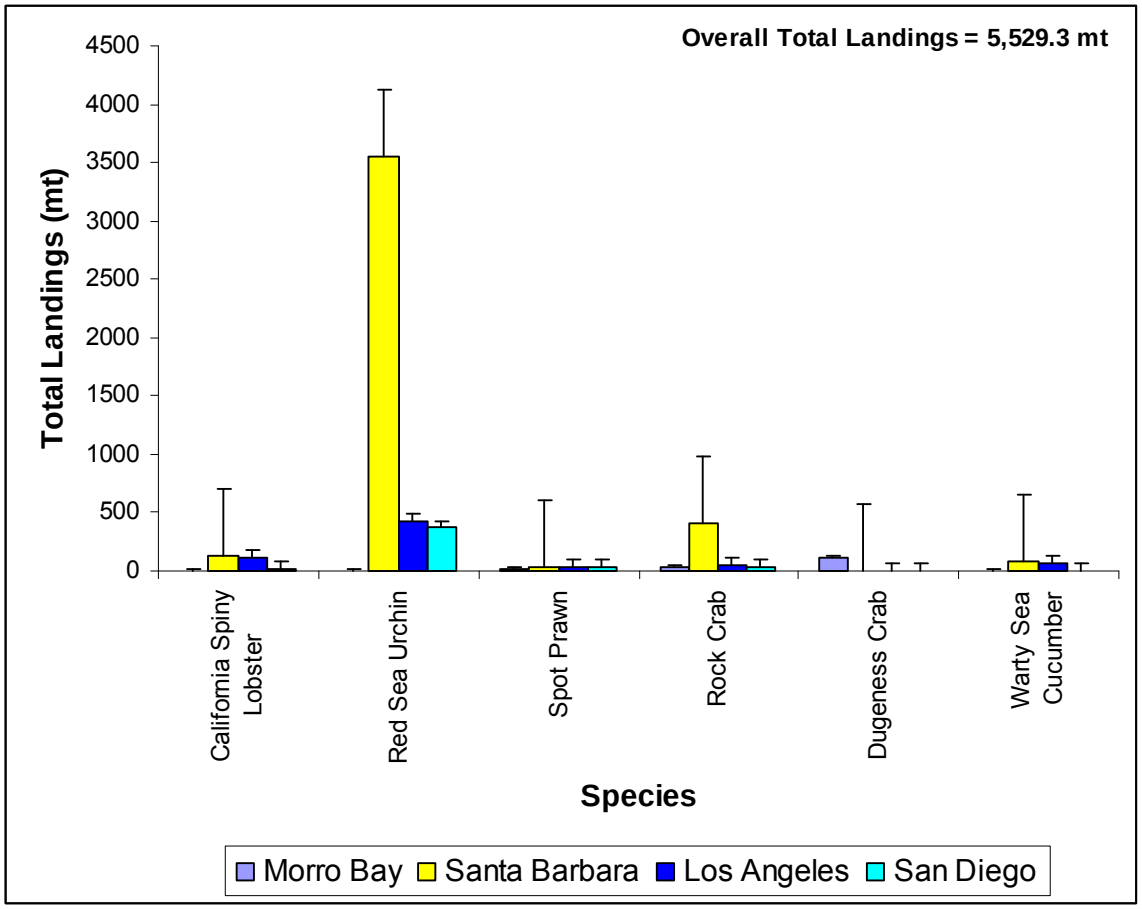

Figure 4-14. Total invertebrate landings in south-central and southern California in 2006. Vertical bars depict ± 1 SE. Source data: (CDFG 2006; CDFG 2007).

4.5.2.7.2 Red sea urchin

Red sea urchins are the most commonly harvested invertebrate species within the SOCAL/Pt. Mugu Study Area. The fishery was initiated in the 1970s 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). Catering to the Japanese export market, the commercial fishery for the red sea urchin has been one of California's most valuable fisheries for more than a decade. Roe, the gonads of both male and female urchin, are the object of the fishery (Leet et al. 2001). Sea urchins are collected by SCUBA divers in nearshore waters using "hooka" gear at depths from 1.5 to 30 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. It is possible for a diver to harvest up to a ton of sea urchins in one day. Divers are size-selective, and evaluate gonads for marketability (Leet et al. 2001). The price paid to fishermen for gonads is based on quality. Gonad value is based on quality which is determined on size, color, texture, and firmness. Prime California sea urchin landings are from southern California; mostly from the northern Channel Islands off Santa Barbara. During 1973 through 1977, 80 to 90% of red urchin landings were from these islands; however, since the late 1990s, fishing effort has shifted south to San Clemente Island, San Nicolas Island, and the San Diego area (Leet et al. 2001). The two El Niño events (1992 to 1994 and 1997 to 1998) and a weakening Japanese economy, have contributed to reduced fishing effort and catches. In 2006, red sea urchin ranked second in revenue and first in overall invertebrate landings. In 2006, total revenue was 5,141,054 dollars and total landings were 4,834 mt (CDFG 2006; CDFG 2007). Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings were 0.39; 3,554; 431; and 373 mt, respectively (**Figure 4-14**) (CDFG 2006; CDFG 2007)

4.5.2.7.3 Spot prawn

The spot prawn fishery was established about 68 yr ago in Monterey when prawns were caught incidentally in octopus traps (Leet et al. 2001). In the early 1970s, the fishery was small, with landings averaging around 0.907 mt annually until the early 1970s. The fishery dramatically grew during the 1980s reaching a peak of more than 170.3 mt in 1981. By 1985, a trap fishery for spot prawn was developed in the SCB which allowed fishermen to target spot prawn around all of the Channel Islands and along coastal submarine canyons in water depths between 1,125 and 2,025 m (Leet et al. 2001). With traps, a live fishery was established and landings increased from 2.9 mt in 1985 to over 112 mt in 1991. During the 1990s, the introduction of rock hopper gear, large rollers which are attached to the groundline of the trawl nets, allowed fishermen to target rocky deep water areas (Leet et al. 2001). Standard trawl gear used for targeting spot prawn is a single-rig shrimp trawl of a semi-balloon, or Gulf Shrimp Act, design. Other gears include a double-rig or paired shrimp trawls. The body of the trawl net is typically constructed of 6.4- to 7.6-cm mesh with a 91.4-cm square bycatch reduction device, and a minimum cod end mesh size of 3.8 cm (Leet et al. 2001). Most fishermen usually use a double cod end composed of 5.1 to 7.6 cm mesh. Standard roller gear varies in size from 20.3-cm disks to 71.1-cm tires. The spot prawn traps are constructed of either plastic oval-shaped or to the more popular rectangular wire traps. Plastic trap sizes are approximately 0.77 m by 0.46 m while wire traps are 0.93 m by 0.46 m by 0.31 m with two chambers (Leet et al. 2001). Usually, fishermen set between 25 to 50 traps that are attached to a single groundline (string) that have anchors and buoys at the terminal ends. In 2006, spot prawn ranked third in revenue and fifth in overall invertebrate landings (CDFG 2006; CDFG 2007). In 2006, total revenue was 3,497,309 dollars and total landings were 146 mt. Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings were 13.7, 32.9, 37.7, and 33.4 mt, respectively (**Figure 4-14**) (CDFG 2006; CDFG 2007).

4.5.2.7.4 Rock crab

The rock crab fishery was initially started in 1950 with a separate reporting category for commercial crab landings. Since then, landings have increased from 9.1 mt to over 907 mt in 1986 (Leet et al. 2001). Today, most rock crabs are landed live for retail sale by fresh fish markets with crabs often cooked and eaten on site and, depending on the tastes of the consumer, muscle tissue, as well as other organs (ovaries in particular) are consumed. There are several types of trap design. The most popular rock crab

trap is a single chamber; however, rectangular traps that are 0.05 m by 0.10 m or 0.05 m by 0.05 m welded wire mesh are also used (Leet et al. 2001). Some fishermen use several types of molded plastic traps that are collapsible. Rock crab traps are set in singles or in pairs when trap loss to vessel traffic is a concern. Fishermen set traps in depths ranging from 28 to 75 m on open sandy bottom or near rocky reef-type substrate. Usually, fishermen set around 200 or more traps, with a fraction hauled each day. Fishermen set traps, "soaked", for 48 to 96 hours prior to hauling (Leet et al. 2001). Commercial crab boats are variable in size ranging from skiffs to vessels of 12 m or more with most being small. In 2006, rock crab ranked fourth in revenue and second in overall invertebrate landings. In 2006, total revenue was 1,465,857 dollars and total landings were 528 mt (CDFG 2006; CDFG 2007). Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings were 27.5, 402.0, 524.8, and 40.7 mt, respectively (**Figure 4-14**) (CDFG 2006; CDFG 2007).

4.5.2.7.5 Dungeness crab

Overall, the dungeness crab fishery is one of the most valuable fisheries in California, being initially established in San Francisco around 1848 (Leet et al. 2001). Prior to the 1944 to 1945 fishing season, the fishery was centered in the San Francisco area, with average annual statewide landings at 1,179 mt. As the fishery expanded into the Eureka-Crescent City area near the end of WWII, landings significantly increased. Since 1945, annual California statewide landings have averaged about 4,398.9 mt, as a result of the replacement of hoop net with the crab traps in the early 1940s (Leet et al. 2001). Today, the fishery is prosecuted from Avila (San Luis Obispo County) to the California-Oregon border. The two main fishing areas are northern California and central California. Central California fishing areas include Avila-Morro Bay, Monterey, and San Francisco-Bodega Bay. The Morro Bay and Monterey fisheries are minor compared to the San Francisco-Bodega Bay fishery (Leet et al. 2001). The fishery begins in late fall and ends in early summer; however, most of the landings (70%) usually occur in November and December. Annual ex-vessel value of dungeness crab landings have ranged from less than 10 million to about 20 million dollars during the last decade (Leet et al. 2001). Approximately three-quarters of the catch is sold as whole crab (live, fresh-cooked, or frozen), and the remainder is processed to remove the meat and the meat is vacuum packed before being sold. Dungeness crab traps are constructed of steel and are 1 to 1.25 m in diameter and weighs 30 to 60 kg. Each trap is required to have two circular openings that measure 11 cm in diameter (Leet et al. 2001). Traps must also possess a destruction device that will release captured crabs should the trap become lost. The traps are heavily-weighted and rest on the sea floor; each trap is independently marked with a numbered buoy that floats on the surface. Traps are fished overnight or longer, depending on sea conditions. Most traps are fished at depths ranging from 19 to 75 m, but some traps are fished in shallower or deeper waters (Leet et al. 2001). In 2006, dungeness crab ranked fifth in revenue and sixth in overall invertebrate landings. With most of the landings occurring in 2006, the 2005 to 2006 fishing season was the third highest season since 1915 and the highest ex-vessel revenue on record (CalCOFI 2007). The total revenue with the SOCAL/Pt. Mugu Study Area was 623,837 dollars and total landings were 119.1 mt (CDFG 2006; CDFG 2007). Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings were 118.6, 0.46, 0.0, and 0.0 mt, respectively (**Figure 4-14**) (CDFG 2006; CDFG 2007).

4.5.2.7.6 Warty sea cucumber

The warty sea cucumber fishery was initially commercially landed at Los Angeles area ports in 1978 (Leet et al. 2001). Annual landings remained under 45.4 mt until 1982 when fishing effort shifted to Santa Barbara Island in the Channel Islands (Leet et al. 2001). In 1996, the combined trawl and dive sea cucumber landings reached a high of 153.9 mt with an ex-vessel value of 582,370 dollars. Trawl landings represented about 75% of the annual sea cucumber harvest during the initial years; however, beginning in 1997 sea cucumbers were mostly landed by divers which accounted for more than 80% landings (Leet et al. 2001). Today, sea cucumbers are mostly landed by trawl gear in southern California, but are targeted by divers in northern California. Most of the warty sea cucumber product is shipped overseas to Hong Kong, Taiwan, China, and Korea, but domestic Chinese markets also purchase a portion of the sea cucumber catch (Leet et al. 2001). Warty sea cucumbers are mostly boiled, dried, and salted before

export, while some are sold frozen, pickled, or as live products. In 2006, warty sea cucumber ranked sixth in revenue and fourth in overall invertebrate landings (CDFG 2006; CDFG 2007)(Leet et al. 2001). In 2006, total revenue was 409,378 dollars and total landings were 146.7 mt (CDFG 2006; CDFG 2007). Within the four primary commercial fishing areas (Morro Bay, Santa Barbara, Los Angeles, and San Diego) found within the SOCAL/Pt. Mugu Study Area, the total landings were 0.0, 77.7, 67.5, and 0.0 mt, respectively (**Figure 4-14**) (CDFG 2006; CDFG 2007).

4.5.2.7.7 Kelp fishery

Commercial harvest of giant kelp in California began in 1911 and although the harvest levels have significantly decreased, kelp is still harvested today (CDFG 2004b; **Figure 4-15**). Volume and area of kelp harvest is currently regulated by the CDFG. World-wide, kelp is harvested for algin, which is used as a binder, emulsifier, and molding material in a broad range of products, and as a food source in abalone aquaculture operations (CDFG 2004c). Historically, about 100,000 mt of giant kelp were harvested per year in California, primarily by one San Diego-based company. Six other leases were harvested for algin and for abalone feed, and another operator leased one bed for research purposes. Typically, kelp was primarily harvested within a five mile-long area between Point Sur and Pfeiffer Point outside the MBNMS (CDFG 2004c) and at Imperial Beach near the U.S./Mexico border. In the past, 97% of the California harvest was from the south-central California area (outside the MBNMS). During the 1930s through the 1970s, kelp harvest increased from 9,070 to 154,190 mt (**Figure 4-16**); however, an El Niño event in the early 1980s destroyed kelp beds, and, therefore, harvest levels remained significantly lower than those of earlier years. In the early 1990s, the kelp harvest was valued 3 and 4 million dollars and in later years supported a more valuable industry (CDFG 2004c). In 2001, the kelp harvesting industry was valued at more than 30 million dollars annually and it was one of the most valuable commercial fisheries in California (CDFG 2004c). Today, U.S. commercial harvest of kelp beds has significantly decreased due to world-wide global market changes and the fact that algin can now be artificially produced (Toropova, C., The Nature Conservancy-Global Marine Team, pers. comm., 7 July 2008). In 2005 and 2006 the total California kelp landings were 0.53 and 0.22 mt, respectively (CDFG 2006; CDFG 2007). In 2005, California kelp landings occurred mostly (94%) in January and in 2006 during May and August (68%). All the landings occurred in Los Angeles County and the estimated value during 2005 and 2006 was 740 dollars and 2,270 dollars, respectively (CDFG 2006; CDFG 2007). Although commercial kelp leases are still available in southern California, kelp is primarily only harvested in California as feed for the abalone aquaculture fishery. Today, kelp is mostly commercially harvested outside of the U.S. (Toropova, C., The Nature Conservancy-Global Marine Team, pers. comm., 7 July 2008).

4.5.3 Commercial Ports

The state of California has nine commercial fishing ports (**Figure 4-17**). Five of the nine commercial fishing ports are considered major with two (Eureka and Cresent City) located in northern California, one (Moss Landing) located in central California, and two (Ventura and Los Angeles) located in southern California (NMFS 2007b). During 2005 and 2006, Los Angles was the most valuable commercial fishing port in California in terms of landings and value and Hueneme-Oxnard-Ventura commercial fishing port was the third most valuable commercial fishing port in California in terms of landings (NMFS 2007b). In 2006, the port of Los Angeles ranked eighth in the U.S. in total commercial fishing landings and twenty-eighth in total value (NMFS 2007b). In 2006, the port of Hueneme-Oxnard-Ventura ranked twenty-second in total commercial fishing landings, but did not rank in the top 50 U.S. fishing ports in terms of value (NMFS 2007b).

4.5.4 Recreational Fisheries

Along with the commercial fishing industry, recreational fishing in southern California is a large significant segment of the fisheries. During 2005 and 2006, California recreational anglers landed 4,603 and 4,984 mt of fish, respectively (NMFS 2007b). The state of California ranked sixth in the nation for the number of angler trips in 2005 and fourth in 2006 (NMFS 2007b). In fact, the California recreational fishing community has a more significant impact on some of the state's marine resources than the commercial fishing industry. Schroeder and Love (2002) found that for 16 of the 17 popular nearshore fish species,

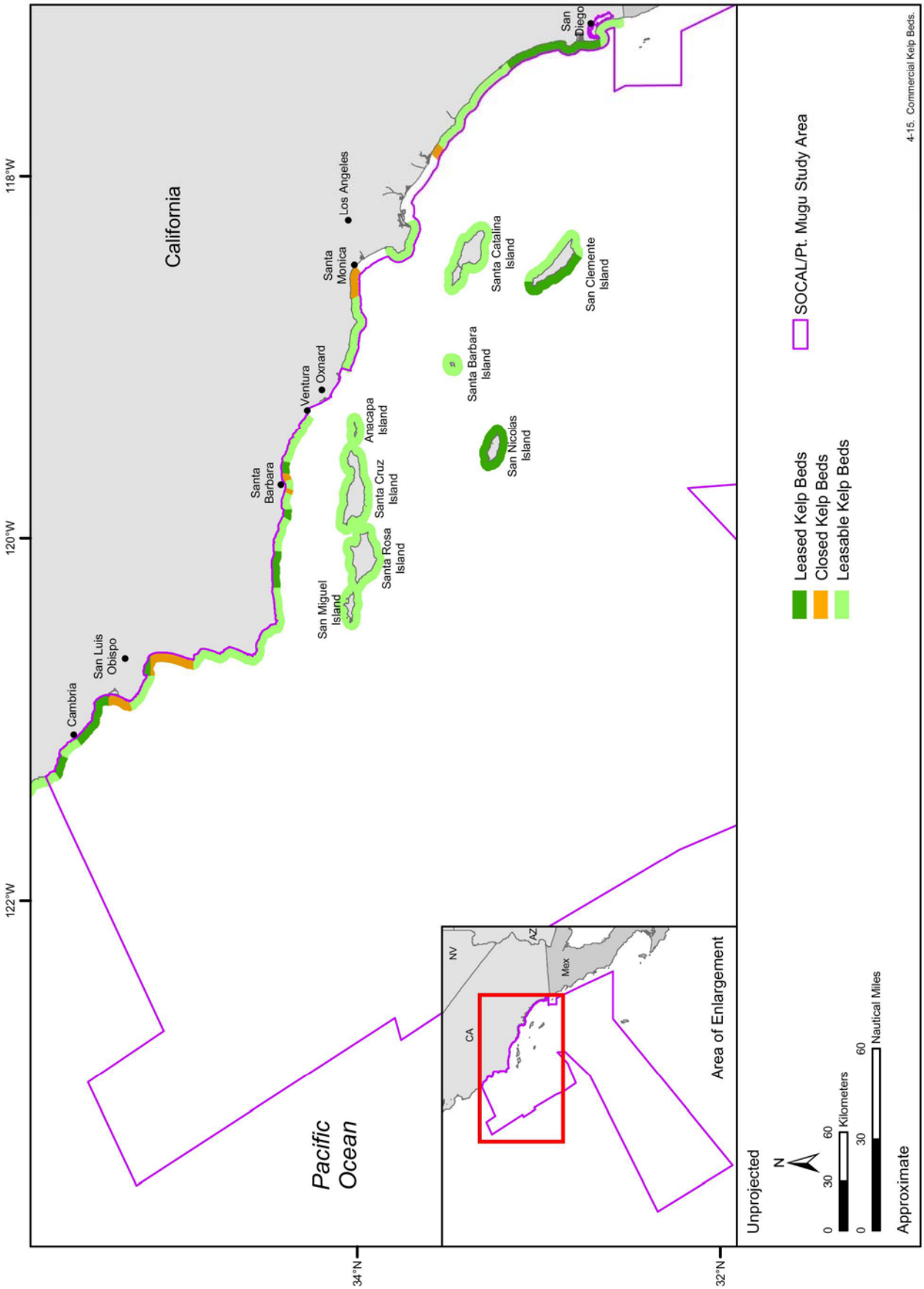

Figure 4-15. Locations of leasable kelp beds in the SOCAL/Pt. Mugu Study Area and vicinity. Leasable kelp beds denote areas of potential kelp harvest and not actual kelp bed locations. Source data: (CDFG 2004a).

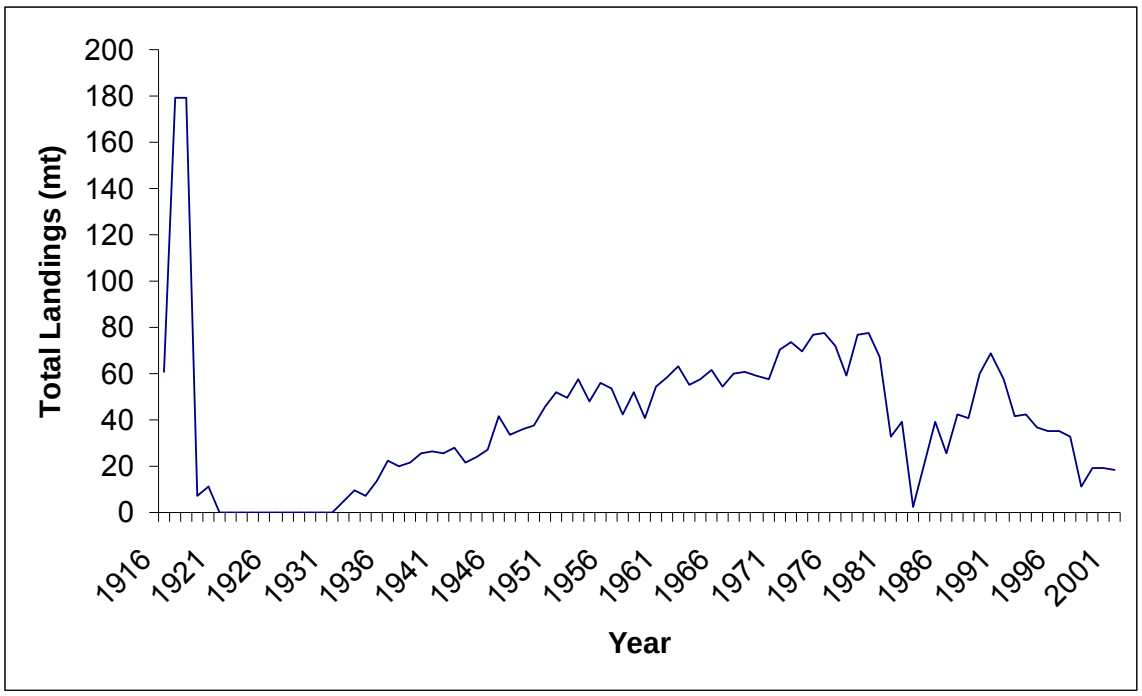

Figure 4-16. Historical California kelp landings during 1916 through 2001. Source data: (CDFG 2004c).

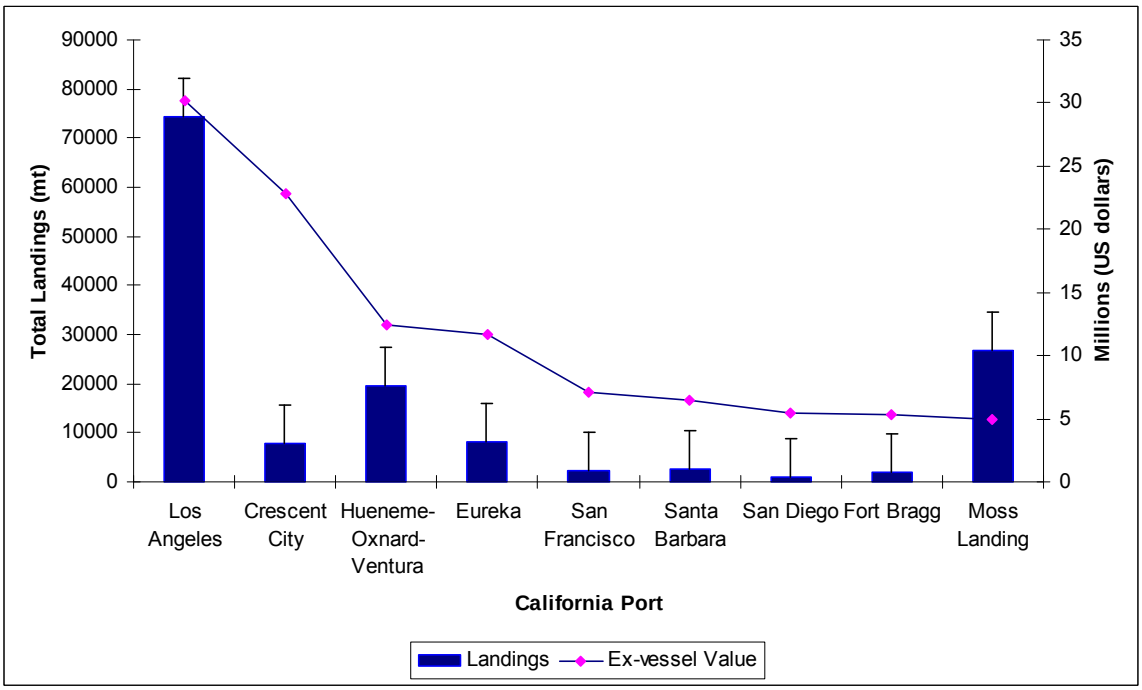

Figure 4-17. California commercial fishing ports. Vertical bars depict ± 1 SE. Source data: (NMFS 2007b).

recreational angling was the primary source of fishing mortality. Also, the study noted that the lowest rockfish density (423 fish per hectare [fish/ha]) occurred in areas only open to recreational fishing. Similar to most areas, recreational fishing in southern California is a popular hobby where anglers do not fish to generate revenue, but rather fish for pleasure and/or to provide food for personal consumption (Thomson 2001). Advanced fishing technologies (e.g. global positioning system [GPS], fish finders, satellite, and internet) and gear types have made finding and catching fish easier in recent decades. Recreational fisherman may use a variety of gears, but hook-and-line gear (angling) with artificial lures and live or dead bait is the most common type. Typical fish and invertebrate species targeted by recreational anglers within the Study Area are described in the following paragraphs.

The state of California regulates and manages recreational species by geographical regions. There are three recreational management regions in California: Northern California Region (42°00'N Oregon-California Border to 40°10'N [near Cape Mendocino in Humboldt County, which includes all of Del Norte County and most of Humboldt County]); Central California Region (North-Central Management Area: from 40°10'N to 37°11'N [Pigeon Point], which includes a portion of Humboldt County and most of Mendocino County); Monterey South-Central Management Area: Pigeon Point to 36°00'N (near Lopez Point), which includes a portion of San Mateo County, all of Santa Cruz County, and a portion of Monterey County; and Morro Bay South-Central Management Area: Lopez Point to 34°27'N (Point Conception) which includes a portion of Monterey County, all of San Luis Obispo County, and a portion of Santa Barbara County), and Southern California Region (Point Conception to the Mexico Border, which includes a portion of Santa Barbara County, and all of Ventura, Los Angeles, Orange and San Diego counties) (CDFG 2008b).

The SOCAL/Pt. Mugu Study Area is contained within the Morro Bay South-Central Management Area of the Central California Region and all of the Southern California Region recreational fishery management areas. Depending on species and fishing method, each region has its own specific recreational fishing regulations. For evaluation purposes, fishing method is defined as shore-based, divers, and boat-based. Shore-based anglers are fishermen that fish from beaches, banks, piers, jetties, breakwaters, docks, and other man-made objects connected to the shore. Divers are spear fishermen entering the water either from the shore or from a boat or other floating object. Boat-based anglers are fishermen that fish from boats or vessels of any size or any other type of floating object, including kayaks and float tubes. Along the Pacific coast, five species dominate recreational landings with the barred surfperch being the primary species caught (landed or released) (**Figure 4-18**) (CDFG 2008a).

Within the SOCAL/Pt. Mugu Study Area, the following species and groups of fish are caught: rockfish, cabezon, lingcod, California sheepshead (*Semicossyphus pulcher*), ocean whitefish (*Caulolatilus princes*), California scorpionfish, kelp (*Hexagrammos decagrammus*) and rock (*H. lagocephalus*) greenlings, Pacific sanddab, California halibut, sanddabs, yellowtail, tunas, kelp bass, barred and spotted seabass, California corbina, striped bass (*Morone saxatilis*), monkeyface prickleback or eel (*Cebidichthys marjorius*) California barracuda, leopard shark, ocean salmon, white seabass, surfperch (shiner and redtail, *Amphistichus rhodoterus*, surfperches), and California grunion (*Leuresthes tenuis*) (NMFS 2007b). Some species (giant black seabass and abalone) are closed year-round to recreational fisheries and others (spiny lobster and dungeness crab) have specific seasons. During 2000 through 2003, the primary groups of recreational species landed in southern California were wrasses, sea basses, and tunas/mackerels. In 2002, recreational landings ranged from 173.8 mt for sharks/skates/rays to 9,583.5 mt for wrasses (NMFS 2007b; **Figure 4-19**).

In January 2004, the California Recreational Fisheries Survey (CRFS) was established to provide better, more improved catch and effort estimates than the NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) for marine recreational finfish fisheries (CDFG 2008a). The CRFS is a collaborative effort between the CDFG and the Pacific States Marine Fisheries Commission (PSMFC). The program is designed to evaluate fisheries information based on geographical defined districts. There are six total districts in California and, of which, three districts (South District, Channel District, and Central District) are located within the SOCAL/Pt. Mugu Study Area (CDFG 2008a).

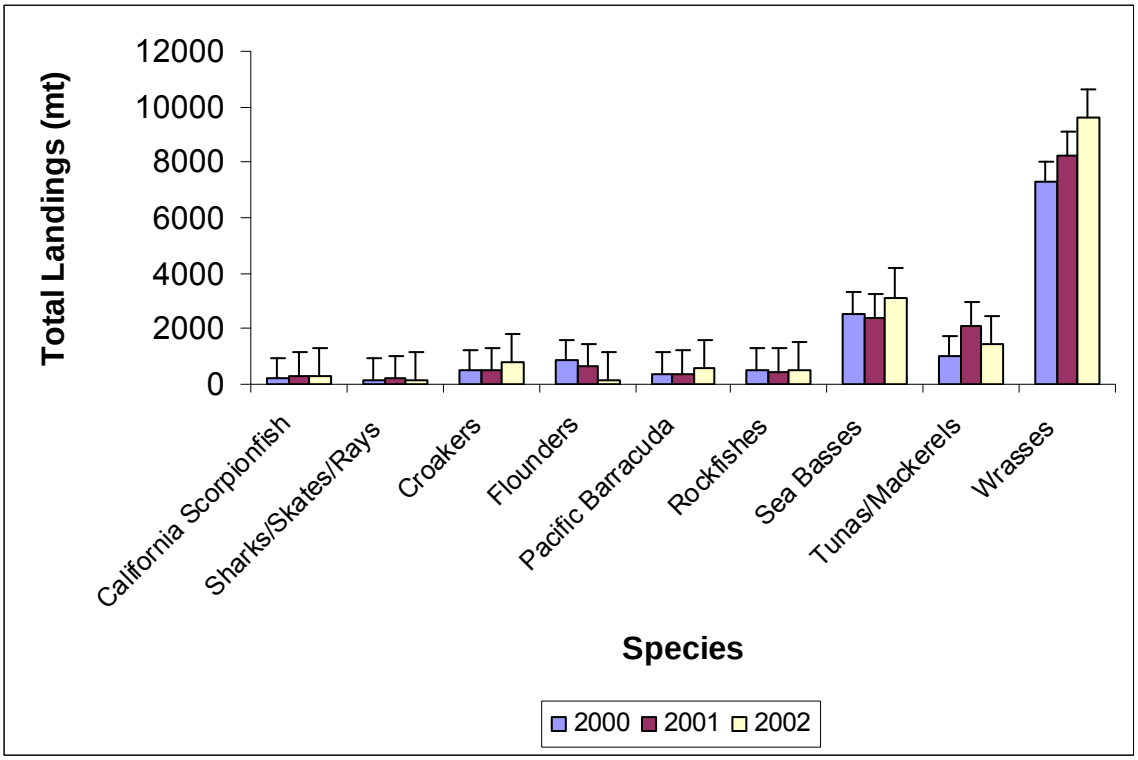

Figure 4-18. Total number of major fish caught on the Pacific coast by recreational anglers. Source data: (NMFS 2007b).

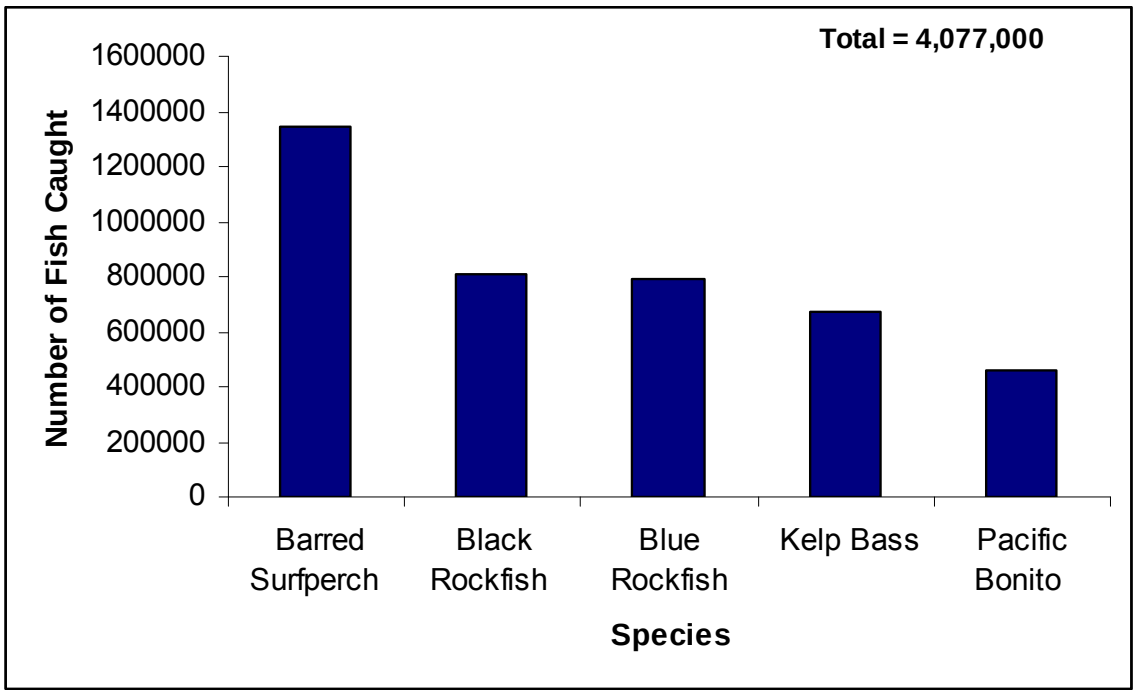

Figure 4-19. Recreational landings in southern California during 2000 through 2002. Vertical bars depict ± 1 SE. Source data: (NMFS 2007b).

The South District consists of Los Angeles, Orange, and San Diego counties. This highly urbanized district has many harbor and marina facilities for boaters, and also has dozens of piers and other man-made structures that are heavily used by shore anglers. The coastal waters within this area are influenced by sub-tropical currents from the south and provide habitat to various warm-water pelagic species, such as tunas, yellowtail, and barracuda. Fishermen fishing in the nearshore coastal waters and the Southern Channel Islands typically harvest kelp and sand basses, white seabass, and California halibut (CDFG 2008a).

The Channel District consists of Santa Barbara and Ventura counties. This district is in an ecological transition zone that harbors both warm- and cold-water fish species. Warm water pelagic and coastal pelagic species such as yellowtail, barracuda, Pacific bonito, white seabass, and kelp bass are seasonally available, while cold-water species, including Chinook salmon and rockfishes are also targeted at various periods. Recreational fishing effort in the Santa Barbara Channel and the Northern Channel Islands is year-around (CDFG 2008a).

The Central District consists of Santa Cruz, Monterey, and San Luis Obispo counties. The Central District has five major ports for private boats and commercial passenger fishing vessels (CPFVs), and miles of open coast that are utilized by surf anglers and rocky bank fishermen for catching surfperch, nearshore rockfish, and cabezon. Boaters fish for Chinook salmon during certain seasons and target albacore and other pelagics in offshore waters. Rockfish, cabezon, and lingcod are also targeted by boat anglers throughout the district. There are large sections of the coast in southern Monterey and San Luis Obispo counties that remain inaccessible to shore anglers, due to their remoteness or lack of public access (CDFG 2008a).

During 2004 through 2007, the primary recreational species landed in each of the three districts (South District, Channel District, and Central District) located within the SOCAL/Pt. Mugu Study Area were Pacific mackerel, barred surfperch, and blue rockfish, respectively (**Table 4-6**). The overall recreational species metric tons landed within the SOCAL/Pt. Mugu Study Area were Pacific mackerel (1,750.0 mt), Pacific sardine (760.7 mt), barred surfperch (597.5 mt), and barred sandbass (566.0 mt) (CDFG 2008a).

Table 4-6. The numbers of fish landed by recreational anglers in the SOCAL/Pt. Mugu Study Area during 2004 to 2007 (CDFG 2008a).

Species Name	District Names			
	South District	Channel District	Central District	Total
Pacific Mackerel	3,331,359.4	356,513.9	171,056.8	**3,858,930.1**
Pacific Sardine	1,291,470.7	328,742.8	57,202.9	**1,677,416.40**
Barred Sandbass	1,153,476.0	95,045.5	113.2	**1,248,634.70**
Pacific Bonito	900,931.5	13,834.6	913.7	**915,679.80**
Barred Surfperch	413,856.1	457,831.1	445,764.8	**1,317,452.00**
Vermilion Rockfish	165,819.2	201,777.8	275,262.7	**642,859.70**
Blue Rockfish	1794.1	95,486.6	662,919.5	**760,200.20**
Northern Anchovy	276,012.9	14,145.4	444,847.3	**735,005.60**
Jacksmelt	496,838.6	114,572.0	400,551.9	**1,011,962.50**

4.5.4.1 Fishing Areas

The California coast can be divided into two distinctly different zones for purpose of fishing: north and south with the dividing line for fishermen being the Point Conception/Point Arguello “corner” (Spira 2000). In the northern zone above Point Conception, the rugged coastline runs mostly north to south where the inconsistent nature of the sea-state (e.g., relatively cold water due to coastal upwellings, strong currents, and unexpected waves of great size) and weather conditions (e.g., prevailing northwest winds, early

morning/late evening fog, southerly storms, rainy winters) can change rapidly making some areas extremely dangerous to salt water angler fishing boat trips (Squire and Smith 1977). In the southern zone below Point Conception, the coast runs mostly southeast to northwest where the weather is generally mild and more conducive to year-round marine sport fishing (Squire and Smith 1977; Spira 2000).

Popular fishing sites commonly visited by recreational anglers within the SOCAL/Pt. Mugu Study Area are known as hot spots. These hot spots are more abundant in the southern portion of the Pt. Mugu OPAREA and in the SOCAL OPAREA (**Figure 4-20**) where excellent facilities are available for fishing in the various bays (i.e., San Diego), along the beach shore (surf zone), from municipal piers, and over the numerous offshore fishing grounds (islands, banks, and fathom spots) from modern sport fishing vessels (Squire and Smith 1977). Hot spots usually involve areas with some structural features, such as kelp beds, shoals, rocks, sand and mud flats, and reefs (artificial and natural). Areas with greater vertical profiles, as found near bank ledges and canyons, help fishes regulate their temperatures by allowing them to quickly reach deep or shallow bottom habitats as needed, while maintaining close proximity to bottom habitat. Natural and man-made features that extend over water or out into waters are generally well-fished sites, such as municipal piers, docks, rock and concrete jetties, and beach groins. Hydrographic features (e.g., California current and countercurrent, Southern California eddy) also concentrate fish and subsequently anglers often target these currents and waters rich with nutrients (Squire and Smith 1977; Spira 2000, 2004).

Within the SOCAL/Pt. Mugu Study Area, the majority of fishing hot spots range (257: U.S. – 241 and Mexico – 16) from below the U.S./Mexico border to Point Conception, California (**Figure 4-20**). Within the San Diego and Mission Bay region, the major offshore sport fishing grounds include the following sites in Mexican waters (e.g., Airplane Bank, 213-Fathom Spot, 1010 Trench, and Box Canyon) and the following outer bank locations in U.S. waters (e.g., Cortez and Tanners banks, 60-Mile Bank, Boomerang, The Pistol, Blockouse Reef, and Dumping Ground). Inshore marine angling can be found in San Diego Harbor (south bay: Coronado Peninsula and north bay: Shelter and Harbor islands shoreline and The South Jetty) and offshore at the rock cod bank (Nine Mile) off Point Loma and the Imperial Flats south of San Diego. North of the San Diego region from La Jolla to Point Mugu, offshore angling is concentrated in the kelp beds and areas along the offshore islands (Santa Catalina, San Clemente, Santa Barbara, and San Nicolas), various banks (209-Fathom Spot, 14 Mile [Lasuen Knoll], and Avalon), Horseshoe Kelp Bed ("Shoe"), deepwater canyons (Redondo and Santa Monica), and artificial reefs/shipwrecks (International Reef). From Point Mugu to Point Conception, the principal offshore fishing areas include various sites (e.g., reefs, shoals, kelp beds, seamounts, and flats), areas around the Santa Barbara Channel Islands, Short Bank, and deepsea canyons (Mugu, Hueneme, and Tecolote). Inshore fishing areas consist of the extensive lush kelp beds (Point Goleta), reefs (Camby, Carpentaria, and Naples), flats (Ventura, Hueneme, and Santa Barbara), artificial reefs, fishing piers, and beaches

The northern portion of the Pt. Mugu OPAREA is within the northern zone which extends from Point Conception to Point Sierra Nevada, California. Offshore fishing sites include Davidson Seamount, Point Arguello Canyon, general salmon trolling area between Point Sal to Estero Bay, and bottomfish areas with nearshore areas restricted to kelp beds, sandy beaches, rocky shore areas, piers, docks, and bank fishing (Squire and Smith 1977; Spira 2000).

Of the 270 popular fishing sites in the SOCAL/Pt. Mugu Study Area, approximately 95% of these 254 locations are located in the area south of Point Conception into Mexican waters with only 5% (16 sites) occurring above Point Conception (**Figure 4-20**). The various offshore islands account for 30% of the recreational fishing locations whereas the numerous outer banks account for 59% of the sport fishing sites. Yellowtail, white seabass, calico bass (*Paralabrax clathratus*), barracuda, and rockfish are commonly caught around the offshore islands with the highly migratory species (tuna, striped marlin, dorado, and mako sharks) being fished on the outer bank locations (Fathom Spots, seamounts, etc.). Inshore angling locations would be fished for California halibut, barred sand bass, and sculpins on the sand and mud flats and corbina, surfperches, yellowfin croaker (*Umbrina roncador*), bat ray (*Myliobatis californica*), and queenfish in the surf along the beaches and off the municipal piers (Smith and Sandwell 1997; Bixby 2001; Waterproof Charts Inc. 2003; Fishing Network 2007; NGA 2007; Spira 2007; The Marlin Club 2007).

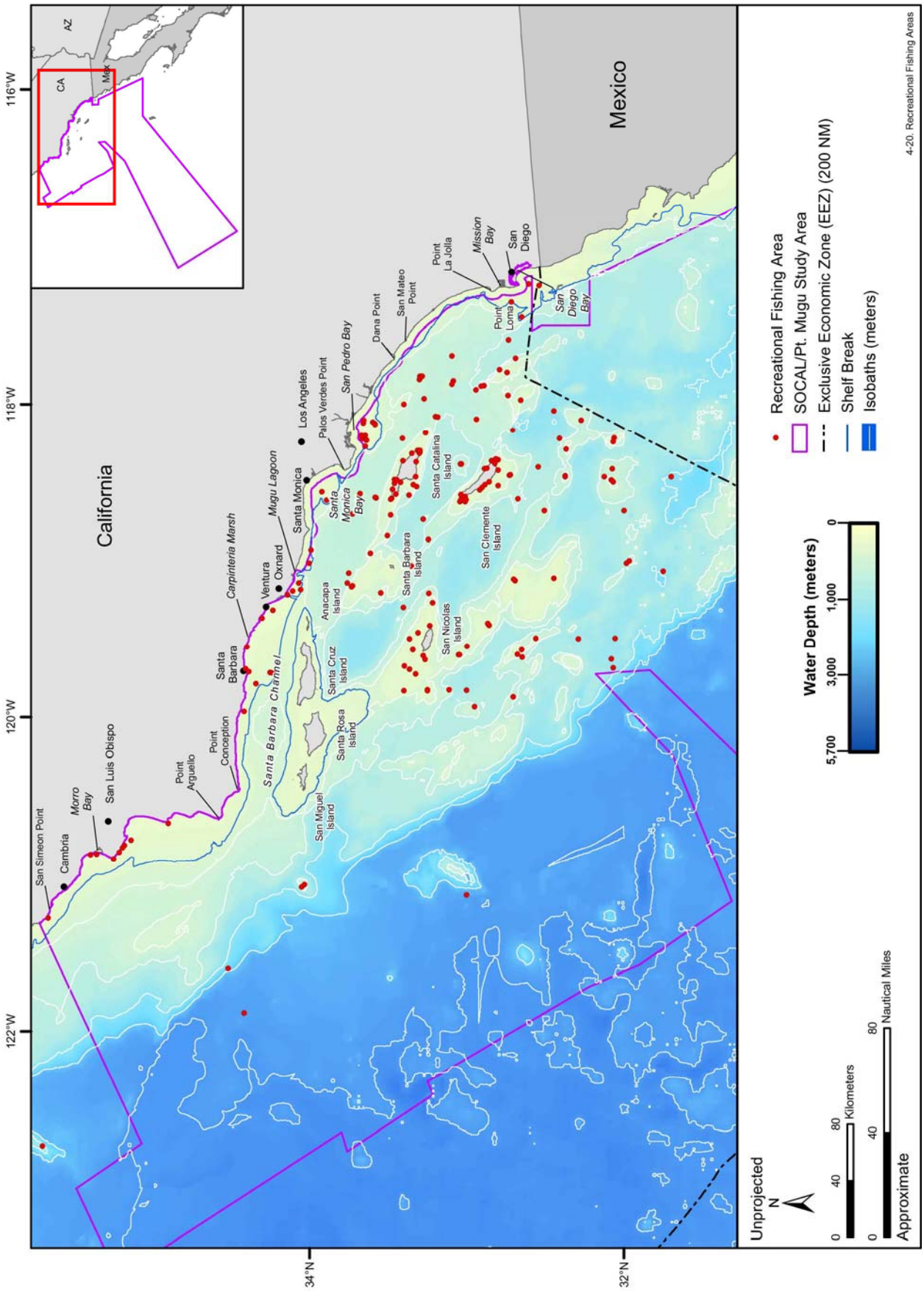

Figure 4-20. Recreational fishing areas in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Smith and Sandwell (1997), Bixby (2001), Waterproof Charts, Inc. (2003), Fishing Network (2007), NGA (2007), Spira (2007), and The Marlin Club (2007).

4.5.4.2 Recreational Fishing Activity

To estimate recreational fishery effort and catch, the CRFS evaluates information collected based on fishing area, which is defined as distance from shore (inshore and offshore). The data is further evaluated by four fishing mode types, which are defined as the type of place or boat type where the fishing effort occurred (beaches and banks, man-made structures [e.g., piers, CPFVs, and private or rental boats]).[9] Inshore recreational fishing occurs in nearshore waters (<3 nm) along beaches and marshes using small vessels, skiffs, kayaks, or canoes. Inshore fishing can occur from man-made structures (jetties and piers), beaches, and banks. Offshore fishing usually involves larger vessels targeting species in federal waters (>3 nm) and can include charter, party boats, or private vessels (CDFG (California Department of Fish and Game) 2008a). Both charter and party boats charge a rate to take clients fishing. Usually, charter boats are smaller vessels and take a limited number of anglers for a fixed daily rate, while party boats or head boats are larger vessels and take more anglers for a per person daily rate (Abbas 1978). Almost all recreational fishermen usually use rod-and-reel gear, which is sometimes called hook-and-line (Spira 2000).

During 2004 through 2007, the average proportion of total recreational fishing effort based on the number of saltwater fishing angler trips by fishing area (inshore and offshore) was 93.4% in California, 3.5% in Washington, and 3.2% in Oregon. In California, the number of salt water fishing trips during 2004 through 2007 ranged from 4,448,800 trips in 2005 to 5,642,800 trips in 2006 (CDFG 2008a).

Within the SOCAL/Pt. Mugu Study Area, the number of recreational angling trips during 2004 through 2007 varied by survey district, month, and year. For each year (2004 to 2007), most of the angling trips were initiated from the South District than from either the Channel or Central districts. In the South District, the number of angler trips ranged from 2.4 million in 2005 to approximately 3.2 million in 2006 (CDFG 2008a). In the Channel District, the number of angler trips ranged from 393,000 in 2004 to 597,000 in 2006. In the Central District, the number of angler trips ranged from 407,000 in 2005 to 621,000 in 2006 (CDFG 2008a). The total number of angling trips for the three areas (South District, Channel District, and Central District) combined during 2004 through 2007 was 14.8 million. The overall number of trips for the Channel and Central Districts were lowest during the winter months and highest during the summer months; however the temporal distribution of the total number of trips in the South District was relatively steady and did not vary significantly throughout the year (**Figure 4-21**). Of the total number of trips (14.8 million), 82% or approximately 12.1 million were classified as offshore trips, and 18% or 2.7 million were inshore trips. The temporal distribution of fishing effort in offshore areas varied by month for each of the districts with the lowest fishing effort occurring during the fall and winter months (October to March) and the highest fishing effort occurring during the spring and summer months (April to September) (**Figure 4-22**). Evaluating the inshore trips indicated that the number of angler trips in the South District mimicked the seasonal offshore fishing effort pattern; however, the Channel and Central Districts did not show any evident pattern (**Figure 4-23**) (CDFG 2008a).

Of the total number of trips, the South District represented 73% or 11 million trips, Channel District 13% or 1971 trips, and Central District 14% or 2,088 trips (**Figure 4-24**). Fishing effort was classified into four categories (man-made, beach/bank, party/charter vessel, and private/rental vessel) depending on fishing mode (CDFG 2008a). Overall, man-made (pier and jetty) mode represented 61% or 9,200 trips and the majority of the fishing effort. Beach/bank, private/rental vessel, and party/charter vessel represented 21%, 16%, and 10% of the fishing effort, respectively (**Figure 4-25**) (CDFG 2008a).

4.5.4.3 Fish Species

The SOCAL/Pt. Mugu Study Area is a productive area for recreational fishing. Anglers catch a diversity of species ranging from large pelagics (tunas and mackerels) to bottom fish (flatfishes). Overall, the primary groups of fish landed by recreational fishermen during 2004 through 2007 were tuna and mackerels, sea basses, and rockfishes (CDFG 2008a). Within the districts located in the SOCAL/Pt. Mugu Study Area, anglers fishing from the South District reported the greatest number of fish landed at 8.2 million, while the least number of fish landed were from the Channel District at 2.1 million. In the South District, tuna and

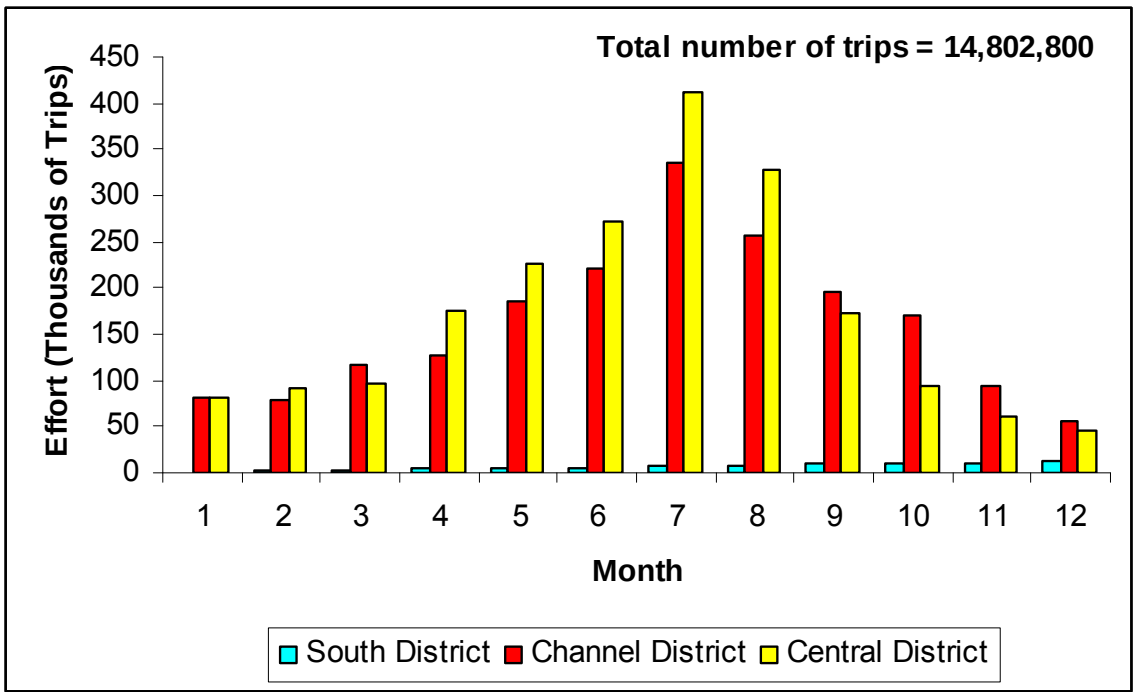

Figure 4-21. Number of monthly recreational saltwater fishing trips in south-central and southern California during 2004 through 2007. Source data: (NMFS 2007a; CDFG 2008a).

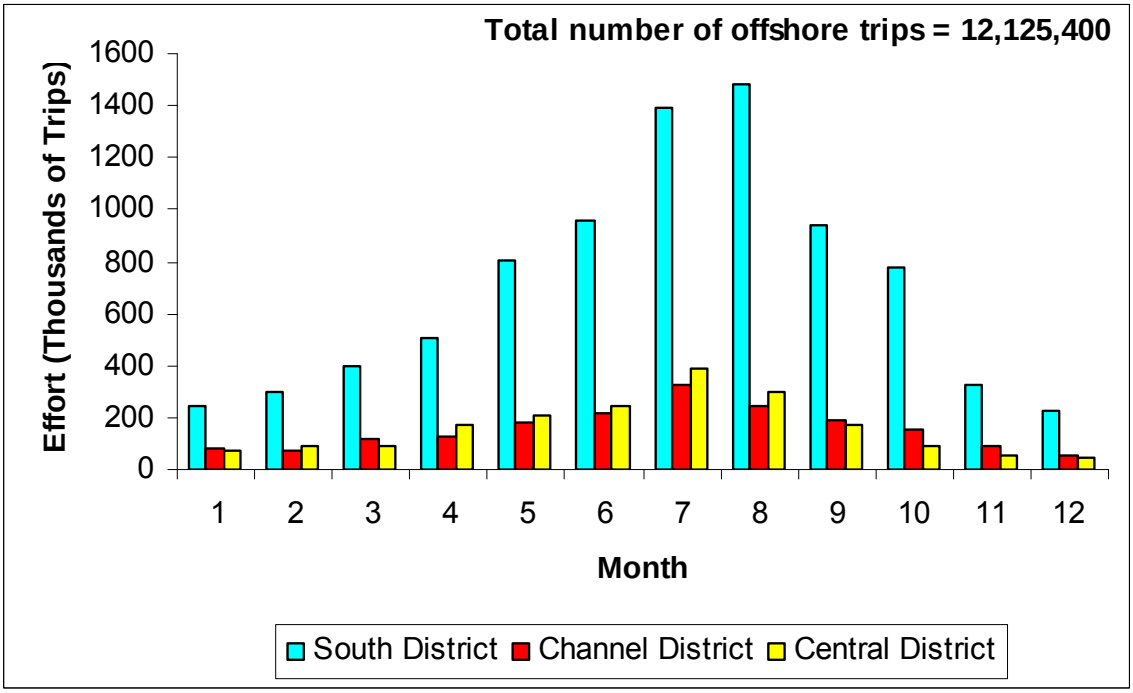

Figure 4-22. Number of monthly offshore recreational saltwater fishing trips in south-central and southern California during 2004 through 2007. Source data: (NMFS 2007a; CDFG 2008a).

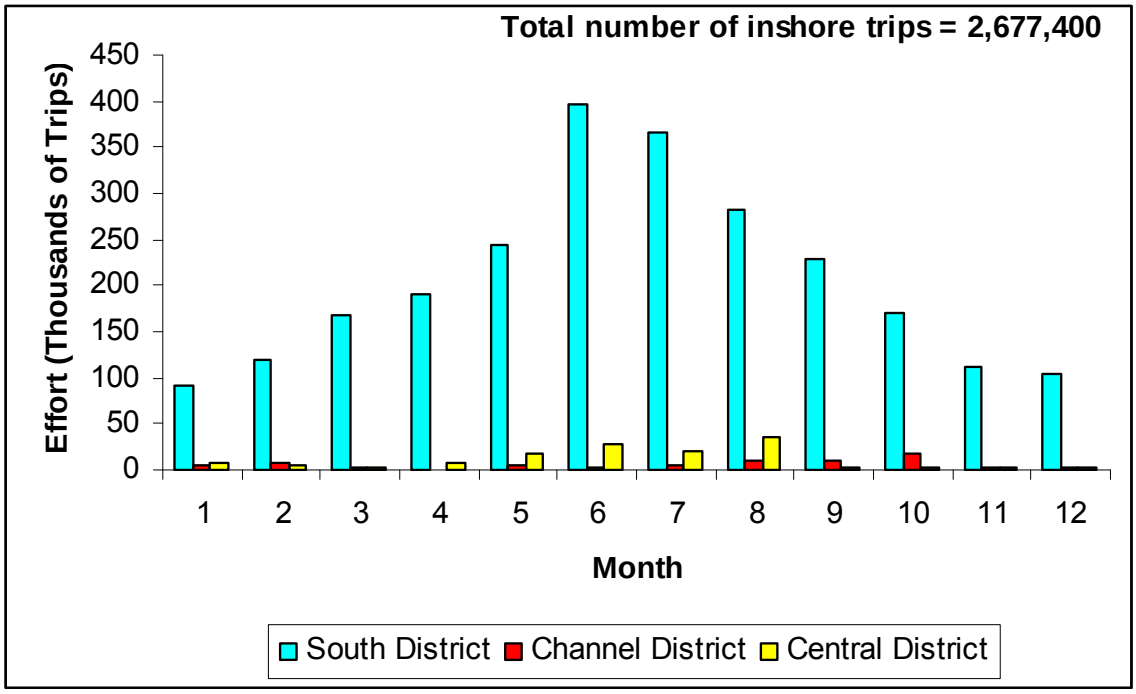

Figure 4-23. Number of monthly inshore recreational saltwater fishing trips in south-central and southern California during 2004 through 2007. Source data: (NMFS 2007a; CDFG 2008a).

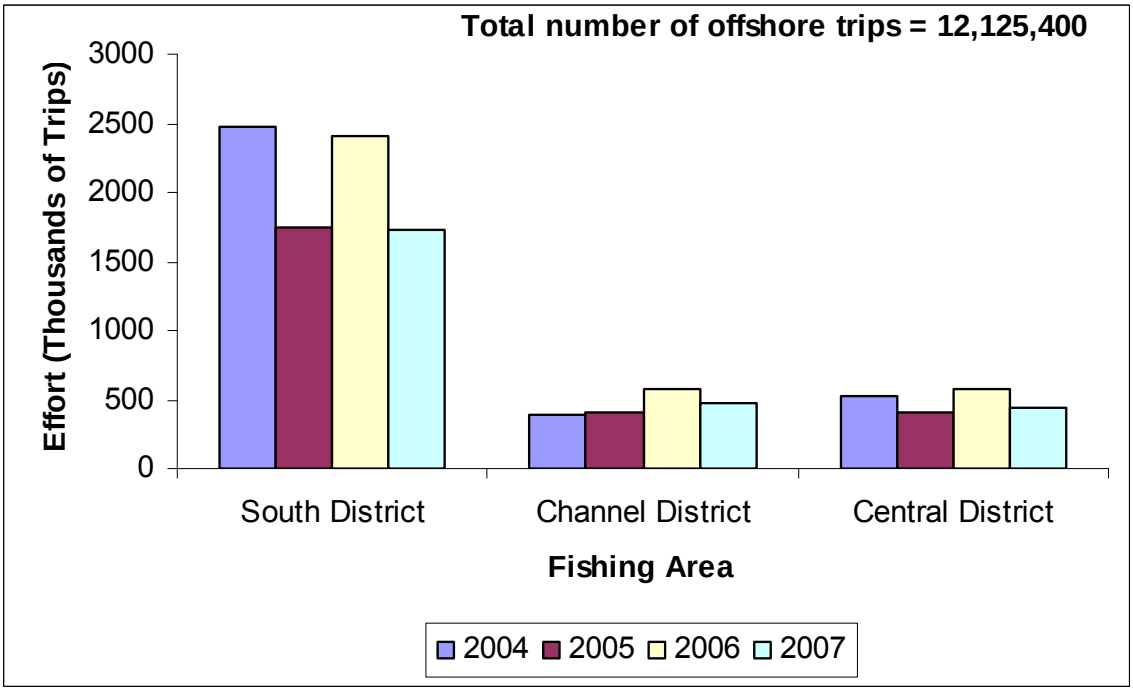

Figure 4-24. Number of offshore recreational saltwater fishing trips in south-central and southern California during 2004 through 2007. Source data: (NMFS 2007a; CDFG 2008a).

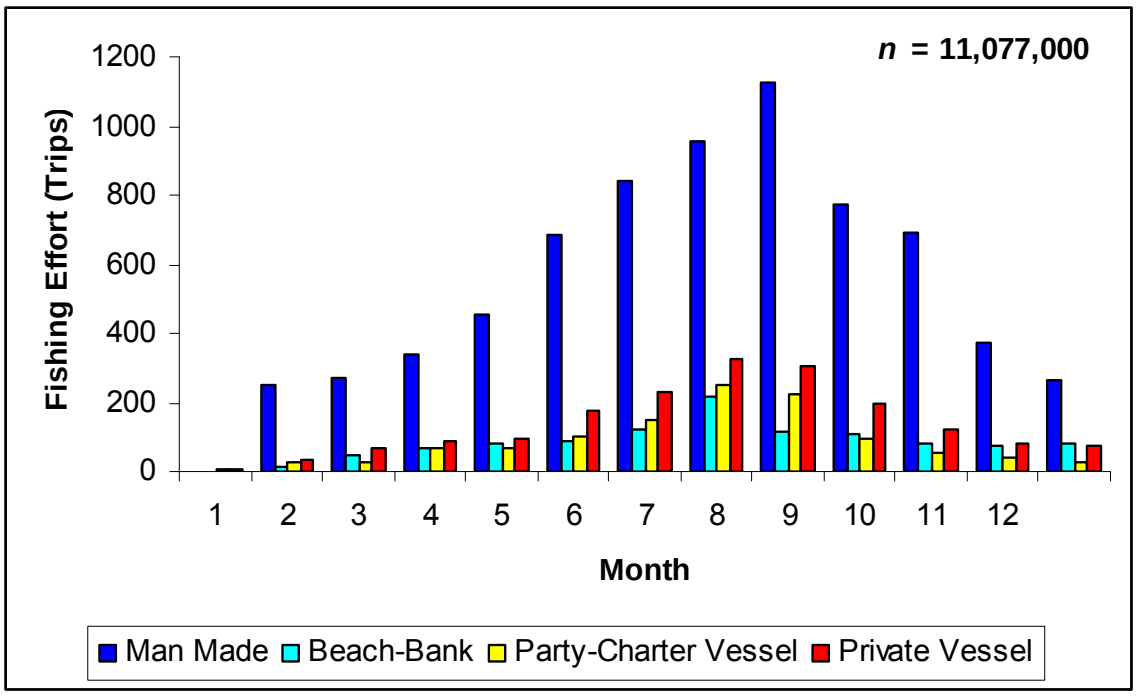

Figure 4-25. Number of monthly recreational saltwater fishing trips in southern California (South District) during 2004 through 2007. Source data: (NMFS 2007a; CDFG 2008a).

mackerels dominated the catch at 4.4 million fish followed by sea basses at 2.1 million fish and croakers at 1.7 million (CDFG 2008a). In the Channel District, rockfishes dominated the catch at 958,000 fish followed by surf perches at 750,000 fish and tuna and mackerels at 374,000 (CDFG 2008a). In the Central District, rockfishes dominated the catch at 1.9 million fish followed by surf perches at 953,000 and anchovies at 445,000 fish (CDFG 2008a). At the species level, the primary fish landed was the Pacific mackerel at 3.4 million, followed by Pacific sardine at 1.3 million, and barred sandbass at 1.2 million (CDFG 2008a).

4.5.4.4 Charter and Headboats

Overall, charter and headboats provide a substantial amount of employment and are economically important to coastal communities (NMFS 2004a). 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 target 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).

4.5.4.5 Fishing Tournaments

Organized fishing tournaments are popular in the SOCAL/Pt. Mugu Study Area, and a variety of them take place along the coast with the highest percentage (97%) taking place in the SOCAL OPAREA. San Diego Bay and Dana Point host the bulk of the tournaments, 23 (38%) and 13 (27%), respectively. Organizations and companies usually sponsor the various tournaments throughout the year. Each tournament has its own set of rules, which include time limits and geographical boundaries. The maximum distance typically traveled by offshore tournament participants is 75 nm from the tournament

host site. The sites fished by anglers within the tournament zones are still dependent on several factors, including the species targeted, tournament rules, or weather. Among the different tournaments, the level of participation varies between individual events, seasons, and years. Although most tournaments are annual events, the list of scheduled tournaments is not static. Existing tournaments may be cancelled due to a lack of participation or support or new tournaments may be organized. The exact dates and weigh-in locations of annual tournaments will vary slightly year to year (**Table 4-7**).

Southern California offers a unique aspect to tournament fishing in the area by hosting numerous kayak fishing tournaments. Kayaks are small decked boats pointed on both ends and propelled with a two-bladed paddle by a single passenger from a seated position (USACE 2002). In 2007, approximately 16 kayak fishing tournaments were held in the southern California area (**Table 4-7**).

Table 4-7. Major recreational fishing tournaments in the SOCAL/Pt. Mugu Study Area.[7-18]

Event Date	Weigh-In Location	Event	Target Species
28 January 2007	Dana Point, CA	Dana Point Derby	Halibut and Calico and Sand Bass
17 March 2007	Shelter Island Wave, San Diego Bay, CA	San Diego Bay Bass Tournament	Sand, Bay, and Calico Bass
31 March 2007	Surfrider Beach, Malibu, CA	Big Kahuna Tournament Series: Event 1	All Legal Species (excluding Sharks, Rays, Skates, and Calico Bass)
31 March-1 April 2007	Dana Landing, CA	MBMC Lingcod Tournament	Lingcod
14 April 2007	Shelter Island Wave, San Diego Bay, CA	San Diego Bay Bass Tournament	Red Type Rock Cod, Cowcod, and Boccaccio
14 April 2007	Mission Bay, CA	Plastic Navy Tournament Trail Event #1 – Kayak Fishing Frenzy	Sand, Bay, and Calico Bass
21-22 April 2007	Marina del Ray, CA	33rd Annual Marina del Ray Halibut Derby	Halibut
28 April 2007	Dana Landing, CA	Southwestern Yacht Club Rockfish Tournament	Rockfish
28-29 April 2007	Dana Landing, CA	MBMC Rockfish Tournament	Rockfish
5-6 May 2007	Dana Landing, CA	MBMC Halibut-White Seabass Tournament	Halibut, White Seabass
12 May 2007	Corral Canyon, CA	Big Kahuna Tournament Series: Event 2	All Legal Species (excluding Sharks, Rays, Skates, and Calico Bass)
12 May 2007	Dana Point, CA	12th May Thresher One Tournament	Sharks
19 May 2007	Shelter Island Wave, San Diego Bay, CA	Triple B Tourney	Sandy, Calico, and Spotty Bass
19 May 2007	San Diego, CA	Spring Shootout	Yellowtail, White Seabass, Albacore Tuna, Halibut
19 May-2007-18 May 2008	La Jolla, CA	West Coast Whoppers	Yellowtail, White Seabass, Halibut
2-3 June 2007	Dana Landing, CA	MBMC Calico-Sandbass Tournament	Sand and Calico Bass

Table 4-7 (*Continued*). Major recreational fishing tournaments in the SOCAL/Pt. Mugu Study Area.[7-18]

Event Date	Weigh-In Location	Event	Target Species
3 June 2007	Newport Harbor, CA	Plastic Navy Tournament Trail Event #2 – Southwind Kayak Expo Day	Sand, Bay, and Calico Bass
16 June 2007	Leo Carrillo, CA	Big Kahuna Tournament Series: Event 3	All Legal Species (excluding Sharks, Rays, Skates, and Calico Bass)
16 June 2007	San Diego, CA	21st Annual Don Blackman Memorial Halibut Derby	Halibut
16 June 2007	Shelter Island Wave, San Diego Bay, CA	First Annual Yellowtail Tournament	Yellowtail
23-24 June 2007	Dana Landing, CA	Potpourri Tournament	All Legal Species (excluding Sharks and Rays)
14 July 2007	Shelter Island Wave, San Diego Bay, CA	Tuna Tournament	Tuna
14 July 2007	La Jolla, CA	Plastic Navy Tournament Trail Event #3 – Calico Chaos La Jolla Final	Calico Bass
21 July 2007	Shelter Island, San Diego Bay, CA	Yellowtail Tournament	Yellowtail
21-22 July 2007	Dana Landing, CA	MBMC Yellowtail Tournament	Yellowtail
21-22 July 2007	Dana Point, CA	9th Mako Madness Tournament	Sharks
5-7 August 2007	Marina del Ray, CA	Annual Mako for Dollars Tournament	Sharks
18 August 2007	San Diego, CA	Jack Bohannon Juniors Tournament	Billfish, Yellowtail, Tuna, Dorado, Halibut
18 August 2007	Shelter Island, San Diego Bay, CA	Offshore Tournament	Largest Fish (excluding Sharks and Rays)
18-19 August 2007	Shelter Island Wave, San Diego Bay, CA	24th Annual Big Fish Tournament	Billfish, Tuna, Shark
19 August 2007	San Pedro, CA	Baytubers 4th Annual Big Summer Tournament	All Legal Species (excluding Sharks, Rays, and Skates)
25 August 2007	San Diego, CA	Presidents Tournaments (Couples)	Marlin
25-26 August 2007	Dana Landing, CA	MBMC *What's Hot* Tournament	Yellowtail and Albacore Tuna
1-3 September 2007	San Diego, CA	Labor Day Tournament	Marlin
1-30 September 2007	Dana Landing, CA	Roy Lively Month-Long Marlin Tournament	Marlin
7-8 September 2007	Avalon Harbor, Santa Catalina Island, CA	KHMC Marlin Tournament	Marlin

Table 4-7 (*Continued*). Major recreational fishing tournaments in the SOCAL/Pt. Mugu Study Area.[7-18]

Event Date	Weigh-In Location	Event	Target Species
7-8 September 2007	San Diego, CA	MCSD Invitational Light Tackle Tournament and Club Challenge	Marlin and Swordfish
8 September 2007	La Jolla, CA	Fifth Annual Steve Moyer Memorial Kayak Fishing Tournament	Yellowtail, Halibut, White Seabass, Barracuda, Bonita, Mackerel (excluding Sharks, Rays, Skates, and Calico Bass)
8-12 September 2007	Oxnard, CA	Channel Islands Billfish Tournament	Billfish
9-11 September 2007	Avalon Harbor, Santa Catalina Island, CA	Avalon Billfish Classic Pro-Am	Billfish
14-15 September 2007	Newport Beach, CA	BAC Master Angler Billfish Tournament	Billfish
15 September 2007	Dana Point, CA	Plastic Navy Tournament Trail Event #4 – Dana Point Calico Challenge	Calico Bass
15 September 2007	Shelter Island, San Diego Bay, CA	Rodeo Tournament	Largest IGAF Fish (excluding Sharks and Rays)
15 September 2007	Shelter Island Wave, San Diego Bay, CA	Fourth Annual Chuck Byron Commemorative "FISH ON" Angler's Tournament	Tuna, Yellowtail, Dorado, Calico Bass and a Category of all IGFA Recognized Species, including Billfish (excluding Sharks)
16-19 September 2007	Avalon Harbor, Santa Catalina Island, CA	Zane Grey Invitational Marlin Tournament	Marlin
21-22 September 2007	Avalon Harbor, Santa Catalina Island, CA	Los Pescadores Billfish Tournament	Billfish
22 September 2007	San Diego, CA	MBMC 33rd Annual Charity Heart Marlin Tournament	Marlin
23-25 September 2007	Avalon Harbor, Santa Catalina Island, CA	Catalina Classic Marlin Tournament	Marlin
28-29 September 2007	Avalon Harbor, Santa Catalina Island, CA	California Billfish Series Championship	Billfish
29 September 2007	La Jolla, CA	Big Water's Edge Kayak Fishing Tournament	All Legal Species (excluding Sharks, Rays, and Skates)
29-30 September 2007	San Diego, CA	17th Annual Make-A-Wish Tuna Challenge	Tuna
6-7 October 2007	San Diego, CA	Small Boat Tournament	Marlin and Yellowfin, Bluefin, and Bigeye Tuna
13 October 2007	Shelter Island, San Diego Bay, CA	IGAF Big Fish Tournament	Largest IGAF Fish (excluding Sharks and Rays)
20 October 2007	Carpinteria, CA	UASC "No Motor" Tournament	Sand, Bay, and Calico Bass

Table 4-7 (*Continued*). Major recreational fishing tournaments in the SOCAL/Pt. Mugu Study Area.[7-18]

Event Date	Weigh-In Location	Event	Target Species
27 October 2007	Newport Harbor, CA	Plastic Navy Tournament Trail Event #5: Southwind Kayaks Part II: The Revenge Tournament	Sand, Bay, and Calico Bass
27 October 2007	Shelter Island Wave, San Diego Bay, CA	Spotted Bay Bass Tournament	Spotted Bay Bass
27 October 2007	Shelter Island, San Diego Bay, CA	San Diego Bay Bass Tournament	Sand, Bay, and Calico Bass
10 November 2007	Shelter Island, San Diego Bay, CA	Chuck Byron Bay Bass Memorial and inter-club Tournament	Bay Bass
10-14 November 2007	Cortez Bank, CA	Islanders 3-day Mothership to Cortez + Islands (Channel/San Clemente)	Yellowtail, Halibut, White Seabass
8 December 2007	San Diego, CA	Plastic Navy Tournament Trail Event #6	Sand, Bay, and Calico Bass

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5.0 ADDITIONAL CONSIDERATIONS

5.1 MARITIME BOUNDARIES: TERRITORIAL WATERS, CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE

Maritime boundaries 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 encompass a 12-nm territorial sea, a 12- to 24-nm contiguous zone, a 200-nm EEZ, and a nation's continental shelf (**Figure 5-1**). Since maritime boundaries are delimited, rather than demarcated, there is generally no physical evidence of the boundary. As a result, there can often be confusion, disagreement, and conflicting versions of marine boundaries between distinct nations and/or territories. In addition, these boundaries are often dynamic due to their dependence upon the changing features of the shoreline from which they are measured.[2]

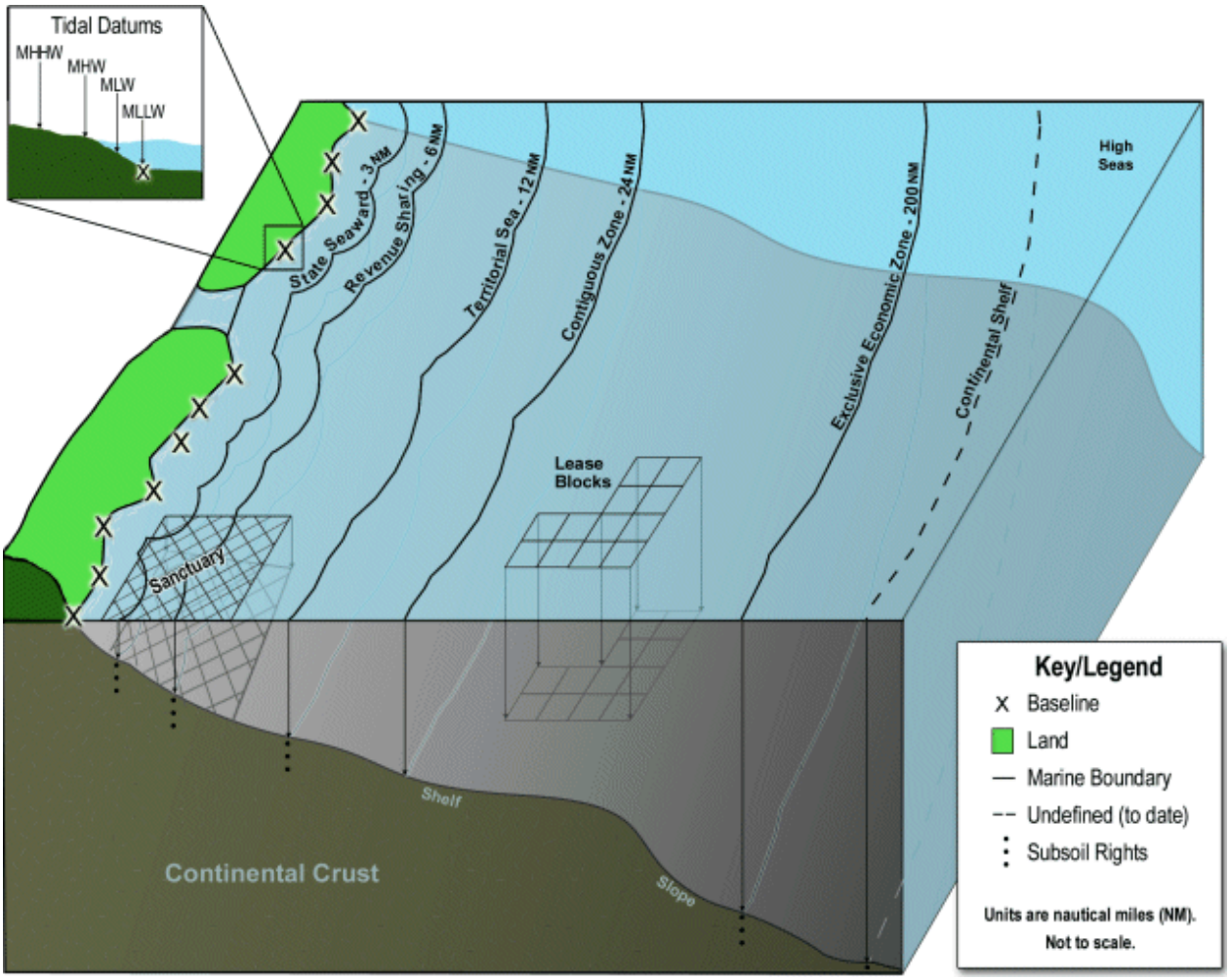

Figure 5-1. A three-dimensional depiction of the U.S. maritime boundaries. The baseline is defined as the mean low water/tide line along the coast or a straight line drawn across coastal bays or other inlets. Tidal datums – MHHW, MHW, MLW, and MLLW. Image taken from NOAA[2], used with the permission of Mr. David Stein.

Historically, the oceans were recognized as a public, or common, resource and no portion was held by any one nation; however, due to defense concerns, many nations began to employ a territorial sea claiming exclusive jurisdiction over the activities within the sea immediately adjacent to their shoreline. The distance of this territorial sea was usually 3 nm from the shoreline (supposedly the distance that could be secured by cannon ball fire from shore), but two states (Texas and the gulf coast of Florida) and the territory of Puerto Rico came to hold 9 nm territorial seas. The breadth of maritime zones is measured from the "baseline" of each nation or state. The U.S. uses the "rule of the tidemark" as the baseline from which to measure the width of its territorial sea. This baseline coincides with the mean lower low water mark (low tide) found along the shore and is often termed the "normal" baseline (Kapoor and Kerr 1986; Prescott 1987). 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 using the traditional normal baseline to determine the breadth of their maritime zones, an increasing number of countries use either a straight baseline similar to that used for coastal discontinuities or, in the case of island nations (or states or territories), a baseline that applies to the island chain as a whole (the archipelagic baseline) (Kapoor and Kerr 1986; Prescott 1987). A baseline, unless fixed by law, is not static. The shoreline may change due to natural processes such as accretion and erosion or due to the construction or removal of man-made structures. The corresponding boundary, which is a line connecting a series of points measured from the nearest point on the baseline to the requisite distance from shore, will shift along with the shoreline (and thus the baseline).

The U.S. maintained a 3-nm limit to its offshore jurisdiction until the latter half of the twentieth century when the desire for offshore oil and gas resources, the threat of pollution and the chronic overfishing of waters adjacent to the U.S. by foreign fleets led President Truman to issue Presidential Proclamation No. 2667 (also known as the Truman Proclamation). The Truman Proclamation, issued in 1945, claimed 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 claim jurisdiction or control over the waters overlying the U.S. continental shelf. In 1953, the Truman Proclamation was nullified and replaced by the SLA and OCSLA (now the OCSLAA of 1978). The SLA (43 U.S.C. 1301-1315) granted to states and territories jurisdiction over the waters adjacent to their coastline to 3 nm, or to the distance provided in the state's constitution at the time of its entry into the Union or as approved by Congress (9 nm for Texas, the gulf coast of Florida and the territory of Puerto Rico). The OCSLA (43 U.S.C. 1331 et seq.) placed the subsoil and seabed of the OCS under U.S. jurisdiction. Section 1331 of this act defines the OCS as the lands lying beneath waters seaward of state jurisdiction but not exceeding 350 nm from the baseline. Like the Truman Proclamation, the OCSLA did not give the U.S. authority over the waters above the continental shelf seabed, thereby leaving them open to navigation and fishing by foreign vessels (**Table 5-1**).

The Truman Proclamation precipitated claims by other nations on the waters adjacent to their shorelines, often on varying geographic and jurisdictional scales, creating a chaotic situation that was neither clarified nor remedied by example when the U.S. passed its submerged lands legislation in 1953. The United Nations hosted a series of three conferences on the Law of the Sea (LOS) beginning in 1958 to attempt to restore order and set global guidelines for maritime boundaries and jurisdictional authority. The outcome of the third (and final) of these conferences was the United Nations Convention on the Law of the Sea (UNCLOS), created in 1982 and entered into force in 1994. The UNCLOS delimited the international maritime sovereignties of coastal nations as 12 nm for territorial seas, 12 to 24 nm for a contiguous zone, and 200 nm for an EEZ (54 FR 777). Additionally, Article 76 of the UNCLOS specifically grants nations the right to claim jurisdiction over the seabed past 200 nm where applicable. U.S. President Bill Clinton signed the UNCLOS treaty in 1994. The U.S. is not an official signatory because the treaty has not been ratified by the U.S. Senate; however, the U.S. has abided by all of the treaty's provisions since 1994 and many of its major tenets have been codified at the federal level, including those extending the territorial sea, creating the contiguous zone, and creating the EEZ.

Table 5-1. Timeline detailing the establishment of U.S. jurisdiction and maritime boundaries in the SOCAL/Pt. Mugu Study Area by treaty, legislation, and presidential proclamation.

Pre-1700s	Global common use of oceans, including waters immediately adjacent to a nation's shoreline
Post-1700s	Nations begin delimiting territorial waters under the so-called "cannon-shot rule"
1945	**Truman Proclamation (Presidential Proclamations No. 2667 and 2668)** exerts U.S. jurisdiction and control of the subsoil and seabed of the continental shelf contiguous to its coast as well as laying claim to high-seas "conservation zones" for U.S. fisheries
1953	**Submerged Lands Act** grants to coastal states and territories jurisdiction over submerged offshore lands within 3 nm (9 nm for Texas, the gulf coast of Florida and the territory of Puerto Rico)
1953	**Outer Continental Shelf Lands Act** (and its amendments of 1978) grants to the federal government jurisdiction over the resources of submerged lands from 3 nm out to the continental shelf break
1958	First **United Nations LOS Conference** convened to seek resolution to global maritime boundary conflicts
1960	Second **United Nations LOS conference** convened
1973	Third **United Nations LOS conference** convened
1976	**Fishery and Conservation Management Act** establishes a 200-nm fishery conservation zone adjacent to U.S. and its territories
1982	**United Nations Convention on the Law of the Sea (UNCLOS)** results from third United Nations LOS conference; this treaty provides international guidelines for the establishment of maritime boundaries and the use of OCS lands
1983	**Presidential Proclamation No. 5030** creates a 200-nm EEZ around the U.S. and its territories, granting the U.S. sovereign rights over the natural resources within the EEZ; does not affect the lawful use of this zone by other nations for navigation or overflight
1988	**Presidential Proclamation No. 5928** extends the territorial seas of the U.S. to 12 nm from the baseline
1994	**UNCLOS** (1982) takes effect; the U.S. abides by all of the provisions of the treaty, but has yet to ratify
1999	**Presidential Proclamation No. 7219** creates a zone of limited jurisdiction contiguous to the territorial waters and extending to 24 nm from the baseline

Source: Brown (1953); Cicin-Sain and Knecht (1998)

As the United Nations LOS conferences sought to establish international guidelines, the U.S. sought to protect its resources with the passage of the federal Fishery Conservation and Management Act (later the MSFCMA) in 1976. The FCMA (16 U.S.C. 1801 et seq.) 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 is 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 equidistant from the two nations where a 200-nm limit is not possible (DoS 1977).

In 1976, Mexico also established a 200-nm EEZ. To delineate the maritime boundaries between the U.S.' fishery management zone and Mexico's EEZ, the two nations signed an agreement in 1976 that provisionally established the maritime boundaries in the Gulf of Mexico and the Pacific Ocean so that the two nations' maritime zones did not overlap.[3] A 1978 treaty between the U.S. and Mexico formalized the maritime boundaries established by the 1976 agreement; Mexico ratified the treaty in 1979, but the U.S. did not do so formally until 1997 (**Figure 5-2**).[3]

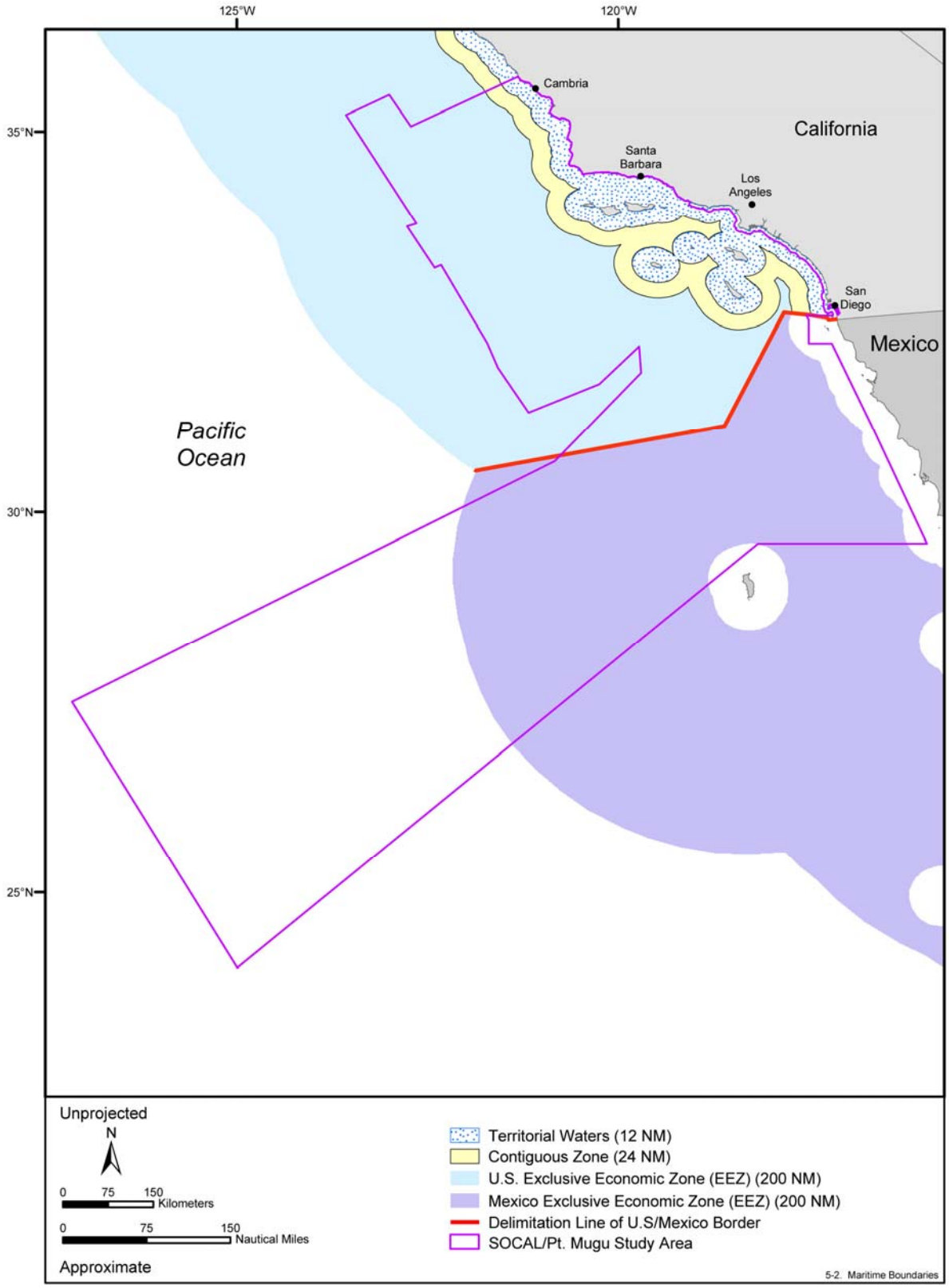

Figure 5-2. Proximity of the SOCAL/Pt. Mugu Study Area to the maritime boundaries of the U.S. Also shown is the proximity of the Study Area to Mexico's EEZ. Source data: GDAIS (2004) and DOALOS (2005).

The FCMA of 1976 established a fishery conservation zone out to 200 nm to conserve and protect the U.S.' fishery resources; however, this protection did not extend to the other resources of the ocean waters offshore of the U.S. In order to affect this additional protection, the U.S. designated an EEZ in 1983 through Presidential Proclamation No. 5030 (**Table 5-1**). This proclamation established an EEZ, per the provisions of the UNCLOS, 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 (including exploration, exploitation, conservation, and management) 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**).[4] 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; 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 unless such boundaries are renegotiated and set by international treaty.

Table 5-2. The maritime boundaries of the U.S. (including its territories and possessions) and their seaward and jurisdictional extents.

Maritime Boundary	Seaward Extent	Jurisdictional Extent
State (or Territory) Waters	3 to 9 nm from U.S. baseline (depending on state's or territory'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
Outer Continental Shelf (OCS)	Up to 350 nm from U.S. baseline	Sovereign rights over resources of the continental shelf lands

Source: DOALOS (2005) and NOAA[2]

In 1988, per the guidelines in the UNCLOS treaty, 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 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 remains under the primary jurisdiction of each coastal state. This area of state jurisdiction is 9 nm for Texas, the gulf coast of Florida and the territory of Puerto Rico and 3 nm for all other U.S. states and territories.

The UNCLOS also provides for a contiguous zone, adjacent to and seaward of the territorial waters, that may be anywhere from 12 to 24 nm seaward of the nation's baseline. In 1999, President Clinton's Presidential Proclamation No. 7219 (**Table 5-1**) extended U.S. federal jurisdiction by the additional 12-nm maximum allowed by international agreement. This zone is an area of limited jurisdiction contiguous with

the territorial waters and extending 24 nm from the U.S. baseline. The U.S. makes no territorial claims within its contiguous zone, but does claim the right to exercise the control necessary to prevent infringement of its fiscal, customs, immigration, or sanitary laws/regulations and to punish infringement of these laws/regulations committed within the zone (DOALOS 2005). The establishment of the U.S. contiguous zone additionally advances both the law enforcement and public health interests of the U.S.

5.1.1 Maritime Boundaries in the Southern California/Point Mugu Study Area

Only a small portion of the SOCAL/Pt. Mugu Study Area is found in the territorial waters of the U.S. The majority of the Study Area falls within the U.S. EEZ or beyond. W-291 in the SOCAL OPAREA (**Figure 1-1** and **Figure 5-2**) extends southwest beyond the delimitation of the U.S./Mexico border from approximately 32°N latitude south to 25°N latitude, encompassing portions of Mexico's EEZ but none of Mexico's territorial sea. Nearshore parts of the Study Area fall within the jurisdiction of the state of California within 3 nm of the coastline. Activities within state jurisdiction or impacting the coastal zone are potentially subject to consistency review under the CZMA and to review by state resource management and conservation agencies. The portion of the SOCAL/Pt. Mugu Study Area within 12 nm of the coastline is located in U.S. territorial waters. With the exception of the consistency review mandated by the CZMA and regulations for discharge of waste materials, maritime boundaries, both domestic and international, have little impact on Navy activities. Federal resource law applies to all persons and vessels subject to the jurisdiction of the U.S. both within U.S. waters and on the high seas, including its own and foreign EEZs (in this case, Mexico). On the high seas and within the territorial waters of foreign nations, federal agencies are compelled by Executive Order (EO) 12114 to conduct themselves in a manner consistent with the NEPA. Therefore, Navy activities are only affected by maritime boundaries to the extent prescribed in pertinent legislation, primarily the MMPA, the ESA, the NEPA and EO 12114, all of which subject them to varying degrees to U.S. federal law both in the U.S. and abroad.

5.1.2 United States Maritime Boundaries and Federal Resource Legislation

In the marine environment, U.S. federal law may apply to persons or vessels under U.S. jurisdiction outside of U.S. territorial waters, to persons and vessels operating within U.S. maritime boundaries or both. Federal resource laws and executive orders, as outlined in **Sections 1.3.1** and **1.3.2**, may regulate activities within certain maritime zones, throughout the EEZ and/or on the high seas (i.e., waters outside the jurisdiction of any one nation). The following is a brief summary of the federal resource laws whose scope or directives are particularly affected by maritime boundaries.

- The MMPA prohibits the take of marine mammals on the high seas, including within the EEZs but not the territorial waters of foreign nations, by persons or vessels under the jurisdiction of the U.S. It also prohibits the take of marine mammals on lands or within waters under U.S. jurisdiction (to the 200-nm limit).

- The ESA regulates the protection, conservation, and management of protected species on lands and in waters under U.S. jurisdiction (to 12 nm). It also regulates the taking of protected species on the high seas by persons or vessels under U.S. jurisdiction. While the ESA is the overarching legislation governing protected species, individual states are encouraged to draft their own protected species legislation; provided this legislation is not more lax than federal standards, coastal states have control over protected species to the seaward boundary of state waters (3 nm; 9 nm for Texas, the gulf coast of Florida and the territory of Puerto Rico).

- The MSFCMA, as amended by the SFA, regulates the conservation and management of fish stocks and fisheries within U.S. territorial waters and throughout the EEZ (3 to 200 nm); the management of fisheries within state waters generally falls outside the scope of the MSFCMA. The MSFCMA does not regulate HMS even when they occur within the 200-nm limit. The U.S. cooperates directly with other nations or with international fisheries management bodies in order to conserve and promote optimum yields of HMS. The 2007 amendments to the MSFCMA (P.L. 109-479) allow for the implementation of regulations to control the importation into the U.S. of products harvested in an unsustainable or illegal manner.

- The NEPA sets forth procedural guidelines for the protection and preservation of the environment by directing federal agencies to give appropriate consideration to the environmental effects of their actions. The NEPA regulates major federal actions (including state or private actions which benefit from federal funding) on the lands and in the territorial waters of the U.S. (to 12 nm).

- EO 12114 on Environmental Effects Abroad of Major Federal Actions pertains to environmental impact evaluation requirements for U.S. federal agencies. Similar to the requirements of the NEPA within U.S. jurisdiction, EO 12114 directs federal agencies to give appropriate consideration to the environmental effects of their actions outside the U.S., its territories and possessions. This includes federal actions on the global commons (the high seas and Antarctica) as well as within the jurisdiction of foreign nations.

- The CZMA requires federal actions that may affect the coastal zone to undergo consistency review with state coastal zone regulations. This includes any federal action originating or occurring within the state's jurisdiction (3 to 9 nm seaward of the baseline, depending on the state or territory) or any federal action originating or occurring outside the state's jurisdiction (seaward of 3 to 9 nm, including U.S. territorial waters, the EEZ and the high seas) but which may affect the coastal zone of that state.

- The CWA outlines the permitting system for point discharges in the territorial waters, the contiguous zone, the EEZ, and the high seas for all vessels (structures, etc.) under U.S. jurisdiction.

- The MPRSA regulates the dumping of waste materials into the ocean and gives procedural direction for the establishment of a NMS program. Titles I and II prohibit the transport of materials from the U.S. (or from foreign locations by persons or vessels subject to U.S. jurisdictional authority) for the purpose of deposition into the ocean. The dumping of materials into U.S. territorial waters or contiguous zone is also prohibited, except where specifically allowed by law. Title III, the NMS Act, directs the NMS program within U.S. territorial waters (and inland waters) and mandates cooperation with state government due to coastal state jurisdiction over waters within 3 nm (except where 9 nm).

- The MPPRCA prohibits the discharge of plastics into the marine environment or navigable waters of the U.S. (to 200 nm) by any vessel. It also prohibits the discharge of plastics into the marine environment, including the high seas, by any vessel under U.S. registry pursuant to Annex V of the MARPOL. The MPPRCA further prohibits the discharge of non-plastic garbage into waters within 3 nm of the coast and stipulates the type of refuse that may be discharged with 12 nm. Foreign military vessels and certain U.S. Navy vessels are not subject to the same guidelines; however, the procedure by which these vessels must manage waste discharge is outlined in 33 U.S.C. § 1902.

- The SLA and the OCSLAA grant jurisdiction over offshore submerged lands and associated resources to the state and the federal government, respectively. The SLA grants authority over the submerged lands underlying state waters (3 to 9 nm, depending on the state) to the state. The OCSLAA grants jurisdiction of the submerged lands underlying waters seaward of 3 nm (to 200 nm or the shelf break) to the federal government.

- Presidential Proclamation No. 7264 was issued in 2000, creating 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 coast. This designation does not include the offshore lands owned by the U.S. Navy.

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. Navigable waters of the U.S. are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use 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 (U.S.C. 401 et. seq.).

There are more than 40,000 km (21,000 nm) of commercially navigable waterways under the U.S. transportation system. While the USCG is responsible for implementing marine navigational regulations, the USACE is responsible for maintaining navigational waterways. The USACE maintains and operates more than 19,200 km of inland waterways, and owns or operates 257 locks at 212 sites on inland waterways. These waterways (a system of rivers, lakes, and coastal bays improved for commercial and recreational transportation) are used to transport about one-sixth of the nation's intercity freight, at a much lower cost than either rail or trucks. Besides cargo vessels, other vessel types that use navigable waterways and commercial shipping lanes are: tug and barges (sea-going), tug and barges (river type), small ships, liquid bulk, dry bulk, break bulk, intermodal (container, roll-on/roll-off, lighter aboard ship), and rail-ferry. Commercially navigable waterways are located in 41 states, 16 state capitals, and all states east of the Mississippi River. Domestic companies operating vessels on U.S. waterways increased 19.6% from 2002 to 2003.[4] It has been estimated that about 90% of the U.S. population is served by domestic shipping and shipping moves about 24% of the nations freight (by ton-mile). The U.S. ranks second in the world in maritime container traffic. It also has been estimated that by the year 2020, container traffic will double in size (DoT 2005). One concern with these demands is that ports will have to accommodate cargo vessels that will double in capacity. Presently, large oversize cargo vessels can sometimes cause major congestion at local ports; thus, based on the projected rate, the ports in California have the largest expected port capacity shortfall than any other ports on the west coast. From 2006 through 2010, U.S. public port project capital expenditures will primarily be dominated (44.1%) by ports located in the South Pacific (California) at estimated costs over 3.5 billion dollars (DoT 2007a; DOT 2007b).

The U.S. DoT's Maritime Administration categorizes commercial shipping ports into strategic (military) and high volume container (DoT 2005). There are a total of 26 ports in the U.S. Of these, seven are located on the west coast. Three are located in southern California. The three major ports are Los Angeles, Long Beach, and San Diego. The ports at Long Beach and San Diego are considered strategic military ports. Long Beach port represented about 6% of the cargo and the port ranked sixth, among U.S. ports in terms of total cargo imported and exported for 2002. Los Angeles is ranked seventh and San Diego ranked 26 (DoT 2005). In addition to cargo transportation, cruise ships are a growing industry. In the U.S., five major ports account for 56% of the departures. Los Angeles port ranked fifth, Long Beach ranked eleventh, and San Diego ranked thirteen. From 2003 through 2006, the port at Long Beach increased 122% in the number of departures (DoT 2007a; DOT 2007b). Another type of maritime industry that is growing is high-speed ferry service. With the rising costs of fuel and traffic congestion, along with recent advances in vessel technology, high-speed ferry service may increase throughout the U.S., especially for California. In fact, the construction of high-speed ferry vessels is at an all time high.[5]

There are four primary shipping lanes that radiate from the SCB: two run south along Mexico's west coast, one extends west towards the central and western North Pacific (Hawai'i and Asia), and another stretches north along the U.S. west coast up to the San Francisco area and beyond (**Figure 5-3**).

Various types of commercial vessels regularly transit the SOCAL/Pt. Mugu Study Area. Vessels include cargo, tug and barges, small ships, liquid bulk, dry bulk, break bulk, intermodal (container, roll-on/roll-off, lighter aboard ship), ferry, tourist passenger vessels (sailboats, ferry, party-boat fishing, whale watching) and cruise ships. In southern California, commercial shipping routes are highly structured and controlled, even in open ocean areas. Although commercial shipping in southern California is dominated by cargo transports, oil tankers, and barges, whale watching traffic is continuing to increase from several major southern California ports such as Santa Barbara, Los Angeles, Long Beach, Newport, and San Diego. The southern California region is primarily used by commercial vessels traveling between eastern North Pacific ports (e.g., Vancouver, Seattle, and San Francisco) and those situated in southern California. Vessels going to and from the Panama Canal also transit the region (DoN 1999). In 2003, there were 27 offshore oil platforms and 6 artificial oil and gas islands that encompassed about 20,000 km^2 along the coast of California, all were located off the southern and central California coastline (McCrary et al. 2003). Thus, to service these facilities, including inspecting pipelines, supply ships must transit through the SOCAL/Pt. Mugu Study Area on a regular basis. In addition, as demand increases and Federal offshore and in-State crude oil production declines, marine vessel traffic associated with the oil industry are expected to increase in the near future (McCrary et al. 2003).

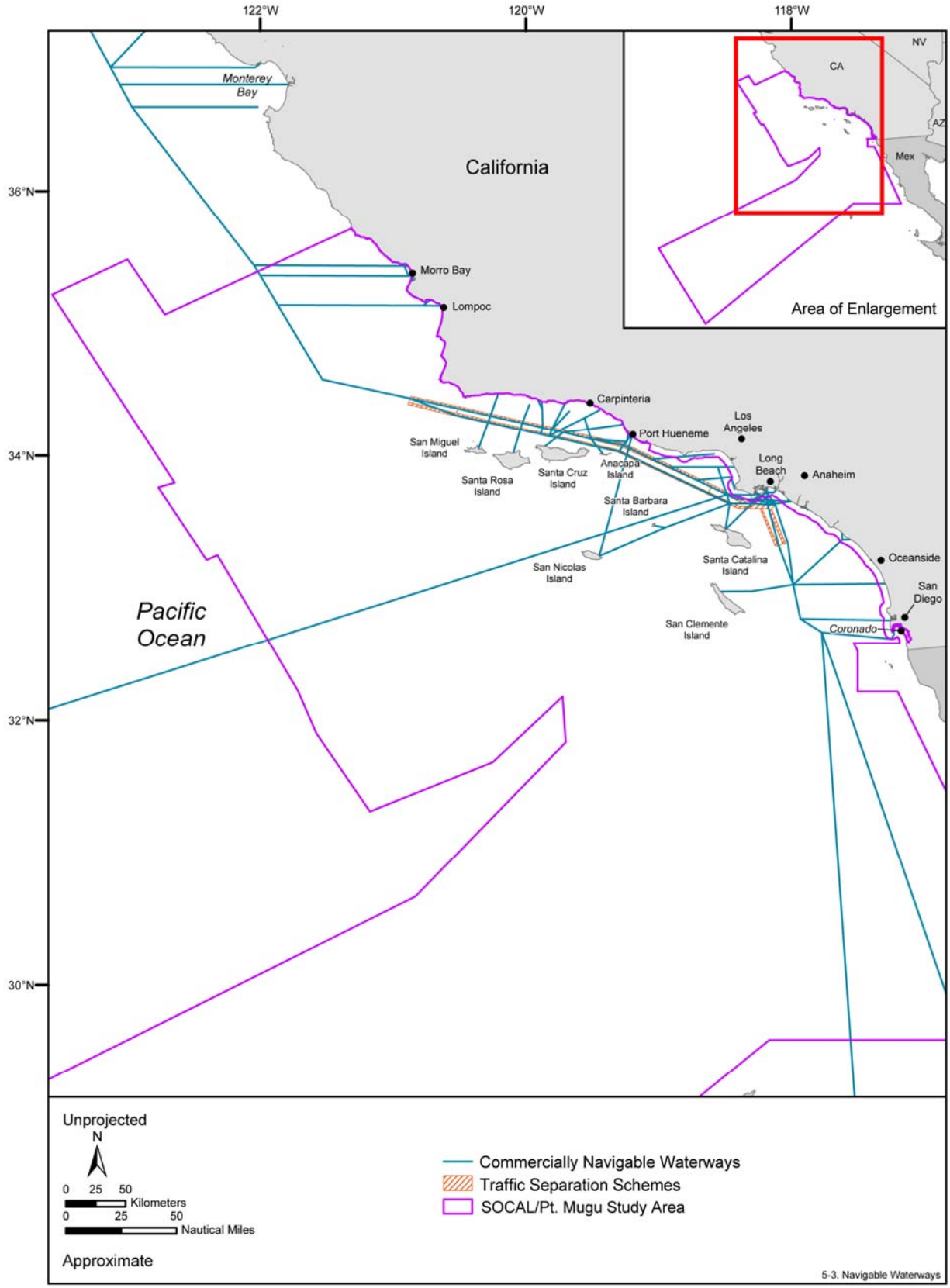

Figure 5-3. Commercially navigable waterways and traffic separation schemes in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: USCG (2000a, 2000b), and DoT (2004).

Vessel traffic in the vicinity of southern California's major ports is often governed by a system of Traffic Separation Schemes (33 CFR 167) (USCG (U.S. Coast Guard) 2000b, 2000a). 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. In some areas, 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; thus, most vessels abide by them.[6,7] Traffic Separation Schemes can be found going into and out of the Ports of Los Angeles and Long Beach, as well as in the Santa Barbara Channel between Point Arguello and Point Vicente (**Figure 5-3**). There are no designated Traffic Separation Schemes located in the waters off San Diego.

5.3 SCUBA DIVE SITES

An abundant and diverse array of marine life, a multitude of professional dive charter boats, and year-round temperate weather make California one of the world's great diving destinations. Although there are many noteworthy sites for beach/shore diving on the region's mainland, nearly all of the best dive sites in southern California are found miles offshore, most of them in the vicinity of the Channel Islands. The exact number of dive sites in the waters of the SOCAL/Pt. Mugu Study Area is not known, although there are definitely a great number of them (Krival 2001)(**Figure 5-4**).

Recreational and commercial divers frequent both natural and artificial marine habitats off southern California. Its nearshore reefs, coves, and kelp forests as well as its offshore banks and seamounts are natural features of southern California's marine environment where diving activities take place. Artificial marine habitats off southern California that are frequently visited by SCUBA divers include shipwrecks, artificial reefs, Navy towers, oil and gas platforms, and even airplane wrecks. Underwater photography of kelp and reef creatures, spearfishing (for rockfish, bass, flatfish, wrasses, bonitos, amberjacks, barracudas, and sculpins), and harvesting of lobsters, abalones, and sea urchins are some of the most popular activities at southern California's dive sites (CDFG 2002).[8,9,10]

Offshore banks, shipwrecks, artificial reefs, Navy towers, oil and gas platforms, and airplane wrecks are additional sites within the SOCAL/Pt. Mugu Study Area where SCUBA and free diving take place. Southern California's deep offshore reefs and seamounts are some of the region's favorite sites for experienced divers, while its artificial marine habitats (predominantly found in shallower, continental shelf waters) provide divers with a glimpse into the region's rich maritime history and habitat diversity.[11]

If done correctly and if visits to any one site are minimized, SCUBA diving can have limited impacts on marine habitats; however, overuse of popular locations or poor diving techniques can result in damage to these resources including living marine resources and their habitats, and submerged cultural resources (NOAA-NMS 2006). The benthos, in particular, are susceptible to intentional or accidental holding, touching, picking up, or covering organisms with sand by divers. Divers entering from the beach can also impact rocky intertidal habitats (NOAA-NMS 2006). Diver use, in combination with other ambient conditions, such as water quality reduction, sport diving overharvesting, and overfishing, can result in negative cumulative effects to these resources, and care should be taken to limit these effects (Agardy 1999).

5.3.1 Mainland Dive Sites

There are numerous shore diving sites located along the southern California coast (**Figure 5-4**). Coastal geography and marine weather patterns determine the diving conditions at each site. The beaches of Los Angeles and Orange Counties are often shielded from large swells by Point Conception and the Channel Islands; however, the Channel Islands are too far offshore and too far north to provide much protection to shore diving sites in San Diego County (Krival 2001). Main attractions at southern California's shore diving sites include extensive kelp beds, reef systems (both natural and artificial), lobsters, game fish, pismo clam beds, sand dollar beds, horn and leopard sharks, drop offs, rocky ledges, submarine canyons, and high visibility in areas of upwelling.[8] Krival (2001) identified the following areas in southern

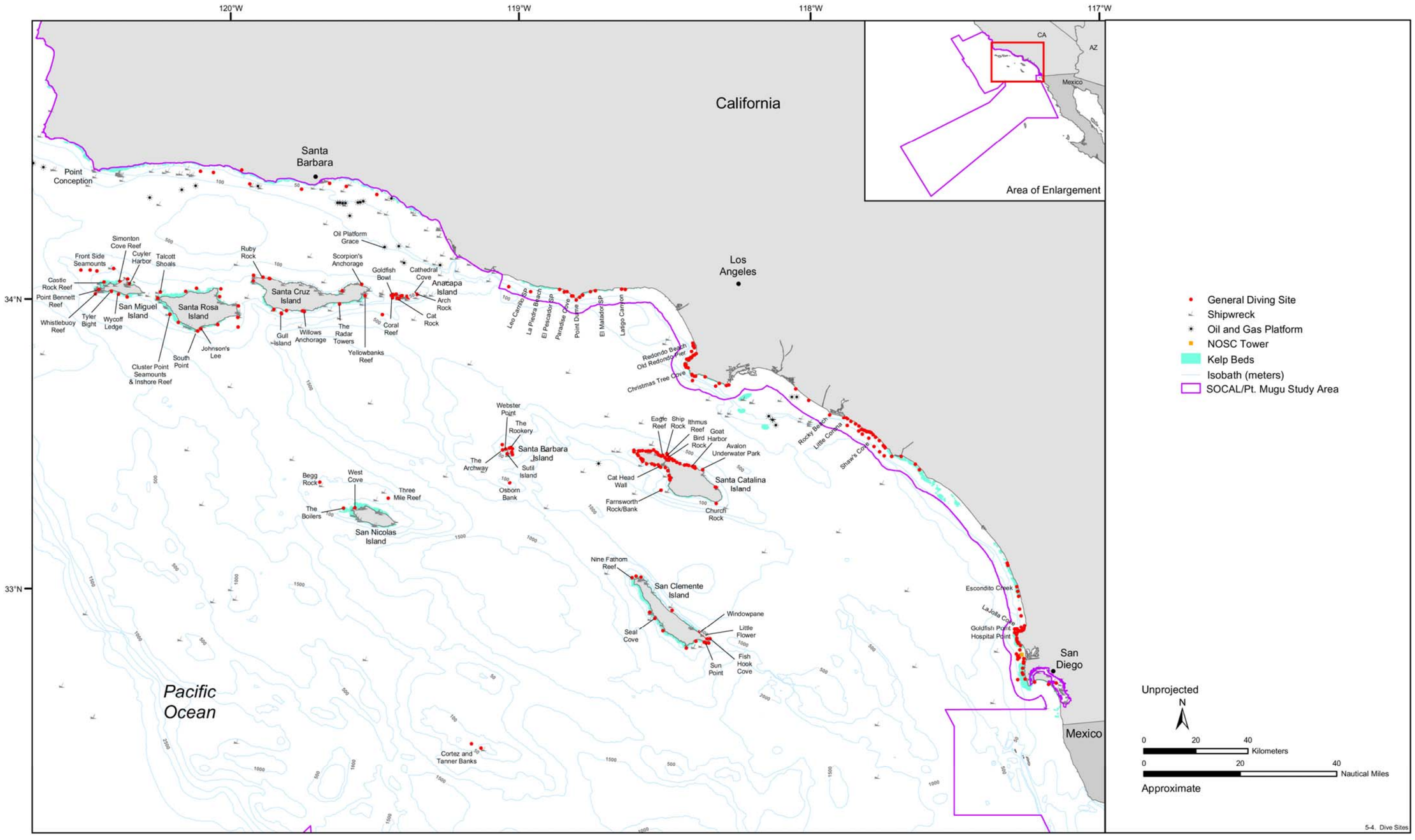

Figure 5-4. Locations of SCUBA dive sites in the SOCAL/Pt. Mugu Study Area. Source data: AMEC Earth and Environment (1999), NOS (2001), Veridian Corporation (2001), CSLC (2004), TerraLogic GIS (2004), NOS (2006), and MMS (2007). Source maps (scanned): Krival (2001), Waterproof Charts Inc. (2003), Sea Sabres (2004), CARE (2007a,b,c), and Nielsen (2007a,b,c,d,e).

California where shore diving occurs: Refugio State Beach, Mohawk Reef, Deer Creek Road, County Line Beach, Malaga Cove, Point Vicente, White Point, Scotchman's Cove, Woods Cove and Moss Street, and La Jolla Canyon. California Diving Adventures (2008)[8] describes additional sites where shore diving is prevalent, including Leo Carillo State Park; El Matador, El Pescador, and La Piedra Beaches; Point Dume; Paradise Cove, Escondito Creek, and Latigo Canyon; Redondo Beach; Old Redondo Pier; Christmas Tree Cove; Little Corona; Shaw's Cove; Rocky Beach; Goldfish Point; La Jolla Cove; and Hospital Point. Practically the entire southern California coast is amenable to shore diving, although the above sites offer the best conditions for divers.

- **San Diego**— In San Diego Bay, SCUBA diving is only allowed with a special permit due to heavy ship traffic. The only divers that are permitted in San Diego Bay are scientific divers (divers conducting scientific research); Navy Sea, Air, and Land (SEAL) team divers; and divers that have been contracted to clean, repair, and/or inspect ship hulls. Recreational diving is prohibited in both San Diego Bay and Mission Bay. Individuals must receive permission from the USCG prior to diving in either of these areas (DoN 2000). Wreck Alley is one of the most popular diving destinations off San Diego (**Figure 5-4**).[12] Located just offshore of Mission Bay, Wreck Alley houses the remains of several vessels that were scuttled in order to benefit divers and serve as artificial reefs, including the *Ruby E*, *ex-HMCS Yukon*, *Shooter's Fantasy*, and *El Rey* (Krival 2001).[12] Also located offshore of Mission Bay is the Naval Ocean Systems Center (NOSC) Tower, a Naval research station that collapsed in a storm in 1988.[13] At an average depth of 9 m, this site is suitable for divers of all skill levels. Off San Diego Bay are two additional shipwrecks, the *ex-USS Hogan* (a destroyer) and *S-37* (a submarine), which were used as Naval bombing targets during WWII. To the north, in the continental shelf waters of the Gulf of Santa Catalina, San Pedro Bay, and Santa Monica Bay, are several more shipwrecks (including an airplane wreck) for recreational divers to explore.[12] Popular dive sites in these waters include the wrecks of the *Olympic*, *Palawan*, and *Avalon*. Like most of the shipwrecks in Wreck Alley, the *Palawan* was sunk so that it could serve as an artificial reef.[11] Also in the San Diego area, New Hope Rock is an inshore kelp dive off Point Loma which is part of Point Loma's mile-long string of shallow rocky substrate. The kelp and rocky substrate of New Hope Rock provides habitat for lobsters, scallops, octopuses, nudibranchs, anemones, garibaldi, sheephead, calico bass, and olive rockfish (Krival 2001).

5.3.2 Channel Islands Dive Sites

Located approximately 17 to 70 nm off the southern California mainland, the Channel Islands are an underwater treasure.[11] Each island offers a unique array of marine life, bottom depths and terrain, underwater visibility, and gaming opportunities. With the exception of a few sites on Santa Catalina Island, dive sites in the Channel Islands are only accessible by boat. Dive charters based in Santa Barbara and Ventura usually take divers to the Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa) while those based in San Pedro, Long Beach, and San Diego most often visit the Southern Channel Islands (San Nicolas, Santa Barbara, Santa Catalina, and San Clemente) (Krival 2001).

- **San Miguel Island**—San Miguel Island is located outside of the lee of Point Conception and can be fairly inaccessible due to large currents and winds. Due to its inaccessibility, San Miguel Island has remained largely pristine and supports several pinniped rookeries (including two large northern elephant seal colonies as well as sea lions, northern fur seals, harbor seals, and occasionally, Steller sea lions) (Krival 2001). Around the west end of the island, the San Miguel Ecological Reserve protects these animals and nesting seabirds by prohibiting boats to approach within 275 m of shore. On the other areas of San Miguel Island, the boating proximity limit is 90 m from March 15 through April 30 and from October 1 through December 15.[9] These restrictions have encouraged abundant fish and invertebrate species assemblages, with the exception of abalone, which have suffered from overharvesting. Dive sites at San Miguel Island include Simonton Cove Reef, Castle Rock Reef, Point Bennett Reef, Tyler Bight, Wycoff Ledge, and Cuyler Harbor (**Figure 5-4**). The abundance of pinnipeds in the area attracts predatory great white sharks, especially at the west end of San Miguel Island; there have been no verified white shark attacks on divers in Southern California.[10]

- **Santa Rosa Island**—Santa Rosa Island is affected by strong currents and wind for much of the year and is rarely favorable for diving.[10] The island offers large expanses of sandy flats with low reefs, boulders, and kelp forests (Krival 2001). Santa Rosa Island provides spawning sites for halibut and habitat for lobster, which skews diver objectives from that of the sightseeing recreational to a halibut and lobster hunting purpose.[10] Dive sites at Santa Rosa Island include Talcott Shoals, Cluster Point Seamounts and Inshore Reef, South Point, and Johnson's Lee (**Figure 5-4**). With depths exceeding 180 m (600 ft) at some sites, it is common to see deeper water species such as vermilion rockfish and lingcod at more midrange depths (Krival 2001).

- **Santa Cruz Island**—Santa Cruz Island is the largest of the Northern Channel Islands at 40 km (25 mi) long.[11] Santa Cruz Island offers inshore reefs, wall dives, and coves; however, the dive conditions are often unfavorable with visibility often cutting off at less than 3 m (10 ft) due to the strong currents and winds. Dive sites at Santa Cruz Island include Gull Island, Willows Anchorage, The Radar Towers (Drop-Off Reef), Yellowbanks Reef, Scorpion's Anchorage, and Ruby Rock (**Figure 5-4**). It is common to see squid spawning year-round, which attracts schools of yellowtail, barracuda, mackerel, and white sea bass as well as sea lions and harbor seals. In addition, there is a growing population of giant black sea bass (*Stereolepis gigas*) that tend to reside around the rocky reefs of Santa Cruz Island (Krival 2001).

- **Anacapa Island**—Anacapa Island is actually three tiny islands: East, Middle, and West islands.[10] It offers visibility that often extends to 30 m (100ft). Much of Anacapa is a no-take zone out to depths of 6 m (20 ft) and up to 18 m (60 ft; in some areas); therefore, there are large populations of lobsters, scallops, and abalone.[10] Dive sites at Anacapa Island include Arch Rock, Cathedral Cove, The Goldfish Bowl, Coral Reef, and Cat Rock (**Figure 5-4**). Arch Rock and Coral Reef are the most popular and deepest dives on Anacapa Island. It is common to see huge schools of yellowtail and dense schools of blue rockfish. The habitats of Anacapa Island allow calico bass, garibaldi, surfperch, and sheephead to hide within the kelp, shallow caves, and underwater archways (Krival 2001).

- **San Nicolas Island**—San Nicolas Island is located 52 nm (60 mi) offshore, and is not as popular for scenic diving as other Channel Islands due to the continuous strong current and wind conditions and its distance from the mainland.[10] San Nicolas is home to a large naval base. Civilian vessels are allowed free access to the waters around San Nicolas unless the Navy is conducting specific operations. The island offers extensive areas of sandy bottom, rocky reef, and kelp forests. Similar to Santa Rosa Island, most divers come to San Nicolas Island with intent to take halibut and lobster. Dive sites at San Nicolas Island include The Boilers and West Cove (**Figure 5-4**). Elephant seals and sea lions have colonized several beaches on the west end (Krival 2001).

- **Santa Barbara Island**—Santa Barbara Island is a major pinniped rookery and one of southern California's best shallow water dive sites. Divers often encounter California sea lions, harbor seals, and sometimes an occasional elephant seal in the shallow waters that surround the island. Dive sites at Santa Barbara Island include the Rookery, Sutil Island, the Archway (which includes Seven Fathom Reef and Hidden Reef), Brittle Star Reef, and Webster Point (which includes Dragon Cave) (Krival 2001) (**Figure 5-4**).[11] The ocean bottom around the island is mostly flat with massive rock piles jumbled about. The rock piles are honeycombed with a maze of small passageways that are home to numerous spiny lobsters and sea urchins. Angel sharks (*Squatina californica*) and bat rays (*Myliobatis californica*) are easily found throughout the island's scattered sand flats, while blue, mako, and even great white sharks may be found in waters further offshore. Due to its exposure to strong currents, Santa Barbara Island is also home to a diverse assemblage of fish including smelts, sardines, rockfish, bass, barracudas, tunas, marlins, and swordfish (Krival 2001).[13]

- **Santa Catalina Island**—There are an abundance of areas around Santa Catalina Island for either SCUBA or free diving. The east side of the island offers some of the best water clarity and diving conditions in southern California. The bright orange Garibaldi, California's state fish, is a common resident along the island's leeward side. The windward side of the island is equally as impressive. Church Rock, Avalon Underwater Park, Goat Harbor, Bird Rock, Isthmus Reef, Ship Rock (home to the *Diosa del Mar* shipwreck), Eagle Reef, and Cat Head Wall are a few of Santa Catalina's many

nearshore dive sites (Krival 2001) (**Figure 5-4**). Avalon Underwater Park, home to several sunken vessels including the *Sue Jac* (a 20-m [65-ft] sailboat) and the *Valiant* (a private luxury yacht), is probably the busiest dive site in southern California. Catalina Harbor is also home to several wrecks, most of which were blown up during motion picture productions in the 1920s and 1930s.

- **San Clemente Island**—San Clemente Island is a very popular diving destination due to its great diversity of marine life and high underwater visibility. Northwest Harbor, on the north end of the island, is home to the shipwrecks *USS John C. Butler* (a Naval destroyer) and *Koka* (a Naval tugboat) as well as a small sea lion rookery.[11] The west (or windward) side of San Clemente Island is known for its lobsters, abalones, purple hydrocorals, gorgonians, anemones, rock scallops, and large game fish, as well as the *ex-USS Gregory*, a Naval bombing target. At Castle Rock, Nine Fathom Reef, and Seal Cove, submarine caves and dense kelp forests can also be found. The east (or leeward) side of the island has consistently good water clarity, with visibility of up to 30 m, although surface currents are often severe. Popular dive sites on the southeast end of the island include Sun Point, Fish Hook Cove, Little Flower, and Windowpane (**Figure 5-4**). Oftentimes the Navy will declare San Clemente's waters hazardous to non-participating vessels and impose strict control over the 274-m (300-yard) buffer zone surrounding the island (DoN 2002). When the Navy holds live-fire exercises, it closes all or part of the area to civilian boat traffic (Krival 2001). Recreational diving at San Clemente is not allowed from shore.

5.3.3 Offshore Dive Sites

Begg Rock, Richardson Rock (Front Side Seamounts), Farnsworth Bank and the other deep reefs and seamounts located in the southern California waters are among the most beautiful dive sites in the world. They are also considered to be demanding dives and more advanced sites. These offshore dive sites are typically deep (30-m [90-ft]) dives and are often complicated by current and poor water clarity near the surface (Krival 2001).

- **Farnsworth Bank**—Farnsworth Bank, a large seamount located 4.3 nm south of Santa Catalina Island, in waters 18 to 40 m deep, is one of southern California's most popular and spectacular dive sites (**Figure 5-4**).[13] It is home to purple hydrocorals, white abalones, and several species of sea stars, anemones, nudibranchs, scallops, rockfish, pelagic fish, and elasmobranchs.[11]

- **Osborne Bank**—Situated 4.3 nm south of Santa Barbara Island (**Figure 5-4**), Osborne Bank is a long ridge that towers as much as a mile above the sea floor.[14] This bank provides technical divers with some of the best reef diving off the west coast of North America.[13]

- **Cortes and Tanner Banks**—Located approximately 87 nm from the southern California mainland (**Figure 5-4**), Cortes and Tanner Banks are two of the region's largest seamounts, the former being larger than the entire area of Santa Catalina Island (Krival 2001). Divers rarely visit these two banks, as they are located in very deep waters and are a long trek from the California mainland; however, lobster hunters and highly advanced SCUBA divers are able to dive these banks under calm conditions (Krival 2001). Cortes Bank has one divable wreck, the *Jalisco*, which was deliberately sunk in 1966.[15]

- **Oil Platform Grace**—Oil Platform Grace is another one of southern California's artificial habitats that is often visited by SCUBA and free divers. Standing in more than 61 m (200 ft) of water, the platform is located between Ventura Harbor and the east end of Santa Cruz Island (**Figure 5-4**). The platforms massive legs and braces provide substrate for diverse and abundant benthos, such as sponges, mollusks, and jumbo scallops. Sea lions and blue sharks are often seen in the area taking advantage of the resident populations of rockfish and calico bass (Krival 2001).

- **Front Side Seamounts**—Located on the north side of San Miguel Island (**Figure 5-4**), these four seamounts (Wilson Rock, Boomerang Bank, Richardson Rock, and Skyscraper) form a 7-mi chain of distinctive sheer walls of rock that rise from a few feet above the water to between 18 and 27 m (60 and 90 ft) of the surface (Krival 2001). The invertebrate life on these seamounts is unparalleled,

which, in turn, encourages an equally astounding fish community of rockfish, garibaldi, lingcod, and wolf eel (*Anarrhichthys ocellatus*) (Agardy 1999). Wilson Rock is the closest to San Miguel Island and unfortunately, the invertebrate life has been hit hard by sport divers harvesting scallops (Krival 2001).

- **Whistlebuoy Reef**—Located approximately ½ nm to the southwest of San Miguel Island (**Figure 5-4**), Whistlebouy Reef is a small seamount that is completely exposed to strong currents, crosscurrents, surge, and wind (Krival 2001). The reef provides unique topography with many turrets and steep walls. Depending on the tide, the seamount may be as deep as 27 m (90 ft) or as shallow as 18 m (60 ft) below the surface. Like most of the seamounts in the Channel Islands area, Whistlebuoy reef is completely encrusted with invertebrate life, which in turn provides shelter for a healthy population of rockfish, cabezon, lingcod, and ocean sunfish (*Mola mola*) (in the warmer months). The waters can be teaming with jellyfish, where, during El Niño years, sea turtles have been seen grazing (Krival 2001).

- **Begg Rock**—Begg Rock is a seamount that consists of a system of reefs and pinnacles located about 6 mi northwest of San Nicolas Island (**Figure 5-4**). Begg Rock rises to a maximum height of 15 feet above the water at average low tide. The entire dive site consists of two steep, inner walls and is unprotected from currents and wind. Consistent with the seamounts of the Channel Islands, the invertebrate life is diverse and abundant and it is common to see sculpin, octopuses, and schools of vermilion rockfish (Krival 2001).

- **Three Mile Reef**—Three Mile Reef is a seamount located at the front side of San Nicolas Island (**Figure 5-4**) that runs for about ½ nm east-west. It is surrounded by 61 m (200 ft) of water and rises to about 21 m (70 ft) below the surface. This site is popular with the recreational underwater photographers because of the abundant colorful invertebrate population including scallops, nudibranchs, sponges, tunicates, anemones, and giant keyhole limpets. In addition, it is common to see rockfish, lingcod, ocean whitefish (*Caulolatilus hubbsi*), and sheephead (Krival 2001).

5.4 SAILING REGATTAS

Sailing and yachting (both competitive and recreational) are year-round activities that occur in the waters of the SOCAL/Pt. Mugu Study Area. The California Department of Boating and Waterways (CDBW) oversees all sailing and yachting activities in the southern California region where there are a multitude of sailing and yachting associations and/or clubs.[16] These sailing and yachting associations/clubs are associated with the Council of Sailing Associations (CSA). The CSA, a component of U.S. Sailing (national governing body of sailing in the U.S.), consists of 11 areas that are represented by 37 Regional Sailing Associations (RSA).[17] The RSA are composed of local sailing associations and yacht clubs in specific geographical areas. Local sailing associations are sailboat racers who conduct local racing, whereas, yacht clubs are private or public organizations, usually with a specific facility. Within the southern part of California, Area J is represented by two Regional Sailing Associations: Southern California Yachting Association (SCYA) and Yacht Racing Union of Southern California (YRUSC).[17,18,19]

The SCYA is one of the most recognized yachting associations along the U.S. west coast and consists of approximately 88 sailing associations/clubs. It was created to support and promote amateur, recreational, and pleasure yachting in southern California by fostering local, regional, national, and international yachting competitions; coordinating race schedules, activities, and regattas; and conducting seminars; and providing training and education on race management and safety at sea.[17,18] The YRUSC is a racing association of 31 Southern California Yacht Clubs with land and water facilities capable of hosting major regattas, such as the Gold Cup, California Match Race Challenge, Stewart Carpenter Youth Regatta, and Pacific Ocean Racing Conference. Its overall purpose is to encourage and promote Corinthian yacht racing and related yachting activities and educational programs related to sailboat racing, race management, cruising, and yacht club management. As a voting member of the U.S Sailing Association CSA, the YRUSC represents the 31 member clubs and their individual members on the national level.[17,19]

The waters in and around San Diego Bay are an internationally recognized venue for competitive yachting.[20] In 1995, the America's Cup regatta race was held in waters just offshore of San Diego Bay.

Today, competitive sailors from a number of different countries frequently practice along the racing course. Inside the southern portion of the bay, a regatta course is located in open waters to the west of Naval Station San Diego and east of Naval Amphibious Base (DoN 2001). San Diego Bay hosts 8,281 boat slips that are currently at over 80% occupancy, 18 public marinas, 4 private yacht clubs, 4 free boat launch ramps, 55 boatyards, restaurant docks, and anchorages. Recreational boat berthing areas are found mainly at Shelter Island, Harbor Island, Embarcadero, Glorietta Bay, Coronado Cays, and Chula Vista. Aside from sailing, other recreational uses of San Diego Bay include motor boating, jet skiing, waterskiing, windsurfing, and kayaking (DoN 2000).

Other bays and/or harbors within the SOCAL-Pt. Mugu Study Area that have active yachting clubs supporting sailing regattas include Santa Catalina Island (3) in the SOCAL OPAREA and Morro Bay, San Luis (Avila Beach), Santa Barbara (2), Ventura Harbor (3), and the northern Channel Islands (4) in the Pt. Mugu OPAREA.[18]

5.5 OIL AND GAS STRUCTURES

Offshore oil and gas structures are under the jurisdiction of either the MMS or the State of California, depending on distance from shore. State waters are contained within 5 km of the shoreline. Oil and gas exploration and development activities on the Pacific OCS began in 1967 (Love et al. 2003). There are currently 27 oil and gas platforms installed in the waters off California; 23 occur in federal waters (under the jurisdiction of the MMS) and 4 are in state waters (Hoffman, C. Minerals Management Service, Pacific Region, pers. comm., 28 April 2004)(McCrary et al. 2003; Love and Schroeder 2006)(**Figure 5-5**).[21,22,23,24] There are also 302 km of pipeline in the Pacific OCS.[23] Of the 23 platforms in the Pacific OCS, 22 produce oil and gas and 1 is a processing platform.[22]

Platforms of the OCS are located in three general areas: Santa Maria Basin, Santa Barbara Channel, and Long Beach Area-San Pedro Basin (**Figure 5-5**).[38] Platforms of the OCS occur within a 29 to 365 m depth range.[23] There are also six man-made oil and gas production islands located in state waters (Bird Island, Rincon Island, Grissom Island, White Island, Freeman Island, and Chaffee Island) (McCrary et al. 2003) (**Figure 5-5**).[21,24] No new platforms have been erected off California since 1989 (Love et al. 2003); it is unlikely that any leasing will occur in the future (McCrary et al. 2003). On the Pacific coast, oil and gas structure names have to conform to a set of rules promulgated by the USCG (Love et al. 2003).

Oil and gas exploration/production structures in the marine environment are quite different from those found on land. The structures may be found some distance from shore (up to 17 km offshore in the case of the Pacific OCS)[23] and contain all the equipment, supplies, and living quarters necessary to explore or develop oil or natural gas reserves beneath the sea floor. Production structures or platforms may house equipment that separates oil, water, and natural gas; generates power; pumps oil and gas to shore; and provides living quarters for the production crews (Fury 2001). Most oil and gas production platforms rest on steel supports known as “jackets.” There are many types of production platforms; the fixed jacket structure is the only one used off California (Schroeder and Love 2004). The artificial oil and gas islands are bordered by armor rock and concrete tetrapods.

Offshore platforms and artificial islands act as artificial habitat for fishes and invertebrates; they increase the amount of available habitat to pelagic and benthic organisms (Schroeder and Love 2004; Love et al. 2006; Love and York 2006).[25] High fish abundances often occur at platforms off California (MBC AES 1987; Love et al. 2003; Love et al. 2006; Love et al. 2007). The portion of the structures above sea level, the living quarters and production facilities, also serve as habitat for migrating birds and insects (Russell 2000). It is commonplace that California sea lions haul out on the lower decks of OCS platforms and on associated mooring buoys. Other marine mammals that are sighted near the platforms include the occasional harbor seals; dolphins (especially common dolphins) and whales (e.g., grays and humpbacks) are routinely sighted around the platforms. It is not known whether sea turtles associate with oil and gas structures as they do in the Gulf of Mexico (Pierson, M. Minerals Management Service, Pacific Region, pers. comm., 6 May). As for the artificial oil and gas islands, the benthic habitat of Rincon Island supports

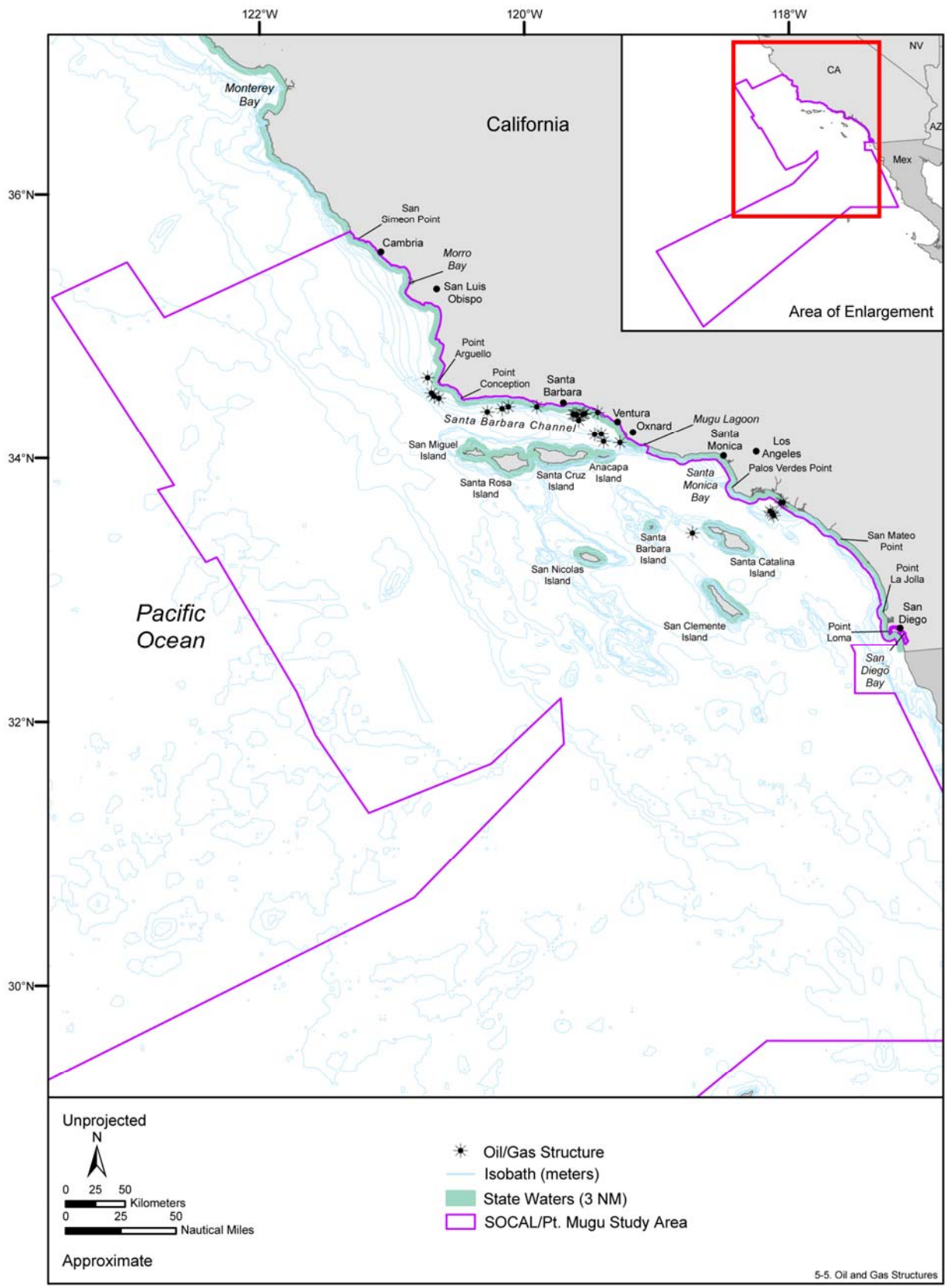

Figure 5-5. Locations of oil and gas structures within the SOCAL/Pt. Mugu Study Area. Source data: CSLC (2004), CARE (2007a,b,c), and MMS (2007).

substantial amounts of lobster[25] as well as diverse and abundant marine fauna and flora which differ significantly from the surrounding seafloor (Johnson and DeWit 1978). Some of the islands are well known to anglers who seek corvina, black sea bass, barracuda, halibut, and white sea bass along sand spits and sand bars of Grissom, White, and Freeman.[26]

When the oil or gas reserves are depleted, production ceases, the platform's usefulness ends, and the platforms must be removed. Originally, there were 34 platforms in the Pacific OCS. Seven of the platforms have been decommissioned and completely removed.[27] There are currently no plans to decommission any of the structures offshore of California (Hoffman, C. Minerals Management Service, Pacific Region, pers. comm., 28 April 2004). It is anticipated, however, that OCS platforms of the SCB located in water depths greater than 121 m will tentatively be decommissioned from 2009 to 2014 (Schroeder and Love 2004).

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6.0 RECOMMENDATIONS

The waters of the SOCAL/Pt. Mugu Study Area and vicinity 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. Although scientists know much about the nearshore waters of the SOCAL/Pt. Mugu Study Area, they know relatively little about offshore waters (beyond the 2,000-m isobath) of the SOCAL and Pt. Mugu OPAREAs. Despite the resulting wealth of information and data that are available for 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 waters of the Study Area, especially those resources that may be potentially affected by Navy operations. Each recommendation is assigned a priority value of 1, 2, or 3; 1 is the highest priority while 3 is the lowest. The priority designations are relative to each other and in no way refer to a recommendation's overall value. The relative cost of each recommendation is labeled low, moderate, or high. Low-cost recommendations may be completed at a cost of several hundred to a few thousand dollars. Moderate-cost projects could range from thousands to tens of thousands of dollars, while high-cost research initiatives range from tens of thousands to over one hundred thousand dollars. The recommendations are grouped into those related to the production and evaluation of the MRA and those needed to adequately complete environmental documentation for the SOCAL/Pt. Mugu Study Area.

6.1 MARINE RESOURCE ASSESSMENTS

- Revise the SOCAL/Pt. Mugu 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 datasets and published literature can be incorporated. The Navy needs the best (i.e., most recent, most complete, and most accurate) available information to evaluate future actions and consider adjustments to training exercises or operations in order to mitigate any potential impacts to protected marine resources. Periodic updates would be of moderate cost relative to the initial MRA. Cost: High. Priority: 1.

- Subject the SOCAL/Pt. Mugu 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 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.

- Obtain marine mammal and sea turtle datasets for the SOCAL/Pt. Mugu 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 additional datasets listed at the end of **Appendix A-3** may ensure more complete data coverage. 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 datasets to our understanding of the distribution of these protected species is high. Cost: Moderate. Priority: 1.

6.2 ENVIRONMENTAL DOCUMENTATION

- Support funding to initiate surveys and mapping to produce a comprehensive GIS shapefile database of benthic habitats (seagrass beds, macroalgae, coral reefs, rocky intertidal, beach, wetlands, and bottom substrates) for the Channel Islands and California coastline. The last comprehensive mapping effort was done by TerraLogic GIS (2004) for essential fish habitat of groundfish. Updated information is needed and the effort should be expanded to include surveys and mapping data to extend to all depths less than 100 ft (30 m). Collection and development of these data and habitat maps will provide essential knowledge to researchers regarding the various substrates for colonization and the Navy by better identifying habitats capable of supporting rare and endangered species. Cost: High. Priority: 1.

Table 6-1. Suggested expert reviewers for the SOCAL/Pt. Mugu MRA.

Name	Affiliation	Expertise	Address	Email
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Table 6-1 (*continued*). Suggested expert reviewers for the SOCAL/Pt. Mugu MRA.

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- Support a survey of the southern and offshore regions of the Study Area to obtain accurate, high-resolution bathymetry data. Currently, high-resolution bathymetry is available only for the northern extent of the Study Area. High-resolution bathymetry that spans the entire Study Area will better allow for an accurate assessment of shelf bathymetry. Cost: High. Priority: 2.

- Support efforts by the University of California System and the USGS to accurately map bottom sediments (unconsolidated sediments) in offshore areas of the SCB and beyond the Patten Escarpment. Bottom sediments in the region have been explored by a variety of groups but the data are not comprehensive, exist for isolated geographic areas, have been collected over a fairly large time period with evolving technology, and the data classifications are often limited to generalized categories (i.e., soft substrate, hard substrate, and mixed). Cost: Low to Moderate. Priority: 2.

- Additional research is required to determine the coverage of deep-sea corals in the Study Area and vicinity. Current research into these organisms is sparse in the continental borderland. This research could be combined with the previous two recommendations to reduce cost and increase the amount of information gained from one survey of the benthic habitats and bathymetry. Cost: Moderate to High. Priority: 3.

- Recreational sea bird pelagic trips are expanding in the SCB area and observations made from these trips, including GPS route tracks, would be helpful to increasing this knowledge. If marine mammal and sea turtle surveys were going to be conducted, there would be very little additional cost to add an experienced sea bird biologist on the surveys. In this way, knowledge and understanding of bird

abundance and distribution in the SOCAL/Pt. Mugu Study Area could be obtained with little to no cost. Cost: Moderate. Priority: 1.

- Fund dedicated marine mammal and sea turtle aerial and/or shipboard surveys in portions of the SOCAL/Pt. Mugu Study Area designated as areas of "no survey effort" (**Figures 6-1a** and **6-1b**). While it is essential to continue surveying in previously-studied areas to account for seasonal and inter-annual variation in 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 NMFS-SWFSC the means to provide greater focus on data collection and thereby greatly improve the ability to estimate species densities within the region. Cost: High. Priority: 1.

- Support onboard specialists to collect cetacean and sea turtle sighting data during CalCOFI surveys. This can be done at 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 support acoustic and visual monitoring for marine mammals at the Navy's Southern California Offshore Range (SCORE). Cost: Moderate to High. 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.

- 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 SOCAL/Pt. Mugu Study Area and vicinity, 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. 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.

- Conduct aerial surveys for sea turtles throughout San Diego Bay to augment the satellite/radio tracking and genetic sampling projects that are currently being performed by the NMFS-SWFSC Sea Turtle Research Program. Not much is known regarding sea turtle distribution in the northern part of the bay in particular. Monthly or quarterly surveys could help to elucidate the distribution patterns of sea turtles throughout the bay and also help to determine whether sea turtles are found there seasonally or year-round. Cost: High. Priority: 2.

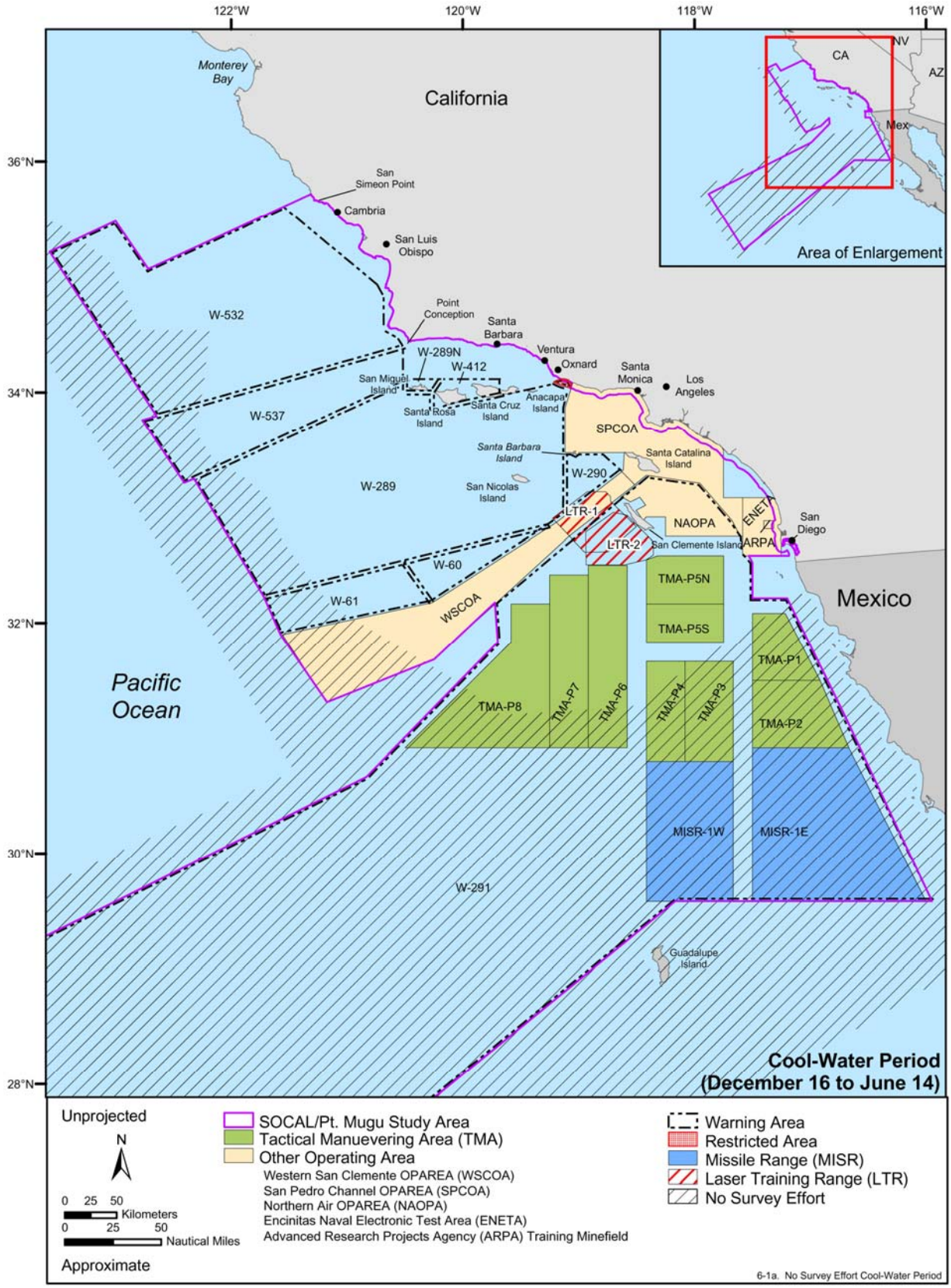

Figure 6-1a. Areas of no survey effort in the SOCAL/Pt. Mugu Study Area during the cool-water period (December 16 to June 14).

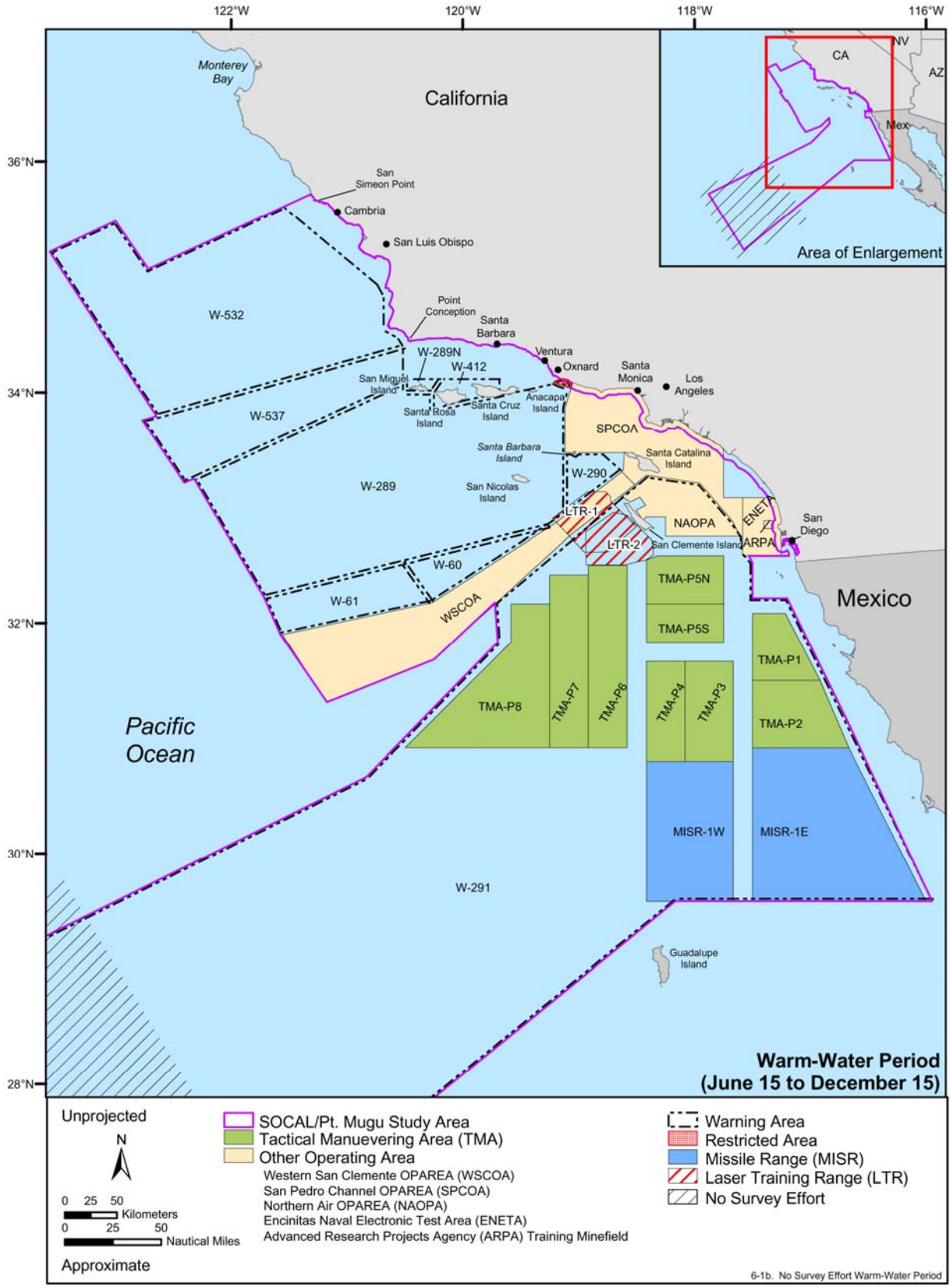

Figure 6-1b. Areas of no survey effort in the SOCAL/Pt. Mugu Study Area during the warm-water period (June 15 to December 15).

- Support research to update the Stinson (1984) report on the biology and distribution of sea turtles in San Diego Bay and the eastern North Pacific Ocean. A vast amount of information on sea turtles in this region has been collected over the past 20 yr. This information could be synthesized and presented in a single document, rather than scattered among journal articles, recovery plans, and gray literature. Cost: Moderate. Priority: 2.

- 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 species of concern, candidate species, proposed threatened/endangered (T&E) species, and critical habitats as they become designated by NMFS and/or USFWS (i.e., black abalone, various rockfishes, smelt, etc.). Cost: Moderate. Priority: 1.

- Update EFH identifications/descriptions/HSP maps, HAPCs, and ecologically important commercial/ recreational closure areas and status of overfished stock assessments as revised or additional amendments and/or FMPs become available from the Pacific Fishery Management Council, NMFS, and/or State of California (e.g., Forage Species Management Plan, Pacific Coast Groundfish, Pacific Salmon, and HMS FMPs). Cost: Moderate. Priority: 1.

- Support the development of a database containing all the SOCAL/Pt. Mugu Study Area EFH data and information, which would provide user-friendly access to all the EFH data and maps. Cost: Low to Moderate. Priority: 1.

- Support the development of a custom GIS-based application designed to provide 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.

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8.0 GLOSSARY

Abalones—are large marine mollusks of the class Gastropoda with single, oval, shallow shell containing beautifully colored interior

Abiotic—refers to nonliving

Abundant—refers to 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—refers to a 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—refers to a 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

Accretion—is a gradual increase in land area due to deposition of water-borne sediment; occurs along shorelines

Adhesive—refers to being sticky

Adjudicated Fishing Rights—are fishing rights of federally-recognized Indian tribes that have been established pursuant to court decree

Adult—is the developmental stage characterized by sexual or physical (full size and strength) maturity

Advection—is the 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—refers to life or biological processes that can occur only in the presence of oxygen

Aggregation—is a group of animals that forms when individuals (usually similar, but can also be dissimilar) are attracted to an environmental resource to which each responds independently; the term does not imply any social organization

Aggression—is 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

Alcid—refers to diving seabirds represented by 16 species that inhabit the nearshore and offshore zones of the North Pacific

Algae—is 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—is the dominant male; within a social group

Alevin—is the 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—is 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 fish, such as salmon, in which adults travel upriver from the sea to breed, usually returning to the area where they were born

Anaerobic—refers to life or biological processes that occur in the absence of oxygen

Anchovies—is a small herring-like schooling saltwater plankton-feeding marine fish of the family Engraulidae

Annelid Worms—are 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—refers to something irregular or abnormal

Anomurans—is a 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 effects, processes, objects, or materials that are derived from human activities, as opposed to those occurring in natural environments without human influences.

Anticyclonic—is the clockwise circulation in the Northern Hemisphere and counterclockwise circulation in the Southern Hemisphere; in oceanography, synonymous with warm-core ring

Area of Primary Occurrence—refers to areas and habitats where specific marine mammal or sea turtle species are primarily found; a biodiversity terminology specifically used for the MRA.

Area of Rare Occurrence—refers to areas and habitats where specific marine mammal or sea turtle species are not expected to be found regularly (in a given amount of time); a biodiversity terminology specifically used for the MRA.

Area of Secondary Occurrence—refers to areas and habitats where specific marine mammal or sea turtle species may be found, especially during “anomalous” environmental conditions; a biodiversity terminology specifically used for the MRA.

Arribada—is a large aggregation of female sea turtles exiting the ocean together to nest at the same time and the same place; mass nesting

Arrow Worms—are known as Chaetognaths, these torpedo-shaped, 2-120 mm long, chordata are found in marine plankton

Artificial Habitat—is a man-made, estuarine/marine habitat (shipwrecks, dedicated artificial reefs: rubble, concrete igloos, trains, tanks, ships, FADs) that provides food, shelter, or habitat which is created to attract aquatic life

Artificial Reef—is a man-made, reef habitat (sunken ships, trains, tanks, concrete igloos, rubble) usually created in the navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Ascidians—are 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—refers to the populations of various species from a larger taxon characteristically associated with a particular environment that can be usually used as an indicator of the environment

Audiogram—is 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—is an electrophysiological far-field recording of the auditory nerve and its associated accessory auditory nuclei in response to a sound stimuli

Baleen—is 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—is a topographic feature on a continental (or island) shelf and over which the depth of water is relatively shallow (20 to 200m)

Barnacles—is 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—is 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 bays where a straight line is drawn from one side to the other to form the baseline

Basket Stars—are various brittle stars of the family Gorgonocephalidae with slender complexly branched interlacing arms

Basking—describes an activity whereby an individual (e.g. pinnipeds and sea turtles) exposes itself to the sun, generally for the purpose of increasing its core temperature; may be done at the water's surface or on land

Batch Spawner—is a species that spawns repeatedly, releasing batches of eggs and sperm into the open-sea marine environment for external fertilization and development

Bathyal—refers 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—refers to the intermediate and lower continental slope usually at depths of 50 to 2,500 m in the Northeast Pacific Ocean

Bathylagids—are deep-sea smelts of the family Bathylagidae that inhabit the meso- to bathypelagic zones of the ocean

Bathymetry—refers to the topography of the ocean floor; study and mapping of the ocean depths

Bathypelagic—refers to the depth zone of the oceanic water column below the level of light penetration at depths between 1,000 and 4,000 m

Bay—is a body of water partly enclosed by land but with a wide outlet and connection to the sea

Beach Groin—is a protective structure of stone or concrete extending into the shore to protect a beach against erosion or to trap shifting sands

Beaked Whales—are members of the family Ziphiidae, includes the genus *Ziphius*, *Mesoplodon*, *Indopacetus*, *Berardius*

Behavioral Audiogram—is 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—are organisms living on or near the ocean floor; the term is used irrespective of whether the sea is shallow or deep

Benthopelagic—is the ecological zone from the seabed to 100 m above the seabed

Benthos—is the collection of organisms that are found in, on, or are attached to the ocean bottom substrate

Bight—is an inward bend or bow in the coastline

Billfish—is a large warm-water fish usually associated with tropical and subtropical seas having a prolonged and rounded toothless upper jaw of the family Xiphidae

Biodiversity—refers to the diversity of living things; variety of life on earth and the ecosystems which support it

Biomass—refers to the amount of living matter per unit of water surface or water volume

Biotic—pertaining to life or living organisms

Bivalve—is a 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—is 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—is 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—are the nostrils or nasal openings on top of the head of a cetacean

Blubber—is a specialized layer of fat found between the skin and underlying muscle of many marine mammals; it is used primarily for insulation and energy storage

Boreal—refers to waters in the far northern latitudes

Bottlenose Dolphin—refers to the former common name for *Tursiops truncatus,* now called the common bottlenose dolphin

Brachyuran Crabs—are a group of crustaceans including the true crab characterized by a short abdomen concealed under the cephalothorax

Brackish—refers to waters having a salinity between that of fresh (0 psu) and sea water (37 psu)

Braided (meandering) Channel—refers to ever-changing smaller channels that together constitute the course of an entire river

Brail Net—refers to a fishing gear consisting 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

Breakwater—is a structure protecting shore area, harbor, anchorage or basin from waves

Brittlestar—is a starfishlike echinoderm belonging to class Ophiuroidea that has five to eight elongate, slender, cylindrical arms distinctly radiating from a flat central disc

Broadcast Spawner—is an organism which releases its gametes into the water, where external fertilization occurs; without parental care

Brood—are young of an animal cared for at one time

Brown Algae—is a 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

Brumation—refers to a state similar to hibernation in which a reptile dramatically reduces its food intake although it may still drink. Both hibernation and brumation are a response to cold weather but in brumation the animal's response does not exhibit the extreme torpor of a hibernating animal

Bryozoans—are 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—refers to a coordinated feeding technique of humpback whales, in which they use bubbles to corral and trap small fish or invertebrates

Bull—is a male seal or whale, especially an adult male

Buoy—is a bright-colored float which is often used in commercial fishery operations. Buoys are attached by rope, line, or cable to the seabed or fishing gear to mark and retrieve gear. Also used mark channels in a harbor or underwater hazards

Bycatch—are marine species incidentally caught in a fishery which intended to target another species, but which are not sold and usually not kept for personal use. Includes economic and regulatory discards; bycatch species can be either alive or dead

Calcareous—refers to being composed of calcium or calcium carbonate

Calf—is a young animal that are dependent on its mother

California Current—is an 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—is a patch of thickened, keratinized tissue on the head of a right whale, inhabited by large numbers of whale lice

Calving Interval—is the period of time from one birth to the next, generally applicable to cetaceans

Calving—is the process of giving birth by marine mammals (whale, dolphin, porpoise, or manatee)

Cancroid Crabs—are a family of crabs, Cancroidea, including the genus Cancer

Candidate Species—is a species that is the subject of either a petition to list or status review, and for which the NMFS or the USFWS has determined that listing (under the Endangered Species Act) may be or is warranted

Canopy—is the cover produced by the intermingling of upper branches of trees in a forest. Analogous cover can be formed by algae and octocorals.

Carangids—are burrowing shrimp

Carapace—is the outer covering, dorsal, convex part of a shell. Can refer to the outer shell of a crustacean or sea turtle. In sea turtles, the carapace is bony with the exception of the leatherback, which has a leathery covering

Carbonate—is a 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—are a caridoid decapod crustacean with phyllobranchiate gills, second abdominal pleura forming a caridean saddle, and usually two pairs of chelae but never three

Carnivora—is an order of living and extinct mammals that includes such species as pinnipeds and otters

Carnivore—is an animal that feeds exclusively on another animal's tissue

Carrying Capacity—is 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)—is a term commonly used by fishery biologists as an index to fish population density. Calculated as measure of a species relative abundance; expressed as the ratio of the number of animals by some level or type of effort (e.g. hooks, sets, trips, landings, weight)

Category 1 Fishery—is a category of fisheries that can not be placed on any of the subsequent categories, because of lack of data; terminology used by the FAO for classification purposes

Category 2 Fishery—is a category of species pursued in directed fisheries, and/or regularly found in bycatch, whose catches have not decreased historically, probably due to their higher reproductive potential; terminology used by the FAO for classification purposes

Category 3 Fishery—is a category of 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; terminology used by the FAO for classification purposes

Category 4 Fishery—is a category of species in this category show substantial historical declines in catches and/or have become locally extinct; terminology used by the FAO for classification purposes

Category 5 Fishery—is a category of species that have become rare throughout the ranges where they were formerly abundant, based on historical records, catch statistics, or expert's reports; terminology used by the FAO for classification purposes

Cephalopods—are any marine mollusk of the class Cephalopoda, with the mouth and head surrounded by tentacles (squid, octopus, cuttlefish)

Cere—is a fleshy area at the base of the bird's beak

Cetaceans—are of the most distinctive and highly specialized orders of mammals which includes whales, dolphins, and porpoises of the order Cetacea

Chaetognaths—are known as arrow worms that are active elongated, transparent predators in marine plankton

Charter Fishing—is 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—is the family of hard-shelled sea turtles that includes seven species within five genera. The sea turtles occur worldwide in all tropical oceans. Found only in the marine with females coming ashore only to nest.

Chevron—is a V-shaped stripe

Chimeras—is a deep-sea cartilaginous fish of the family Chimaeridae having a smooth-skinned tapering body and a whip-like tail

Chitons—are 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—is green algae

Circumglobal—refers to animals that are found or range around the world

Circumpolar—refers to animals that range around high northern or southern latitudes

Cladocerns—refers to an order of microscopic crustaceans with trunk limbs enclosed in a carapace used for feeding and antennae used for swimming; called water fleas

Clan—refers to 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—is 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—refers to the total number of eggs from one nesting usually in reference to turtles

Cnidarians—are 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—are marine waters that are along and near the coastline

Coast—refers to the boundary where land and water meet

Cochlea—is 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—refers to a patterned series of 3 to 20 clicks lasting about 0.5 to 2.5 seconds, used by sperm whales for communication

Cods—refers to any of various marine fishes of the family Gadidae, especially the Pacific hake

Cold-core ring—is an eddy or circular current of warm water; in the North Atlantic Ocean, the water in cold-core rings circulates cyclonically (counterclockwise)

Cold-stunning—refers to the state that turtles enter when they are suddenly exposed to very cold water (< 10 °C). They become lethargic and begin to float on the surface of the water. In this state, they are susceptible to predators, accidental boat strikes, and even death if water temperatures continue to drop

Cold-temperate—is the latitudinal zone extending between 45 degrees and 58 degrees in both northern and southern hemispheres

Colonial—are nesting in groups or colonies rather than in isolated pairs

Colony—is a highly integrated group of animals; herein refers specially to birds and land-breeding pinnipeds

Commercial Fishing—is fishing in which the fish is harvested, either in whole or part, an which is intended to enter commerce through sale, barter, or trade

Common—is terminology often used for population status. It indicates occurrence. Common indicates animals have been recorded in all, or nearly all, proper habitats, with some areas of the presumed habitat

Community—is a group of killer whales that can be linked together through associations. Although all whales in a community may not have been observed to mix, all can be linked together through intermediate associations

Conservative Plate Margin—refers to a boundary between two tectonic plates along which neither plate is destroyed.

Conspecific—refers to a member of the same species, and in many cases, the same age or even sex

Continental Divide—is 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—is the boundary or transition area between the continents and the ocean basins that consists of the physiographic provinces of the continental shelf, continental slope, and continental rise

Continental Rise—refers to an area; the province of the continental margin with a sloping seabed (1:100-1:700 gradient change) and a generally smooth surface; the area which lies between the abyssal plains and continental slope

Continental Shelf Break—is 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—refers to an area; 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—refers to an area; 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—are small planktonic crustaceans present in a wide variety of marine habitats and in great abundance, 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

Coralligenous—refers to the formation of biogenic concretions; coral forming

Coral Reef—is a massive, wave-resistant structure built largely by colonial, stony coral via deposition of calcium carbonate; forms habitat for a variety of marine animals; only formed under specific environmental conditions and locations

Coriolis Effect (Force)—is a change in motion resulting from the Earth's rotation. It causes objects in motion to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere. The Coriolis Effect varies with latitude, being nonexistent at the equator and maximum at the poles. It dominates motion at large spatial and temporal scales (e.g., circulation in ocean basins) but is negligible at smaller scales (e.g., circulation in a swimming pool)

Cosmopolitan—refers to having a broad, wide-ranging distribution

Cottids—see sculpin

Councils—refer to the fishery management council system that was established by the Magnuson-Stevens Fishery Conservation and Management Act by Congress in 1976. The eight regional fishery management councils are decision-making bodies and develop and recommend specific management measures in the form of fishery management plans, subject to approval and implementation by NOAA Fisheries

Countershading—is 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 more difficult to detect

Coverts—are rows of feathers that border and overlay the edges of the remiges and the rectrices on both the lower side and upper side of the body. The covert streamlines the shape of the wings and tail while providing the bird with insulation.

Crangonids—is a small slender-bodied chiefly marine decapod crustaceans with a long tail and single pair of pincers of the family Crangonidae

Crèches—IS a group of young animals all around the same age that herd together

Crepuscular—refers to being most active at low light levels during dusk and dawn

Crinoids—is a 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 Habitat—refers to the minimum portion of the habitat that is essential for the survival and recovery of protected (threatened and endangered) species, including but not limited to, areas for feeding or reproduction; designated through federal rule by NMFS or USFWS on a case-by-case basis under the authority of the Endangered Species Act of 1973

Croakers—is a member of the abundant and varied family Sciaenidae, carnivorous, spiny-finned fishes including the weakfishes, drums, and whitings

Crustaceans—are arthropods that have two pairs of antennae and a hard exoskeleton (shell); lobster, shrimp, and crabs are the most familiar examples

Cumaceans—is a sediment-dwelling invertebrate with a carapace that encloses the anterior thoracic segments, which form a gill chamber

Curved Carapace Length—is a measurement used by sea turtle researches defined as the length of a sea turtle's carapace as measured by a flexible tape measure

Cusk Eels—are elongate compressed somewhat eel-shaped fishes

Cuttlefish—is a marine mollusk of the class Cephalopoda that has 10 arms including two long tentacles it can draw back into its body

Cyclonic—refers to the counterclockwise circulation in the Northern Hemisphere or clockwise in the Southern Hemisphere; in oceanography, synonymous with cold-core ring

Damselfish—is a group of fish species of the family Pomacentridae with thin, compressed bodies and circular outlines

Davidson Current—refers to the coastal countercurrent found north and inshore of the California Current; located along west coast of U.S. (from northern California to Washington to at least 48 degrees north) during winter months

Decapod—is an 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)—is the 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 μPa and the reference range is 1 m, while for underwater sound, the reference is 1 μPa and the reference range is also at 1 m

Deep Scattering Layer—is 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—is the area of the ocean that is offshore of the continental shelf break; refers to waters deeper than 100 to 200 m

Delayed Implantation—refers to mammals; it is the suspended development of an embryo between shortly after conception and subsequent attachment (implantation) to the uterine wall

Delimitation—is terminology used in reference to maritime boundaries; refers to 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—refers to fish that live close to or on the seafloor, such as cod and hake

Demography—refers to 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—it is the physical property measured by mass per unit volume. Often used in biology, as a unit of measurement defined as the number of organisms per unit of distance or volume; often used as measure of abundance

Dermochelyidae—refers to classification, family of leatherback sea turtles

Desiccation—is the removal of water; the process of drying

Determined Spawner—refers to eggs that are fertilized simultaneously and hatch around the same time

Detritus—is a mass of dissolved organic waste material from decomposing dead plants or animals usually found on the seafloor

Diadromous—is the ability for animal to migrate 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—are 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—is the intermixing of particles as a result of movement caused by thermal agitation

Dinoflagellates—are 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; often used to harvest small fish such as chub mackerel

Dispersal— refers to those processes by which a species maintains or expands the distribution of a population. Can refer to the movement of individuals throughout suitable habitat within or outside the population range.

Display—is any behavior that conveys information, usually to members of the same species or to predators; often used during mating or territory defense

Diurnal—refers to activity occurring during daylight hours; having a daily cycle

Dive Gear—refers to gear such as snorkel or SCUBA that is used to harvest commercially valuable invertebrates (sea urchins, abalone, or sea cucumbers) or fish. Divers often use a "hookah" system consisting of a long air hose connected to an air compressor on the deck of a boat to harvest animals

Dominant Species—are species most prevalent in a particular community, or at a given period

Dorsal—refers to the upper surface of an animal

Drift Algae—is detached intertidal and subtidal kelp forming floating mats

Drift Gillnetsrefers to commercial gillnet fishing gear that is attached un-attached to the stern of a fishing boat. Drift gillnets drift with the currents at the surface or below the ocean surface; sharks, tunas, and swordfish are among some of the targeted species

Dropoff—is a very steep or perpendicular descent

Drum Seines—are purse seines that are hauled into drums requiring less people to operate; species commonly targeted include sardines, anchovy, and mackerel

Ebb Tide—refers to outgoing or a falling tide

Echinoderms—is a 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—is known as spoonworms; are sediment dwellers that extend their proboscis onto the sediment surface

Echiuroids—refers to unsegmented marine worms with one or more pairs of bristles; these worms live in sand or rock crevices intertidally or in shallow water

Echolocation—refers to the production of high-frequency sound waves and reception of echoes to locate objects and investigate the surrounding environment

Ecosystem—is a system of ecological relationships in a local environment comprising both organisms and their nonliving environment, which are intimately linked by a variety of biological, chemical, and physical processes

Eddy—is the circular movement of water; this formation can be short-term or exist for a longer period. Eddies are influenced by major current systems, such as the California Current or Gulf Stream Current

Eelgrass—is a vascular flowering plant of the genus *Zostera* that are adapted to living under water while rooted in shallow sediments of marine bays and estuaries

Eelpout—is an elongate, tapering marine fish commonly found in the North Pacific

Ekman Layer—refers to the upper layer of the water column extending from the surface to the depth at which the wind stress affects water motion. The depth of the Ekman layer varies with the magnitude of the wind stress and latitude (Coriolis Effect).

El Niño—refers to the 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—are fishes of the class Chondrichthyes that are characterized by having a cartilaginous skeleton; includes sharks, skates, and rays

Electroreception—is the ability to detect magnetic fields radiated by marine animals

Embayment—is an indentation in the shoreline that forms a bay

Embryogenesis—is development of an embryo

Emigration—refers to the movement out of or away from an area by members of a given population

Endangered Species—refers to 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—refers to an animal or plant found in a specific area

Endothermy—refers to organisms which are capable of maintaining their bodily temperature above the temperature of the external environment

Environmental Impact Statement (EIS)—is 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—refers to animals living on the surface of the ocean floor; any encrusting fauna

Epi-mesopelagic—is zone of marine waters between epipelagic and mesopelagic

Epipelagic—is the oceanic zone from the surface to 200 m

Equidistant Line—refers to a median line, or equidistance; every point of which is the same distance from the nearest points on the baselines of two countries

Erosion—is the gradual wearing away; loss of land due to the wearing away or transport away of materials by water, wave and wind action

Essential Fish Habitat—refers to those habitats necessary to fish for spawning, breeding, feeding, or growth to maturity; designated by the NMFS

Estuarine—refers to, relating to, or found in an estuary

Estuary— is a semi-enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the open sea; the area where freshwater water meets and mixes with seawater; typically a bay; often an area of high biological productivity and important as nursery areas for many marine species

Euhaline—is water with salt concentrations of 30 to 40 ppt

Euphausiids—is known as krill, these are pelagic shrimp-like crustaceans

Euphotic Zone—is the uppermost area (up to 150 m) of the ocean that is sufficiently illuminated to permit photosynthesis by phytoplankton, algae, and submerged aquatic vegetation

Eutrophication—is the process by which nutrient-rich water promotes a rapid growth of algae and phytoplankton, thereby reducing the water's dissolved oxygen content

Evolutionary Significant Unit—refers to a population that is substantially reproductively isolated from conspecific populations and represents an important component in the evolutionary legacy of the species (e.g. salmonids); often used as a regulatory term by government agencies under the authority of the ESA (Endangered Species Act) for protecting and conserving the species

Exclusive Economic Zone—refers to 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

Exclusive Economic Zone—refers to the waters from the low-tide line seaward to 200 NM in which the inner boundary is a line coterminous with the seaward boundary of each coastal state or territory; special circumstances exist for situations where EEZs of nations overlap

Extirpated—is a species that no longer exists in the wild

Extirpated—is a local extinction; refers to the loss of a species in a given geographic area

Extralimital—refers to 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

Ex-vessel Value—is the value in currency of seafood products at the dock as it is offloaded from the fishing vessels

Eye patch—is the elliptically-shaped white patch located above and behind a killer whale's eye

Eyrie—is the nest or dwelling made by a bird of prey, usually elevated in a tree or on a cliff

Falcate—refers to the sickle-shaped and curved (refers to the dorsal fin of some cetaceans)

False Crawl—refers to an event; a female sea turtles' attempt to lay a clutch of eggs, digging a nest, or part thereof, but not actually depositing any eggs

Fathom—is a marine unit of measure of water depth equaling 1.83 m

Fauna—refers to the animals of a given region

Fecundity—is the potential of an organism to produce offspring (measured as a number of gametes)

Fingerlings—is terminology used for describing juvenile salmonids up to nine months of age, generally two to four inches in total length. Also called parr, but can also be referred to as hatchery juveniles

Fish Aggregating Device—is a single or multiple floating structures that are connected to the ocean floor by ballast or anchors; used to attract fish

Fishery Management Plan—is a management plan prepared by a Regional Fishery Management Council or by NMFS (if a Secretarial plan) to manage commercial fisheries in a given geographical area of the United States

Fishery—is one or more stocks of fish that can be categorized as a unit for purposes of conservation and management; 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 (e.g. otters)

Fjord—is a glacially over deepened valley, usually narrow and steep-sided, extending below sea level and filled with salt water

Flabelliferan Isopod—is a member of the suborder Flabellifera. Characterized as having 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. One of the most common shallow-water marine species

Flank—refers to the side of the body; used mainly to refer to the side of the posterior half of the body

Flatfish—are members of the fish order Heterosomata. Flatfish swim or lie on one side of its body; sides are greatly flattened and compressed; mainly marine animals (e.g., flounders, soles)

Flipper—refers to the flattened forelimb of a marine mammal

Flood tide—refers to incoming or rising tide

Flora—refers to the plant species of a given area

Flotsam—refers to marine debris; can also refer to the wreckage or cargo left floating on the sea surface after a shipwreck

Flounder—see flatfish

Flukes—refers to the horizontally spread tail of a cetacean

Flying Fish—is a tropical marine fishes of the genus *Exocoetus* having enlarged winglike fins used for brief gliding flight

Flying Gurnard—is 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—are any fish preyed upon by larger predatory fish, seabirds, or marine mammals; usually associated with large schools of swimming fishes (e.g., anchovies, sardines)

Forage—is the act of searching for food (prey items) or provisions; can also refer to graze or consume

Fork Length—refers to the length of a fish measured from the tip of the snout to the fork of the tail

Front or Frontal—see "ocean front"

Fry—is a newly hatched fish; smaller than a juvenile

Fundamental Frequency—is the lowest frequency of a harmonic series; measured in the Hz (cycles per second)

Fusiform—is a spindle-shaped or torpedo-shaped and tapering at one or both ends

Gadids—are members of the family Gadidae which includes Pacific cod and hake

Gametes—is a mature egg or sperm, capable of reproduction after fertilization with sperm or egg from same species

Gammarid Amphipods—are amphipods commonly associated with sediments

Gape—is the mouth in cetaceans, usually referring to the junction of upper and lower lips

Gastropods—are a class of symmetrical, univalve mollusks that have a "true" head, an unsegmented body, and a broad, flat foot

Genera—is one of taxonomic or scientific classifications of plants and animals

Geologic—pertaining to, or based on the scientific study of the earth's structure (geology)

Gestation—is the period of development in the uterus from conception until birth (pregnancy)

Gillnet—is 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; can be constructed of nylon or monofilament

Gonadal—pertaining to reproductive organs, ovaries (females) or testicles (males)

Gonochoristic—referring to a species that has separate sexes (i.e., male and female individuals)

Greenlings—are small cold-water fishes of the family Hexagrammidae found only on the Pacific coast

Gregarious—is used to describe animals that form social groups

Groundfish—are 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—is the trough or lengthy, narrow, depression in the sea floor extending into a continental shelf or toward a seacoast

Gyre—is the circular movement of waters, larger than an eddy; usually applied to oceanic systems

Habitat Area of Particular Concern—are 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; can also be used to describe a type of marine protected area

Habitat—is the area where an organism is found temporarily or permanently; it provides the essentials for survival: sustenance, food, water, shelter, and space

Habitat Preference—is an ecological term that refers to the specific choice by an organism to a particular habitat in relation or preference to others

Hake—are any of various marine food fishes of the genus Merluccius and Urophycis, relater to and resembling the cod

Hard Bottom Community—is an 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—are a group of females whose breeding is controlled by a single male who seeks to prevent other males from breeding with them

Harmful Algal Bloom—is an increased biomass (blooms) of harmful phytoplankton, including red tides, brown tides, and toxic and noxious blooms; may affect upper trophic levels, including humans, directly or indirectly through bioaccumulation

Harvestable Rate—is terminology used in fishery science that refers to the 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—is terminology to describe fish taken as a result of encounters with fishing gear; usually for profit

Hatchling—is a newly hatched bird, amphibian, fish, or reptile

Haul Out—refers to the process by which pinnipeds and sea turtles crawl or pull themselves out of the water onto land for the purpose of respite, basking, breeding, nesting and/or molting; can be intertidal rock outcrops, sandbars, shoals, mudflats, or sandy beaches; important area where marine mammals periodically and purposefully come ashore

Haul Out Site—refers to intertidal rock outcrops, sandbars, shoals, mudflats, or sandy beaches where marine animals, such as pinnipeds, periodically and purposefully come ashore

Headlands—are high, steep-faced promontory areas that extend into the sea

Hemipelagic—is originating from both the pelagic and nearshore environment (e.g., hemipelagic seawater).

Herbivore—is an animal that consumes plants as its main source of energy

Hermit Crab—is a marine crustacean living in cast-off shells of gastropods

Herring—are various marine fishes of the family Clupeidae; these fish are an important prey item for other species of the Pacific and Atlantic waters

Heterogeneous—is having a non-uniform structure or composition

Histioteuthid Squids—are deep water squids that do not have a transparent corneal membrane but have eyelids; of the suborder Oegopsida

Holdfast—is 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 fish 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—refers to fishing gear where hooks are placed at the end of a line (monofilament, cable, nylon) includes pelagic longlines used to target tuna and swordfish

Hydric Soil—are 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

Hydrodynamism—refers to wave action

Hydrographic—refers to the structure and movement of water bodies, particularly currents and water masses

Hydrography—is the science of measuring and describing the earth's surface waters

Hydroids—are a 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—is a transducer used for detecting underwater sound pressures; an underwater microphone

Hyperiid Amphipods—family and suborder of Amphipoda with a large head and eye, five abdominal segments and seven pairs of thoracic legs

Hypersaline is seawater with salinity above 35 psu

Hypoxia—waters with a low oxygen concentration, usually less than 2 to 3 mg/L; 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—refers to fish species found in a particular geographical area

Ichthyoplankton—refers to fish eggs and larvae that usually drift in the water column

Immature—refers to bird; one hatched in the spring of the same year

In situ—refers to the natural or original position

Incubation—the act of maintaining an egg warm so that development is possible

Indigenous—is having originated in and being produced, growing, living, or occurring naturally in a particular region or environment.

Infaunal—refers to invertebrates found in the sediment of the seafloor

Infrasonic—sound at frequencies too low to be audible to humans, generally below 20 Hz

Inshore—refers to an area close to the shore or coast

Insular—is geographically isolated; usually pertaining to an island

Internal Wave—is a gravity wave propagating in the interior of the ocean with typical spatial and temporal scales of kilometers and hours. The amplitudes are on the order of 10 meters, much larger than their surface counterparts.

Inter-nesting Interval—is the amount of time between successive sea turtle nesting events during the nesting season

Interpolate—refers to the 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—refers to the area of shore exposed between high and low tide in marine or estuarine environment

Invasive Species—is a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health; not all non-native species are considered invasive

Invertebrate—is an organism which lacks a backbone (e.g., mollusks, crustaceans); not vertebrate

Irruptive—refers to entering an area where not characteristically recorded

Isobath—refers to the bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isohaline—refers to the contour of equal salinity, usually shown as a line connecting points of the same salinity

Isopods—are shrimp-like animals of the order Isopoda that have their body flattened dorso-ventrally

Isopondylous Fish—are herring-like fishes with simplified anterior vertebrate

Isopycnal—refers to the contour of equal density; usually shown as a line connecting points of the same density

Isotherm—refers to the contour of equal temperature; usually shown as a line linking points of the same temperature

Iteroparity—refers to the reproductive strategy where individuals reproduce several times throughout their life

Iteroparous—is an organism that reproduces several times during its lifespan (i.e., does not die after spawning)

IUCN Red List—is a list of animal species and subspecies established by the International Union for Conservation of Nature and Natural Resources which are thought to be threatened or endangered of extinction and those which are known or thought to have already become extinct in the wild

Jellyfish—is 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—are cargo or equipment deliberately thrown overboard from a ship and which either sink or wash ashore.

Jetties—refers to a 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—are mostly similar in form to adult but not yet sexually mature; a smaller replica of the adult

Kelp Holdfast—is a branched, modified stem that attaches kelp to rocks or other hard substrata

Kelp Sporophyll—is a leaf structure that bears sporangea (a spore-bearing structure)

Kelp—are a 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) an important habitat in the Pacific Ocean

Kilopascal (kPa)—is a standard unit of pressure in the International System of measurements

Kleptoparasitism—is a form of feeding where one animal takes prey from another that has caught, killed, food theft from another animal

Kogia—refer to the genus comprised of the pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*Kogia sima*)

Krill—see euphausiids

La Niña—is an oceanographic event 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—is secretion or formation of milk by the mammary glands for the purpose of nursing offspring

Lair—refers to 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—are large elongate scaleless oceanic fish with sharp teeth and a long sail-like dorsal fin of the family Alepisauridae

Lanternfish—refers to a small, usually deep sea fish with many luminescent spots on their bodies of the family Myctophidae

Larval—refers to fish life stage between time of hatching and attainment of juvenile characteristics

Larvaceans—is any small free-swimming tunicates of the class Larvacea

Lead-210—refers to a method of dating that makes use of the ratio of the amount of the radioactive isotope lead-210 to that of the stable isotope lead-206. The is particularly useful for determining the ages

of relatively recent marine sediments and so has been applied to studies concerned with the impact of human activity on the aquatic environment

Leads—long narrow channels of open water in the sea ice which form between pack ice and the shore

Lithodids—are cold water deep-sea crabs of the family Lithodidae

Littoral—refers to the zone or division of the ocean bottom between the high and low tide lines; intertidal

Live Bottom Community—is 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; provides habitat for many marine species

Longline Gear—is a type of commercial fishing gear where lines (cable, nylon, monofilament) are deployed horizontally to which gangions and hooks or pots are attached; gear can be stationary, drift, anchored, or buoyed. Gear may be hauled manually, electrically, or hydraulically; gear is used to catch various types of bottom fish (rockfish, sablefish, halibut, sharks)

Longshore Transport—is an oceanographic process where sediment transported (moved) down the beach (parallel to the shoreline) caused by longshore currents and/or waves approaching obliquely to the shoreline

Loral—is the area between the eye and the base of the bill; refers to birds

Lost Year—refers to an early juvenile stage (first years of life) of most sea turtle species that is spent far offshore; a period during which few turtles are observed

Low-frequency Sound—is sound having frequencies below 1,000 Hz

Lumpsuckers—refers to a 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—refers to small to moderate sized invertebrates found on or in bottom sediments; visible with the naked eye

Macrophyte—refers to the macroscopic plant in an aquatic environment

Macroplanktonic—refers to large planktonic organisms 20 to 200 mm in diameter

Macroscopic algae—are large algae, commonly referred to as seaweed

Macrourids—are common and abundant deep-sea fishes; also known as rattails or grenadiers of the family Macrouridae

Map Projection—is a mathematical formulation that transforms feature locations on the earth's curved surface (three-dimensional) to a map's flat surface (two dimensions)

Marine—of or pertaining to the sea or ocean

Masking—is the process of obscuring sounds of interest by interfering sounds, generally at similar frequencies

Matriarch—is the eldest female in a matrilineal group, pod, or subpod; can refer to marine mammals (killer whales)

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—are the process of becoming mature

Maximum Sustainable Yield—is a fishery science term that refers to the largest long-term average catch or yield that can be taken from a fish stock or fish stock complex under prevailing ecological and environmental conditions

Mean—refers to the (arithmetic) calculated average

Mean Higher High Water—refers to the average height of all daily higher high waters recorder over 19-year period, or computed equivalent period

Mean Lower Low Water—refers to the 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 Sea Level—is the arithmetic mean of hourly water elevations observed over a specific 19-year tidal epoch

Median—is (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

Median Line—is an imaginary line equidistant from the baseline of each country; used to determine breadth of a nation's EEZ where nations lie within 400 NM of one another

Melon—is 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—is water with a salt concentration of 5 to 18 psu

Mesopelagic—is ocean zone of intermediate depths from about 200 to 2,000 m below the surface, where light penetration does not typically occur

Mesoplodon—are a taxonomic classification; 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—refers to large scale; typically pertaining to atmospheric phenomena

Metabolism—refers to all biochemical reactions that occur in an organism

Metadata—refers to 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—is a process of transforming from one body form to another form during development (e.g., tadpole changing to a frog)

Microhabitat—is a smaller part of a habitat that has some internal interactions allowing it to function self-sufficiently within a generally larger habitat

Midshipmen—is any of various fishes classified under the genus *Porichthys*, having several rows of light-producing organs along their bodies

Migration—refers to a 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

Migratory—is the classification of organism or group of organisms that undertake a migration as an essential part of their life history

Mollusk—are largely aquatic phylum of bilaterally symmetrical, unsegmented invertebrates consisting of snails, squids, octopuses, clams, and others

Molt—refers to the shedding of an external shell or skin; often used in growth. In pinnipeds, this refers to fur shedding; 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—is the form and structure of an organism considered as a whole; appearance

Morphometric—is the study of comparative morphological measurements

Mudflat—is muddy or sandy coastal strip usually submerged by high tide; provides habitat for various marine life

Multiple Brooders—is a species which releases multiple batches of larvae over the course of a spawning period

Myctophids—refers to a taxonomic family (Myctophidae) of small oceanic fishes which are found 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—are small shrimp-like crustaceans

Mysticeti—is a suborder of cetaceans comprised of the baleen whales

Nape—is the back of the neck; generally refers to birds

Natal—refers to or associated with the time or place of animal's birth

Nasal septum—is the wall of flexible cartilage dividing the nasal cavity into halves

Nauplii—is earliest life stage of a crustacean larvae

Nautical Mile—is a distance unit used in the marine environment that is equal to one minute of latitude or 1.85 km

Navigable Waters—are waters of the U.S. subject to the ebb and flow of the tide and/or are presently used, or have been used, or may be susceptible for use to transport interstate or foreign commerce

Nearshore—is an indefinite zone that extends seaward from the shoreline; generally refers to waters from the coast to the continental shelf break

Nekton—refers to actively swimming pelagic organisms that are able to move independently of water currents; typically within the size range of 20 mm to 20 m

Nektobenthic—is swimming off the seabed

Neonate—refers to a newborn

Neritic Zone—is the shallow portion of pelagic ocean waters; ocean waters that are found over the continental shelf, usually no deeper than 200 m

Neotropical—refers to tropical environs located in the western hemisphere, particularly southern Mexico, Central America and much of South America

Neustonic—refers to organisms found on or just under the water surface, often dependent on surface tension for support

Nocturnal—refers to events that occur during nighttime hours

North Pacific Transition Zone—is an ocean wide 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—is the region of the Pacific Ocean found north of the equator

No-take—is an area of sea that has been temporarily or permanently closed to fishing and other extractive activities to protect fish stocks and natural habitats

Nudibranch—is a 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—refers to a process by which saltwater or freshwater systems develop high nutrient concentrations

Occurrence Record—is a research term. Refers to 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

Ocean Front—is 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—refers to 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—is the scientific study of the oceans, including the chemistry, biology, geology, and physics of the ocean environment

Octave Band—is the frequency band whose upper limit in Hz is twice the lower limit

Odontoceti—is the suborder of cetaceans comprised of toothed whales (e.g., beaked whales, dolphins, porpoises, sperm whale)

Offshore—refers to the open ocean waters over the continental slope that are deeper than 200 m; water beyond the continental shelf break

Offshore Killer Whales—are 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

Olfaction—refers to the act or process of smelling

Olfactory—refers to the sense of smell

Oligotrophic—refers to the water that is lacking nutrients, which results in low primary production

Omnivore—refers to an animal that feeds on both plant and animal tissue

Ontogenetic Migration—refers to the movement by an animal to different habitats at different stages of development

Oophagous—refers to an animal that feeds on eggs

Opalescent Squid—is market squid which occurs in open coastal waters from the ocean surface to the bottom

Ophuiroid—are echinoderms known as basket stars or brittle stars that have long, slender, jointed arms distinctly separated from the body

Opisthobranchs—are gastropods with a well-developed shell and a single gill

Opportunistic—is terminology used to describe organisms that take advantage of all feeding opportunities; have wide-ranging diets

Optimum Sustainable Population—refers to any population stock in which the number of animals will result in the maximum productivity of the population or the species, dependent upon the carrying capacity of the habitat and the health of the ecosystem

Osmoregulatory—refers to the maintenance of an optimal, constant osmotic pressure in the body of a living organism

Ostracods—refers to crustacean like crabs and lobsters that have thicker ornamented valves

Otariids—refers to members classified under the family Otariidae; eared seals (sea lions and fur seals), which use their foreflippers for propulsion

Outer Continental Shelf—is the farthest of 200 nautical miles seaward of the baseline or, if the continental shelf that can be shown to exceed 200 nautical miles, a distance not greater than a line 100 nautical miles from the 2,500-meter isobath or a line 350 nautical miles from the baseline

Overfish—is a fishery science and regulatory term referring to 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—refers to an animal that is found in one particular area during the winter months (e.g. right whales return to northeastern Florida each winter to calve)

Oviparous—refers to producing eggs that develop and hatch outside the maternal body (i.e., externally)

Ovoviviparous—refers to giving birth to live young which have developed from eggs that hatched within the mother's body

Oxygen Minimum Zone—is a layer in the water column that has depleted oxygen levels as a result of bacteria consuming food material that is in the or passing through the area (layer)

Pack Ice—refers to sea ice, especially that which is unattached to land; characterized by its dynamism and seasonal expansion/diminution

Pandalid Shrimp—refers to nearshore and offshore members of the infraorder Caridea; coldwater "true shrimp" are commercially important

Parademersal—refers to animals that are found in 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—refers to the planktonic life stage of cephalopods

Parr—see fingerlings

Parturition—is the act of giving birth

Pathogen—is an biological agent that causes disease or illness to its host

Pectoral Fin—refers to flipper; flattened fore-limb of a cetacean (supported by bone)

Pelage—refers to the fur or hair covering a mammal

Pelagic—is the 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—refers to 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—refers to the 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—is brown algae

Phenology—refers to 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—refers to 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—is the uppermost zone in the water where sunlight permits photosynthesis

Photo-identification—is 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—is 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—refers to the geographic features of the earth's surface

Physiography—is the physical geography of the ocean bottom and continental margins

Phytoplankton—are 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

Piers—are platforms extending from a shore over water and supported by piles or pillars, used to secure, protect, and provide access to ships or boats

Pinnacles—are sharp pyramidal or cone-shaped rock partly or completely covered by water

Pinnipeds—refers to seals, sea lions, fur seals, and walruses

Pipefish—fish with long tubular snout and slim body covered with bony plates

Piscivorous—is a carnivorous animal that consumes and preys upon fish

Pistol Shrimp—refers to symbiosis or snapping shrimp of the family Alpheidae consisting of very short eye stalks and one much larger pistol claw

Planktivore—is an animal that consumes phytoplankton and/or zooplankton

Plankton—are small (mostly microscopic) organisms (including both plants and animals) that drift in the water column

Pleopods—refers to one of two pairs of abdominal appendages among crustaceans; “swimming legs”; may be used in swimming, fanning water, respiration or reproduction

Plumage—refers both to the layer of feathers that cover a bird and the pattern, color, and arrangement of those feathers

Plume—can refer to a feather or a moving and expanding body of water

Pod—refers to marine mammals; 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—refers to the latitudes near one of the poles (North or South), typified by cold and ice-infested waters

Pollock—are an important food and game fish of the northern seas, related to cod

Polychaete—is a 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—refers to water with a salt concentration between 18 and 30 psu

Pompanos—are any one of several marine food fishes of the genus *Trachynotus*

Population—refers to a group of individuals of the same species occupying the same area

Posterior—is a descriptive term; situated near or toward the back of an animal's body

Post-flexion—refers to the transformation of larvae into juvenile

Practical Salinity Unit—is a relatively new term used as the dimensionless unit for salinity, replacing parts per thousand (ppt)

Predation—refers to the 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—refers to an animal that is hunted, pursued, and caught for food (diet)

Pricklebacks—are small elongated, compressed, slightly eel-like fishes with long dorsal fin consists entirely of spines of the family Stichaeidae

Primary Producer—refers to the autotroph or organism able to utilize inorganic sources of carbon and nitrogen as starting materials for biosynthesis; uses either solar or chemical energy

Primaries—are the outer remiges and the largest and strongest of the flight feathers. Primaries are attached to the skeletal structure; sometimes equivalent to the "hand" of the bird.

Procedural—is not substantive; refers to the classification of law that dictates rules for application of substantive law (i.e., laws which define, create, and regulate legal rights and obligation)

Protected Species—is a species that is afforded special consideration as (by law) a result of being listed, or being considered for listing, under state or federal resource law such as the Endangered Species Act or the Marine Mammal Protection Act; a protected species often has a depleted or imperiled population and is in some form of extinction danger

Proboscis—is the flexible, elongated snout, of certain animals

Promontories—is a high ridge of land or rock jutting out into a body of water; a headland

Protogynous Hermaphrodite—refers to a sequential hermaphrodite; a fish that can reproductively transform from female to a male

Protracted Spawning—is a longer or extended spawning period

Psycho-acoustic Study—is 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—refers to 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

Pup—refers to a young animal of various species; (e.g., pinnipeds, sharks)

Pupping—is the process of giving birth (e.g. pinnipeds, sharks)

Purse seine—is 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—refers to a zone of marked water density gradient that is usually associated with depth

Pyrosomas—refers to blue-green bioluminescent, pelagic, tunicates that form thimble-shaped colonies of the genus *Pyrosoma*

Range—refers to the maximum extent of geographic area occupied or used by a species

Rare—is terminology used in population status; reference to a plant or animal that is restricted in distribution or number; in the case of sea turtles, rare means that a species is found, or probably is found,

regularly within the region but in very small numbers; in the case of marine mammals, rare means a species that only is found in the area sporadically

Ratfish—is a fish of Pacific waters having a long narrow tail

Ratify—refers to affirm or approve; in the case of a treaty, to agree to be bound by the treaty

Recreational Fishing—is fishing for sport or pleasure without the exchange of monies

Rectrices—are the tail feathers which are used to provide stability and control. Collectively, rectrices are connected to each other by ligaments, with only the innermost feathers attaching directly to the tailbone.

Redd—refers to a nest made in gravel consisting of a depression dug by a fish for egg deposition (and then filled) and associated gravel mounds (e.g. salmon nests)

Refractive Index—refers to the ratio of the speed of light in air or in a vacuum to the speed of light in another medium

Refugia—is an area that has escaped ecological changes occurring elsewhere and so provides a suitable habitat relict species

Regular—is terminology used in population status; in the case of marine mammals, a species that is found as a regular or normal part of the fauna of the area, regardless of how abundant or common it is

Relaxed Season—refers to the period (October-March) when winds are light and variable and the seas can remain calm in the Pacific Northwest

Relief—is the inequalities (elevations and depressions) of the sea bottom

Remiges—refers to the largest contour or flight feathers which area used for supporting the bird during flight; remiges are attached by ligaments or directly to the bone.

Remigration Interval—is the period (amount of time) between successive sea turtle nesting seasons

Resident Killer Whales—is a form of killer whale that feeds preferentially on fish, especially salmon, and has a very stable social structure

Rhodophyte—is red algae

Riffle—is a shallow area of a stream in which water flows rapidly over a rocky gravelly stream bed

Riparian Vegetation—are plants that grow rooted in the water table of a nearby wetland such as a river, stream.

Robust—is powerfully built; muscular, powerful (e.g. sharks)

Rock Crab—is any one of several species of large crabs of the genus *Cancer*

Rockfish—refers to marine food and game fish of the genus *Sebastes* found along the northern coasts of America and Europe

Roe—are eggs or egg-laden ovary of a fish

Rookery—is an animal's breeding ground; it is the specific beach on which they nest (turtle or birds) or pup (pinniped)

Roost—refers to birds; an area where sleeping occurs (e.g. tall tree)

Rorqual—refers to 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—refers to the snout or beak of a cetacean; in fish, a forward projection of the snout

Roundfish—is an ordinary market fish exclusive of flounders, soles, halibut, and other flatfishes

Rufous—refers to color; reddish-brown

Saddle—refers to a light-colored patch behind the dorsal fin of some cetaceans

Sagittal Crest—refers to the prominence on top of the cranium, causing a noticeably raised forehead on males of some otariid pinniped species

Salinity—refers to the concentration of salt in water, measured in practical salinity units (psu)

Salmonid—is a member of the Salmonidae family of fishes

Salp—is a barrel-shaped tunicate without an exoskeleton that forms asexual polymorphic colonies that are found in the upper levels of most oceans

Salt Marsh—is a 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—refers to sand eels, a 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—refers to 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—is any of various important marine food flatfishes of the family Paralichthyidae

Sardines—are any of various small or half-grown edible herrings or related fishes of the family Clupeidae

Satellite Telemetry—refers to the transmitting of data over long distance communication links (i.e. satellites) from a transmitter attached to a sea turtle in order to monitor its movements and/or behavior

Saury—is a slender long beaked fish of the family Scombersocidae

Secondaries—are the inner remiges that are attached to the "forearm" of the bird. Secondaries are located between the body of the bird and the primaries. Secondaries provide lift in both soaring and flapping flight

Scaphopod—is 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

Scapulars—are one of a special group of feathers which arise from each of the shoulder regions and lie along the sides of the back.
Scarp—is a line of cliffs produced by faulting or erosion

School—is a group of fish, drawn together, 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; fish typically school to avoid or minimize predation

Scleractinian—refers to 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—refers to marine fishes of the family Scorpaenidae having a tapering body with an armored head and venomous spines

SCUBA—refers to underwater dive equipment; self-contained underwater breathing apparatus

Sculpin—refers to any of numerous spiny large-headed broad-mouthed usually scaleless scorpaenoid fishes

Scutes—are long, thickened scales that cover underlying bony plates of carapace; plastron of sea turtles that are used for protection; can also be hard scales on fish (sturgeon) or birds

Scyphozoans—are 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—are large, heavy, complex polyps that belong to the cnidarian class Anthozoa

Sea Cucumbers—are echinoderms having a flexible sausage-shaped body with tentacles surrounding the mouth and tube feet; free-living feeder

Sea Lilies—refers to a 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—are one of the class Asteroidea of echinoderms having flat, usually fine-armed body containing embedded calcareous plates bearing spines or tubercles

Sea Surface Temperatures—refers to the temperature of the uppermost layer of seawater (approximately 0.5 m deep). Measured over large spatial scales by remote sensing satellite-based detectors and at point locations by moored buoys or ships.

Sea Urchins—are 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—refers to 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—refers to any macroscopic marine alga or sea grass

Sedentary—refers to an organism that spends the majority of its time in one place

Sediment—refers to solid or fragmented material, either mineral or organic, that is deposited by ice, water, or air

Semelparous—refers to 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—refers to fish that spend part of their life on the bottom and part in the water column above

Sergestid Shrimp—refers to several species of non-commercial shrimp of the decapod crustacean family Sergestidae

Sessile—is terminology used to describe an animal that is attached to something rather than free moving

Set gillnets—are 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—is the state in which an animal is physiologically capable of reproducing

Sexually Dimorphic—is differences in the appearance between the sex of a species; size differences are a primary difference where males (terrestrial animals) can be generally larger than females; other differences may be in body shape and color

Shallow Water—refers to water that is between the shore and the continental shelf break or shallower than 200 m

Shelf Break (continental)—refers to the region where the slope of the seabed rapidly changes from gently sloping on the continental shelf to steeply sloping on the continental slope; the world-wide average water depth at the shelf break is 155 m, and on average, the shelf break usually occurs between 100 to 200 m

Shelf Break Region—refers to the geographic area surrounding the continental shelf break and including both the outer continental shelf and upper continental slope

Siphon—is an opening in mollusks or in urochordates (tunicates) which draws water into the body cavity

Site Fidelity—terminology used to describe the tendency of animal to return to the same site repeatedly

Slough—refers to 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—is a landslide where the underlying rock masses tilt back as they slide from a cliff or escarpment

Smelt—refers to a 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—is 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—refers to the 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—is 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—is 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—is the region of the Pacific Ocean found south of the equator

Sovereign—is the supreme lawmaking authority; usually subject to no other

Spawn—is the release of eggs and sperm during mating

Species Diversity—refers to the number of different species in a given area

Species of Concern—is a species about which the NMFS has some concerns regarding population status and threats, but for which insufficient information is available to indicate the need to list the species under the Endangered Species Act of 1973

Species—is a population of plants or animals, or series of populations of organisms, that can interbreed freely with each other but not with members of the other species

Standard Deviation—is 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

Standard Error—is a statistical measure; it estimates the standard deviation of the difference between the measured or estimated values and the true values; derived by dividing the standard deviation by the square root of the sample size

Stenella—is the genus of oceanic dolphins consisting of striped, pantropical spotted, and spinner dolphins, which are similar in appearance; found in the Pacific

Stenellid—refers to dolphins of the genus *Stenella*

Stock Structure—is the genetic diversity of a stock or population of animals

Stock—is a genetically separate population of a species (biological stock), or a discrete population subject to management (management stock)

Stranding—refers to the act, an unusual event, where marine mammals or sea turtles come ashore, either alive or dead

Strategic Stock—regulatory terminology; 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—refers to maturing individuals that are not yet sexually mature

Subarctic—refers to regions adjacent to the Arctic Circle

Sublittoral—refers to the benthic region extending from mean low waters to a depth of about 200 meters

Submarine Canyon—refers to a 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—is a ridge of submarine mountains where two massive tectonic plates are moving apart

Subpopulations—is an identifiable fraction or subdivision of a population

Subsistence—refers to 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

Sustainable Use—refers to the consumption of a resource at a rate which optimizes benefits to both present and future generations of humans while preserving that resource *in situ*; commonly applied to the harvest of wildlife and plants

Substrata—is layer or base (region) on which animal or plant attaches to or is found

Substrate—is the material to which an organism is attached or in which it grows and lives; also, the underlying layer or substance

Subtidal—is a marine or estuarine environment that lies below mean low-water; always submerged in a tidally-influenced area

Subtropical—refers to the region between the tropical and temperate latitudes

Suction Feeding—refers to the capture of prey using suction method, generally with the tongue employed as a piston to create a vacuum pressure

Surf Line—is a point offshore where waves and swells are affected on by the underwater surface and become breakers

Surf zone—refers to area of the water from the surf line to the beach

Surfperches—are short deep bodied fish with continuous, long dorsal fins of the family Embiotocidae; inhabit surf zone along sandy shores

Sympatric—is a species or subspecies found together; having overlapping areas of distribution

Talon—is the claw of a bird of prey (e.g., hawk, eagles)

Talus—is weathered rock which has fallen from and accumulated at the bottom of a cliff

Taxa (taxon)—is a defined unit (e.g., species, genus, or family) in the classification of living organisms

Taxonomy—is the study of the rules, principles, and practice of classification, especially of living organisms

Temperate—refers to the latitudes (middle latitudes) between subpolar and subtropical regions, where the mean annual temperature ranges between 50 and 55°F (10 to 13°C)

Temporary Threshold Shift—refers to a temporary impairment in hearing ability caused by exposure to strong sounds

Terrigenous—refers to terminology to describe that something is derived from land or a continent

Territorial Sea—are waters adjacent to the coastline of a nation, its territories and possessions over which that nation has full jurisdictional authority; by international agreement, the breadth may not exceed 12 NM from the baseline

Territory—is an area occupied exclusively by one animal and defended by aggressive behavior or displays

Thermocline—refers to 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—is a density-driven water circulation caused by differences in temperature and/or salinity

Thermoregulatory—is an organism's ability to maintain a specific body temperature regardless of the environmental temperature

Thornyhead—is a marine fish of the genus *Sebastolobus* found along the Pacific coast of America

Threatened Species—is 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 of 1973

Tidepools—are pool of waters remaining on beach or reef after recession of tide

Tidewater—is low-lying coastal land drained by tidal streams

Tintinnids—is a 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—refers to physical features of the earth or ocean floor, such as mounds or ridges

Topsmelt—is a small, schooling surface-dwelling fish of the family Atherinopsidae having silver side along each side

Total Allowable Catch—is a regulatory term used to describe the number or weight of fish that may be harvested in a specific unit of time

Total Length—describes 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—is a plan, generally internationally agreed on, by which vessels in congested areas use one-way lanes to lessen the danger of collisions

Trammel Net—is a commercial fishing gear; 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—is able to cross borders

Transform Fault—refers to a geologic fault occurring along a conservative plate margin where the tectonic plates move parallel to each other either in opposite directions or at different rates in the same direction.

Transient Killer Whales—is 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—is 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—refers to on or from the other side of the ocean

Trans-Pacific—refers to spanning or crossing the Pacific Ocean

Trap or pot—refers to a commercial fishing gear constructed of galvanized wire that may or may not be vinyl coated; used to target fish, lobsters, or crabs

Trawl Net—refers to a towed commercial fishing gear or net that consists of a cod-end or bag used for collecting the fish or other target species; trawls can be towed at any depth of the water column

Troll Gear—refers to commercial fishing gear that 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—refers to a step in the transfer of food or energy within a chain; an ecological term

Tropical—refers to 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—refers to 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—refers to the genus of bottlenose dolphins comprised of the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)

Ulvoid—refers to the characteristic of the green algal family Ulvaceae; most species have broadly expanded, membranous, green blades

Underwing—refers to the underside of the wing

Unknown—refers to terminology used specifically for the MRA occurrence polygons for sea turtles and marine mammals, 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—refers to the movement of dense, cold, nutrient-rich water up from ocean depths to the surface

Upwelling Season—refers to period between April and September when upwelling conditions are high in the Pacific Northwest

Urochordates—refers to 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—refers to a portion of the ventral surface around and near the excretory and genital orifices

Vagrant—refers to a wanderer, in the same sense of an animal moving outside the usual limits of distribution for its species or population

Veliger—refers to the larval stage of various invertebrates (e.g., white abalone) having one or two ciliated membranes for swimming

Ventral—refers to the underside (or belly side) of an animal

Vertebrates—are animals having a backbone (e.g., fish, mammals)

Visual Acuity—refers to the sharpness of vision; the visual ability to resolve fine detail.

Viviparous—describes a 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—is 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—refers to the vertical column of seawater extending from the surface to the sea bottom

Water Mass—refers to a body of water that can be identified by a specific temperature and salinity

Watershed—is a region draining into a river, river system or other body of water

Weaning—refers to the end of the lactation period; the process of changing from milk to a solid diet in juvenile mammals

Wetland—refers to 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—is an amphipod crustacean 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—refers to a narrow band frequency sound produced by some toothed whales and used for communication; they typically have energy below 20 kHz

Worm Tubes—are usually comprised of calcium carbonate or particles of mud or sand built on submerged surface by polychaete worm

Wrasses—are predominately warm-water fish represented by 20 species of the family Labridae on the Pacific west coast

Yolk-sac larvae—are 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—refers to a juvenile fish usually less than one year old

Zoea—refers to an early larval stage of crabs and shrimp

Zonation—is the occurrence of single species or groups of species in recognizable bands that might delineate a range of water depth or a range of height in the intertidal zone

Zoogeography—is the study of the patterns of the past, present, and future geographic distribution of animals (and their attributes) in nature and the processes that regulate these distributions

Zooplankton—are a 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 SOCAL/Pt. Mugu Study Area GIS maps.

The level of data confidence is dependent upon three factors: precision, accuracy, and currency. Each of these three factors is 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.

SOCAL/Pt. Mugu Study Area MRA Map Examples	Description of Map Data	Confidence Level
Bathymetry, Sea Surface Temperature, Chlorophyll, Artificial Habitats, Pinniped Haulout Sites, Marine Mammal and Sea Turtle Occurrence Maps, Maritime Boundaries, Marine Managed Areas, Oil and Gas Structures	Data from original/reliable sources. Provided in a digital format with geographic coordinates given. Identified as "*source data*" in map captions.	**High** 101 maps 73% of total number of maps)
White abalone sightings, California brown pelican Foraging range, Sea Surface Temperature Anomaly, Dive Sites	First- or second-hand data sources. Locations obtained through scanning geo-referenced* maps. Identified as "*source map(s) scanned*" in map captions.	**Medium** 32 maps (23% of total number of maps)
Surface Currents, Migration Maps, developmental migration of loggerhead turtles	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** 5 maps 4% 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 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 3-D) to planar coordinate (2-D), 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 (nm).

Appendix A-3. Overview of research efforts that provide occurrence information for marine mammals and sea turtles in the SOCAL and Pt. Mugu OPAREAs.

To subjectively determine the areas of occurrence for marine mammals and sea turtles in the SOCAL and Pt. Mugu OPAREAs, attempts were made to compile available records from aerial and shipboard survey sightings, strandings, incidental fisheries bycatch, taggings, pinniped haulout/rookery sites, and 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 depicted in **Appendices B** and **C** were based on both aerial and shipboard survey (on effort) data as well as the known habitat preferences and distributions of individual species in southern and central California.

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 calculating 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. Aerial and shipboard surveys have been conducted throughout most of the Point Mugu OPAREA and the northeastern portion of the SOCAL OPAREA; however, survey effort is non-existent in offshore waters of the Study Area (**Figures A-1** and **A-2**). The SOCAL and Pt. Mugu OPAREAs have been surveyed much more intensely during the warm-water period (15 June to 15 December; **Figure A-2**) than during the cool-water period (16 December to 14 June; **Figure A-1**).

➢ 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.

- Between 1990 and 2000, the **NMFS-SWFSC** flew multiple **coastal bottlenose dolphin surveys** along the central and southern California coasts (from roughly 32°N to 38°N). The purpose of these line-transect surveys was to determine the abundance and seasonal distribution of bottlenose dolphins off California (Carretta et al. 1998). Only data from 1990 through 1994 and 1999 through 2000 are included in this MRA.

- 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). The Study Area was bounded by the U.S./Mexico border in the south and extended out to approximately 280 km offshore of 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.

Table A-1. Inventory of the marine mammal and sea turtle data sources included in the MRA for the SOCAL and Pt. Mugu OPAREAs.

Data Source	Record Dates
Aerial Surveys	
NMFS-SWFSC California coastal bottlenose dolphin surveys	1990-1994, 1999-2000
NMFS-SWFSC California coastal cetacean surveys	1991, 1992
NMFS-SWFSC Navy Outer Sea Test Range (OSTR) ship-shock surveys	1993-1994
BLM/MMS Oil Spill Prevention and Response (OSPR) marine mammal and seabird surveys in the Santa Barbara Channel and the Santa Maria Basin	1994-1997
CINMS surveys	1997-2003
NMFS-SWFSC San Clemente Island marine mammal surveys	1998-1999
NMFS-SWFSC Harbor Porpoise Aerial Surveys (HPASs)	1988-2002
Shipboard Surveys	
NMFS-SWFSC California Marine Mammal Survey (CAMMS)	1991
NMFS-SWFSC Population of *Delphinus* Stocks (PODS) surveys	1992,1993
NMFS-SWFSC Cetacean Acoustic Detection and Dive Interval Studies (CADDIS)	1995
NMFS-SWFSC Oregon, California, and Washington Line-Transect Expeditions (ORCAWALE)	1996, 2001
NMFS-SWFSC Monitoring of Porpoise Stocks (MOPS) surveys	1986-1990
NMFS-SWFSC Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS)	2002
NMFS-SWFSC Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE)	2005
USGS seismic-reflection surveys; Cascadia Research marine mammal surveys	1998-2002
Aerial and Shipboard Surveys	
BLM/MMS Marine Mammal and Seabird Surveys of the Southern California Bight Area	1975-1978
SCORE surveys	2000-2003
NOSC surveys	1968-1975
Strandings	
NMFS-SWR California Marine Mammal Stranding Network (CMMSN) database	1995-2000
NMFS-SWR sea turtle stranding records	1995-2000
Santa Barbara Museum of Natural History Stranding database	1960-2007
Incidental Fisheries Bycatch Records	
NMFS-SWR Fisheries Observer Program (California/Oregon drift gillnet fishery)	1990-2003
NMFS-SWR Fisheries Observer Program (California set gillnet fishery)	1990-2000
NMFS-Pacific Islands Fisheries Science Center (PIFSC) Hawai'i Longline Observer Data System (LODS)	1994-2005
Miscellaneous Data Sources	
CalCOFI	2004-2007
Cascadia Research, small boat surveys	1986-2004
North Pacific Right Whale Database (sightings, strandings, and whaling records)	1900-1999
NMFS Platforms of Opportunity (POP) database	1958-1997
USGS sea otter occurrence records	1994-2004, 2007
NOS Environmental Sensitivity Index	2001
U.S./Union of Soviet Socialist Republics (USSR) unpublished sperm whale sightings	1964-1975
Published Literature and Reports	
Benson and Groody	1942
Fiscus and Niggol	1965
Hubbs	1951
Kelly	1983
Lamont-Doherty Earth Observatory	2004
Lustig	1948
PIROP Opportunistic surveys	2006
Norris and Prescott	1961

Table A-1 (*continued*). Inventory of the marine mammal and sea turtle data sources included in the MRA for the SOCAL and Pt. Mugu OPAREAs.

Data Source	Record Dates
Published Literature and Reports (*continued*)	
Rice	1977
Rice	1965
Rodgers[1]	2007
Morejohn and Rice	1973
Leatherwood	1975
Leatherwood and Walker	1979
Leatherwood et al.	1980
NMFS	2002
Mead et al.	1982
Stinson	1984
McDonald and Fox	1999
Pitman et al.	1999
Dalebout et al.	2002

- From January 1993 through May 1994, the **NMFS-SWFSC** conducted aerial line-transect surveys to determine the relative spatial and seasonal distribution and abundance of marine mammals within a portion of the **Navy Outer Sea Test Range (OSTR)**, located west of San Nicolas Island in the Point Mugu OPAREA (Carretta et al. 1995). In April and May 1994, line-transect surveys were conducted in waters located 120 km southwest of the OSTR. The Navy requested that these surveys be performed prior to undertaking ship-shock trials on the destroyer *U.S.S. John Paul Jones*.

- **BLM/MMS Oil Spill Prevention and Response (OSPR) Surveys** were conducted as part of a larger program funded by the CDFG and in cooperation with the University of California at Santa Cruz. These surveys were initiated to maintain readiness for oil spill response.[2,3] Between November 1994 and August 1997, 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 for **seabirds and marine mammals in the Santa Barbara Channel and Santa Maria Basin**. Species, numbers, behavior, and other information were described, and date, time, and position of the aircraft were recorded (Schmitt and Bonnell 2003). Data collected from surveys conducted between 1994 and 1997 were provided by the **MMS** for inclusion in this report.[2]

- In June 1997, the **CINMS** instituted an aerial survey program to better study the sanctuary's environment and to alleviate the difficulties in responding to physical and cultural activities within its boundaries. Data collected during these aerial surveys include marine mammal sightings (cetaceans and pinnipeds) as well as locations of kelp beds, marine debris, commercial fishing and recreational vessels, and aircraft. Standard survey transects are flown in a "figure-eight" pattern between the sanctuary's northern islands and a double outward radiating spiral at Santa Barbara Island. The survey aircraft generally flies at an altitude of 305 m and a speed of 185 km/h. Marine mammal sighting data collected for this MRA include records from June 1997 to December 2003 (Schwemm et al. 2000; Waltenberger and Pickett 2000).

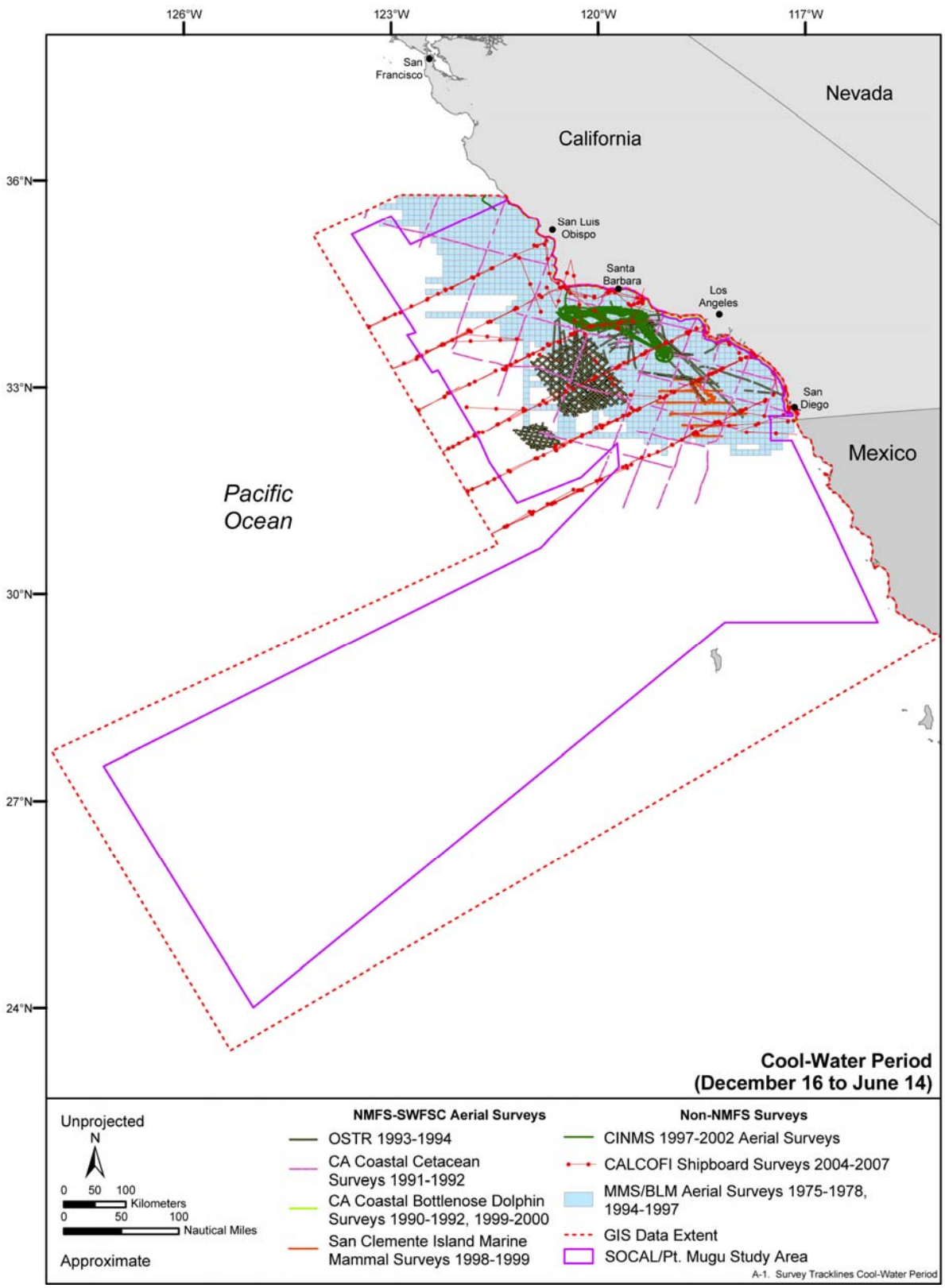

Figure A-1. On-effort tracklines and survey grid blocks for aerial and shipboard surveys conducted in the SOCAL/Pt. Mugu Study Area during the cool-water period (December 16 to June 14).

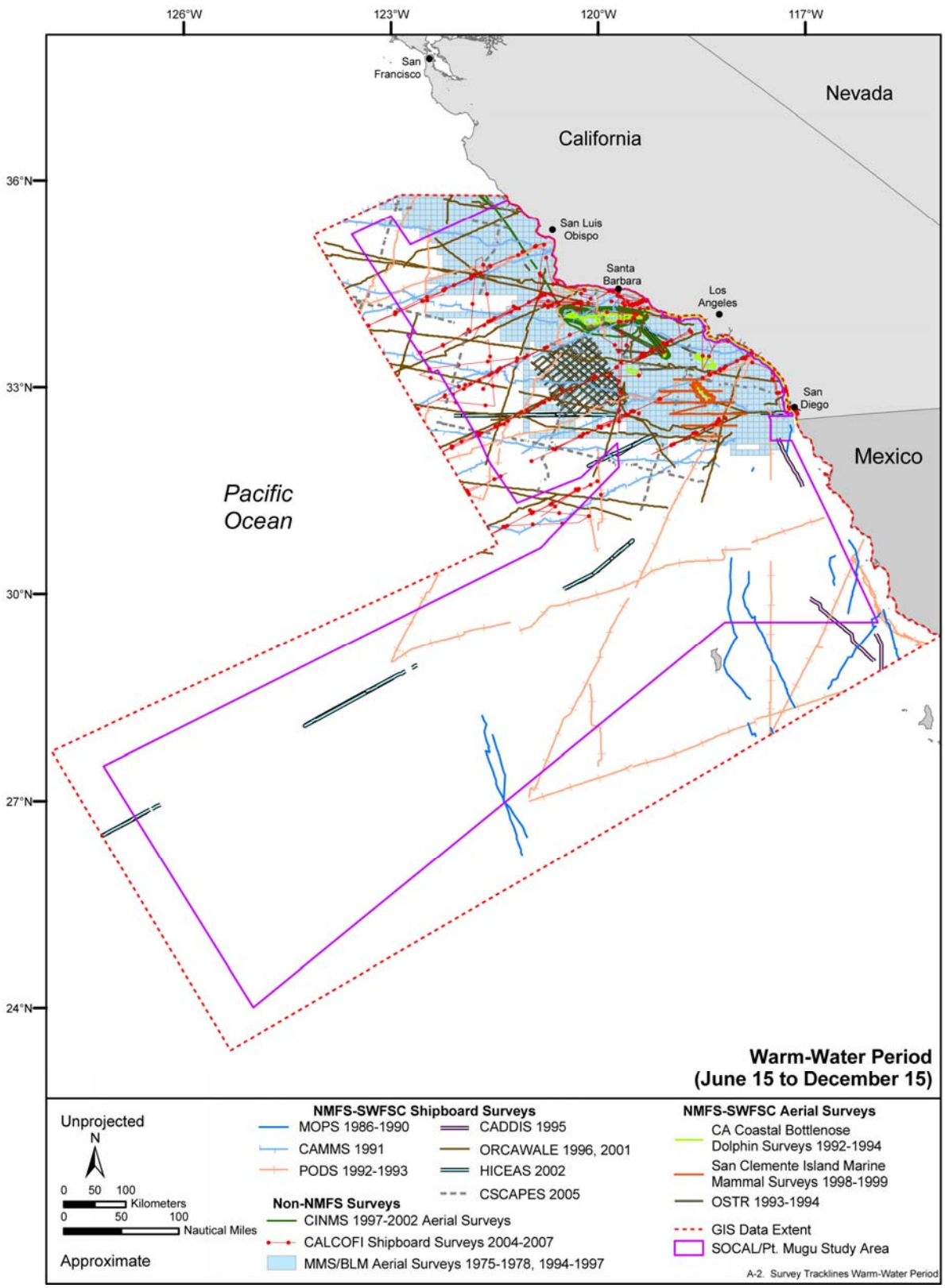

Figure A-2. On-effort tracklines and survey grid blocks for aerial and shipboard surveys conducted in the SOCAL/Pt. Mugu Study Area during the warm-water period (June 15 to December 15).

In 1996, the Navy requested that the **NMFS-SWFSC** conduct a marine mammal survey of **San Clemente Island** and its associated offshore training ranges in order to gather baseline information on the abundance and distribution of marine mammals around the island. The NMFS-SWFSC flew aerial line-transect surveys around San Clemente Island from April 1998 through July 1999 (Carretta et al. 2000). Both nearshore and offshore transects were flown during the study. Additional surveys were also conducted under this program; these included quarterly photogrammetric and ground surveys of pinniped rookeries along the San Clemente Island shoreline and opportunistic aerial photogrammetric surveys of gray whales and common dolphins. Only the aerial survey data were available for inclusion in this MRA.

- Between 1988 and 2002, the **NMFS-SWFSC** conducted **Harbor Porpoise Aerial Surveys (HPAS)**. The primary objective of these surveys was to estimate abundance and trends of harbor porpoise in central and northern California. A secondary objective was to conduct habitat studies of harbor porpoise in central California. The aerial surveys were conducted using standard line transect methods from a twin-engine, high-wing airplane flying at 650 ft altitude primarily between August 15 and November 15 of each year. Additional surveys may be flown at other times of the year to conduct habitat studies in areas of harbor porpoise concentration (Carretta and Forney 2004).

➢ **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, SARs for each marine mammal stock that occurs in U.S. waters. These SARs contain a description of the stock, information on its distribution, and a minimum population estimate (Wade and Angliss 1997). Shipboard surveys are one of the primary methods the NMFS collects marine mammal population data for use in SARs.

Most shipboard surveys included and discussed in this MRA were conducted along the U.S. west coast. However, NOAA research vessels that survey waters of the ETP often depart from San Diego and can provide some sighting data for the SOCAL OPAREA. Data from the following ETP cruises were provided by the NMFS-SWFSC for inclusion in this MRA and are discussed in more detail below: a 5-yr series known as the Monitoring of Porpoise Stocks (MOPS; 1986 through 1990) survey and a single-year Population of *Delphinus* Stocks (PODS; 1992) survey.

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 populations, sighting records from shipboard surveys often provide valuable information that can be used to determine distribution and life history patterns.

- 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 are 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 2 November 1992, the **NMFS-SWFSC** conducted the **Population of *Delphinus* Stocks (PODS)** surveys in the ETP. The NMFS-SWFSC utilized the NOAA ships *David Starr Jordan* (Cruise DS-92-08, SWFSC Cruise Number 1468) and *McArthur* (Cruise AR-92-04, SWFSC Cruise Number 1467) for these surveys. In addition, between 28 July and 6 November, 1993, another PODS survey was conducted along the U.S and Mexico west coasts. These surveys were also conducted aboard the NOAA ships *David Starr Jordan* (Cruise DS-93-

08, SWFSC Cruise Number 1509) and *McArthur* (Cruise AR-93-02, SWFSC Cruise Number 1508). The Study Area for this survey ranged from the California/Oregon border to Cabo Corrientes, Jalisco, Mexico and also included the Gulf of California. The primary purpose for both years 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).

- From September through November 1995, the **NMFS-SWFSC**, in collaboration with several Mexico institutions, performed the **Cetacean Acoustic Detection and Dive Interval Studies (CADDIS)** aboard the NOAA ship *McArthur* (Cruise AR-95-08, SWFSC Cruise Number 1601). The purpose of the project was to learn how to better estimate the abundance of deep-diving whales (e.g., beaked whales, dwarf and pygmy sperm whales) during line-transect ship surveys (Barlow et al. 1997). Although the CADDIS were conducted primarily in the southern Gulf of California, survey tracklines for both legs of the research cruise ran along the western coast of Baja California (Barlow et al. 1997).

- 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 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 characterize the animals' environment. The 1996 cruise consisted of two 30-d 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

- The **NMFS-SWFSC** conducted the **Monitoring of Porpoise Stocks (MOPS)** surveys aboard the NOAA ships *David Starr Jordan* and *McArthur* between late July and early December 1986 through 1990. These surveys were designed to estimate the abundance of several stocks of cetaceans in the ETP, particularly those dolphin species that were being incidentally taken in the purse seine fishery for yellowfin tuna (Wade and Gerrodette 1993).

    - **MOPS 1986**: *David Starr Jordan* – 29 July to 5 December, Cruise 86-09 (204), SWFC Observer Cruise 989 (Holt and Sexton 1987); *McArthur* – 29 July to 6 December, Cruise AR 8690-12, SWFC Observer Cruise 990 (Holt and Jackson 1987)

    - **MOPS 1987**: *David Starr Jordan* – 8 August to 10 December, Cruise 87-06 (210), SWFC Observer Cruise 1081 (Holt and Sexton 1988); *McArthur* – 30 July to 10 December, Cruise AR 87-0812, SWFC Observer Cruise 1080 (Holt and Jackson 1988)

    - **MOPS 1988**: *David Starr Jordan* – 28 July to 6 December, Cruise 88-07 (217), SWFC Observer Cruise 1164 (Holt and Sexton 1989); *McArthur* – 28 July to 8 December, Cruise AR 88-02, SWFC Observer Cruise 1165 (Sexton et al. 1989)

    - **MOPS 1989**: *David Starr Jordan* – 29 July to 7 December, Cruise DS-89-05 (222), SWFC Observer Cruise 1267 (Hill et al. 1990b); *McArthur* – 29 July to 7 December, Cruise AR-89-03, SWFC Observer Cruise 1268 (Hill et al. 1990a)

- o **MOPS 1990**: *David Starr Jordan* – 28 July to 6 December, Cruise DS-90-06 (229), SWFSC Observer Cruise 1369 (Hill et al. 1991a); *McArthur* – 28 July to 6 December, Cruise AR-90-04, SWFSC Observer Cruise 1370 (Hill et al. 1991b)

- From 27 July to 9 December 2002, the **NMFS-SWFSC** conducted the **Hawaiian Islands Cetacean and Ecosystem Assessment Survey (HICEAS)** using the NOAA ships *David Starr Jordan* and *McArthur* (Cruises DS-02-07 and AR-02-07, SWFSC Cruise Numbers 1621 and 1622). The purpose of these cruises was to determine the distribution and abundance of cetaceans around the Hawaiian Islands. Although nearly all of the survey work was conducted around the Hawaiian Islands, both research vessels departed from and returned to the U.S. west coast. On-effort sightings of marine mammals were recorded from waters off southern California during the beginning and ending legs of these cruises (Barlow et al. 2004).

- From 4 June through 23 July and 2 August through 7 December 2005, the **NMFS-SWFSC** conducted the **Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE)** ship line-transect survey abroad the NOAA research vessels *McArthur II* and *David Starr Jordan*. The CSCAPE 2005 cruise was a collaborative effort between the NMFS and the NMSP to assess the abundance and distribution of marine mammals and to characterize the pelagic ecosystem in the waters off California, Oregon, and Washington. The primary objective was to conduct a marine mammal assessment survey in offshore waters (approximately 300 nm from shore) and to provide fine-scale surveys within the boundaries of four of the five West Coast NMS. A secondary objective was to characterize the pelagic ecosystem through the collection of underway and station-based biological and oceanographic data, seabird studies, and acoustic sampling. A final objective was to conduct biopsy sampling and photo-identification studies of marine mammal species of special interest (Barlow and Forney 2007; Forney 2007).

- The **USGS** conducted seismic-reflection surveys in waters off California, Washington, and British Columbia in a series of six surveys from 1998 to 2002 (Quan and Calambokidis 1999; Gutmacher et al. 2000). 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).

Published Literature and Reports

- 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.

➢ **Aerial and Shipboard Surveys**

- Between May 1975 and March 1978, the **BLM** (which later changed its name to **MMS**) funded aerial and shipboard **marine mammal and seabird surveys of the Southern California Bight area**. These surveys were conducted by the University of California, Santa Cruz to determine marine mammal and seabird distribution and abundance in the Southern California Bight from Point Conception, California to the U.S./Mexico border (Bonnell et al. 1980; Dohl et al. 1981).

- Marine mammals within the **SCORE** were monitored using line-transect aerial and shipboard surveys, as well as mobile and fixed-site acoustic surveys (SERDP 2001). This program is a joint

partnership between the DoD, NMFS, SIO, and Cascadia Research. Since 2000, shipboard surveys have been conducted between four and six times per year primarily aboard the R/V *Gordon Sproul*; aerial surveys have occurred quarterly since 2001 (SERDP 2001; Calambokidis et al. 2002b; Calambokidis et al. 2003). Data from aerial surveys conducted from 2001 through 2003 and 19 shipboard surveys conducted from 2000 through 2003 were available for inclusion in this MRA; however, trackline information for this dataset was not available.

- From 1968 through 1975, the **Naval Undersea Center** (now the **NOSC**) conducted aerial and shipboard surveys. The aerial surveys we conducted over the continental shelf from Point Conception south to 31°30'N and offshore to 121°W. The 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.

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 and Jozwiak 1991). Mr. Joe Cordaro, the Southwest Regional Stranding Coordinator with the NMFS-SWR, provided the **CMMSN Database** for inclusion in this MRA. Over 6,000 stranding records for the southern California area during 1995 through 2000 were included in this data set. The vast majority of stranding locations were available only as locality descriptions (e.g., beach, street, or landmark location); relatively few records were available in coordinate (latitude/longitude) form.

- 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 1995 to 2000. A total of 43 sea turtle strandings occurred in southern California over this time span. Stranding locations were available as either geographic coordinates or locality descriptions.

- The Department of Vertebrate Zoology at the **Santa Barbara Museum of Natural History** has been collecting marine mammal stranding data for over 30 yr. These data helped to develop a diverse collection of skeletal and tissue samples and the **Marine Mammal Stranding Network Database**. This database, collected primarily by Dr. Charles Woodhouse and received from Ms. Michelle Berman, includes over 400 stranding records for central and southern California between 1960 and 2007. All stranding locations were available in coordinate (latitude/longitude) form.

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 MMPA, the ESA, and the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (Carretta et al. 2004). 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.[4] Observers are required to complete sighting forms, document the

circumstances of captures, and obtain biological data (e.g., measurements) on incidentally captured marine mammals and sea turtles.

Marine mammal and turtle bycatch records from the California/Oregon drift gillnet fishery and the California set gillnet fishery are included in this MRA. These data were received from the NMFS-SWFSC which uses data collected by the NOP to estimate bycatch and produce technical reports. In addition, concern over sea turtle bycatch and under-reporting of takes led the NMFS to initiate a mandatory observer program for the Hawai'i-based longline fishery, which operates in the central North Pacific Ocean (including part of the SOCAL/Pt.Mugu Study Area) in an area extending roughly from 10°N to 45°N and 170°E to 140°W (Forney 2004). This ruling, passed as an amendment to the 1986 FMP for the Pelagic Fisheries of the Western Pacific Region, mandated that observers be placed aboard all Hawai'i-based pelagic longline vessels targeting billfish and tunas. Species that interact with this fishery include sea turtles (especially loggerheads, leatherbacks, and greens), seabirds (notably Laysan and black-footed albatrosses), and, to a lesser extent, some cetaceans. In waters located far offshore, incidental bycatch records from commercial fisheries are often the only occurrence records available for protected species, especially sea turtles.

- In July 1990, the **NMFS-SWR Fisheries Observer Program** 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 from 1990 to 2003.

- In July 1990, the **NMFS-SWR Fisheries Observer Program** also began placing mandatory observers on vessels in the set gillnet fishery 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.

- A more comprehensive set of incidental bycatch data, collected by the Pacific Islands Region Longline Observer Program and housed within the **Hawai'i Longline Observer Data System (LODS)**, was obtained from the NMFS-Pacific Islands Region (PIR) and **NMFS-Pacific Islands Fisheries Science Center (PIFSC)**. The LODS is a complete suite of tools designed to collect, process, and manage fisheries data and information. Guided by the principles of the NOAA Data Quality Act, the LODS is the result of the collaboration and cooperation of scientists, data collectors, and information management experts across the Pacific Islands region (NMFS-PIFSC 2005b). The LODS includes both incidental bycatch and opportunistic sighting records of marine mammals, sea turtles, and seabirds collected from Hawaiian longline vessels since 1994. A few of these records were applicable to the SOCAL/Pt. Mugu Study Area.

Miscellaneous Data Sources

- Incidental marine mammal observations have been documented during seabird abundance surveys on **CalCOFI cruises** since 1987 (Larkman and Veit 1998). CalCOFI is a partnership program between the NMFS, CDFG, and SIO. These cruises are part of an ongoing assessment of the California current system for central and southern California (CalCOFI 2007).[5] A new component has been added to the CalCOFI ecosystem studies to understand cetacean ecology and habitat offshore of southern California. Since July 2004, visual and acoustic line-transect surveys have been conducted for cetaceans on quarterly CalCOFI cruises (Soldevilla et al. 2006). While the ship transited between CalCOFI stations, visual observers watched during daylight hours when weather permitted. Dr. John Hildebrand of Scripps Institute of Oceanography provided marine mammal sighting data from cruises conducted between 2004 and 2007.

- **Small-boat surveys** have been conducted by **Cascadia Research** since 1986 in the waters off California, Oregon, Washington, and British Columbia. During the effort, Cascadia Research scientists obtained identification photographs of humpback, gray, and blue whales. Sightings of humpback and gray whales from 1986 to 2004 were available for inclusion in this MRA. In addition,

data from Cascadia Research published reports (Calambokidis et al. 2001; Calambokidis et al. 2002c; Calambokidis and Barlow 2004; Calambokidis et al. 2004) were used in this MRA.

- The **North Pacific Right Whale Database** is a review of all available 20th 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 and 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).

- 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.[6] The NMML, a branch of the NMFS, assigns a species identification as either "sure," "likely," "unsure" or "not possible." Dr. Sally Mizroch of the NMML provided POP sighting data used in this MRA; these data only represent confirmed (i.e., "sure") sightings from 1958 to 1997.

- Since 1982, aerial and ground-based surveys for sea otters have been conducted cooperatively by scientists of the USGS, California Department of Fish and Game, USFWS, and the Monterey Bay Aquarium. These surveys provide data for documentation of **sea otter occurrence records** for about 375 miles of California coast, from Half Moon Bay south to Santa Barbara. The surveys were conducted bi-annually, once in early autumn and once again in late spring. The ground-based surveys (from shore) were plotted on maps and then entered into a spatial database. The aerial surveys were directly entered into a GIS-linked database in the aircraft.[7] The entire database from 1994 to 2004 and 2007 was provided by Mr. Brian Hatfield of the **USGS** Western Ecological Research Center for inclusion in this MRA.

- In 2001, the **NOS's** Office of Response and Restoration published data characterizing coastal environments and wildlife by their sensitivity to oil spills. This data set comprises the **Environmental Sensitivity Index (ESI)** atlas for the shoreline of southern California from the U.S./Mexico border to Point Conception (NOS 2001b) and also in 2001, ESI maps were published for the coastal areas of Central California from Point Conception to Point Reyes National Seashore (NOS 2001a). These ESI datasets include pinniped haulout sites located in the Channel Islands and along the California mainland within the SOCAL/Pt. Mugu Study Area.

- In a joint venture between the US and the USSR, from 1964 through 1975, recoveries of sperm whales were marked during **U.S./Union of Soviet Socialist Republics (USSR)** whale marking cruises. These **sperm whale sightings** were never published; however, this unpublished data was made available as sperm whale sightings for this SOCAL/Pt. Mugu MRA (Rice, D.W., USFWS, pers. comm., 17 January 2006).

Applicable Data not available for inclusion in the SOCAL/Pt. Mugu MRA

- A **coastal marine mammal survey** was conducted by the **NMFS-SWFSC** from the NOAA ship *David Starr Jordan* between 27 September and 20 October 1979 between Cape Mendocino and the tip of Baja California (Smith et al. 1986). A second marine mammal survey was made between 17 June and 11 July 1980 following a similar track pattern but going south only to the latitude of Point Eugenia. There were additional legs on this cruise seaward of the previous September through October coverage, designed to investigate the correlation between deep-sea seamounts and cetacean distribution.

- During the Fall of 1995, a dual-mode (acoustic and visual) research survey referred to as **Whales '95** took place in the Southern California Bight (Clark and Fristrup 1997). The goal of this survey was to demonstrate and document the advantages of combining acoustic and visual shipboard survey techniques for baleen whales. The primary vessel was the R/V *Acoustic Explorer*. A shakedown/calibration took place from 24 to 27 September 1995 within the sonobuoy test range off the eastern shore of San Clemente Island. Cruise 1 took place from 30 September through 7 October 1995 in an area southwest of San Nicolas Island, while Cruise 2 occurred between 11 and 18 October 1995 near the San Nicolas Integrated Undersea Surveillance System (IUSS)/Sound Surveillance System (SOSUS) arrays.

- Since 1981, the **Pinniped Aerial Surveys Project** (a collaborative project between the **CDFG** and **NMFS-SWFSC**) has conducted censuses of five species of pinnipeds for monitoring trends and abundance of populations found in the U.S. Surveys along the California coast are conducted in February for elephant seals; May through July for harbor seals; and July for California sea lions, Steller sea lions, and northern fur seals (Lowry 2002).

- The **NMFS-SWFSC** collaborated with the CDFG to conduct aerial surveys between December 1980 and March 1981 for pilot whales in the immediate vicinity of Santa Catalina Island (Oliver and Jackson 1987). The NMFS conducted **pilot whale surveys** at Santa Catalina Island beginning in December 1982 and expanded the coverage to other areas within the Southern California Bight (Oliver and Jackson 1987). Other areas included Point Dume, the San Pedro Escarpment, San Clemente Island, Santa Barbara Island, and the Santa Barbara Channel. There were two purposes for the surveys: (1) to duplicate transects used during the BLM aerial surveys (discussed previously) and (2) to gather data on the relative abundance of the short-finned pilot whale (Evans et al. 1984; Lee 1994). Evans et al. (1984) also conducted vessel surveys during January through November 1982 for pilot whales that also included acoustic recording efforts.

- Since December 2000, the **Green Turtle Tracking Project** of the **NMFS-SWFSC** has been an ongoing effort to identify home ranges and habitat use patterns of green turtles in south San Diego Bay. From December 2000 through 2002, green turtles were captured near the San Diego Bay Power Plant and instrumented with sonic transmitters. They were then released at the initial capture sites and tracked throughout the study period. Results from the tracking data were used to estimate overall home ranges and core areas of activity for green turtles in San Diego Bay (Dutton et al. 2002).

- During July through September 1994, the **Navy** conducted the **Magellan Sea Tests** off California. The Magellan Sea Tests consisted of at-sea exercises designed to test new and existing systems and tools and to demonstrate their usefulness in anti-submarine warfare operations. The Navy monitored whales using acoustics (Aburto et al. 1997). The shakedown cruise took place during 18 to 28 July while the portion of the cruise that took place within the SOCAL/Pt. Mugu Study Area occurred from 3 through 19 August.

- Boat-based surveys were initiated in January 1997 to describe the occurrence patterns, habitat partitioning, and the impact of El Niño/La Niña on **cetaceans in Santa Monica Bay** (Bearzi 2003). Unsuccessful attempts were made to obtain these data for inclusion in this MRA. Sightings were available from maps in Bearzi (2003); however, the data resolution did not qualify through data quality control measures and GPS coordinates were not available for inclusion in this MRA.

- From January 1981 through February 1991, **marine mammal surveys** were conducted at **Santa Catalina Island** (Shane 1984, 1994). Fieldwork lasted from 3 d to 4 mo each winter using small-boat surveys. These data were not available electronically or in coordinate form.

- Boat-based **photo-identification surveys of bottlenose dolphins** have been conducted since 1982 in the Southern California Bight (e.g., Defran et al. 1986; DeDecker et al. 1999; Defran and Weller 1999; Defran et al. 1999).

- The **NMFS-SWFSC** funded the Pacific Cetacean Group to compile and catalog photographs of **killer whale sightings off California** and western Mexico (Black et al. 1997).

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APPENDIX B: MARINE MAMMALS AND PINNIPEDS

LIST OF FIGURES

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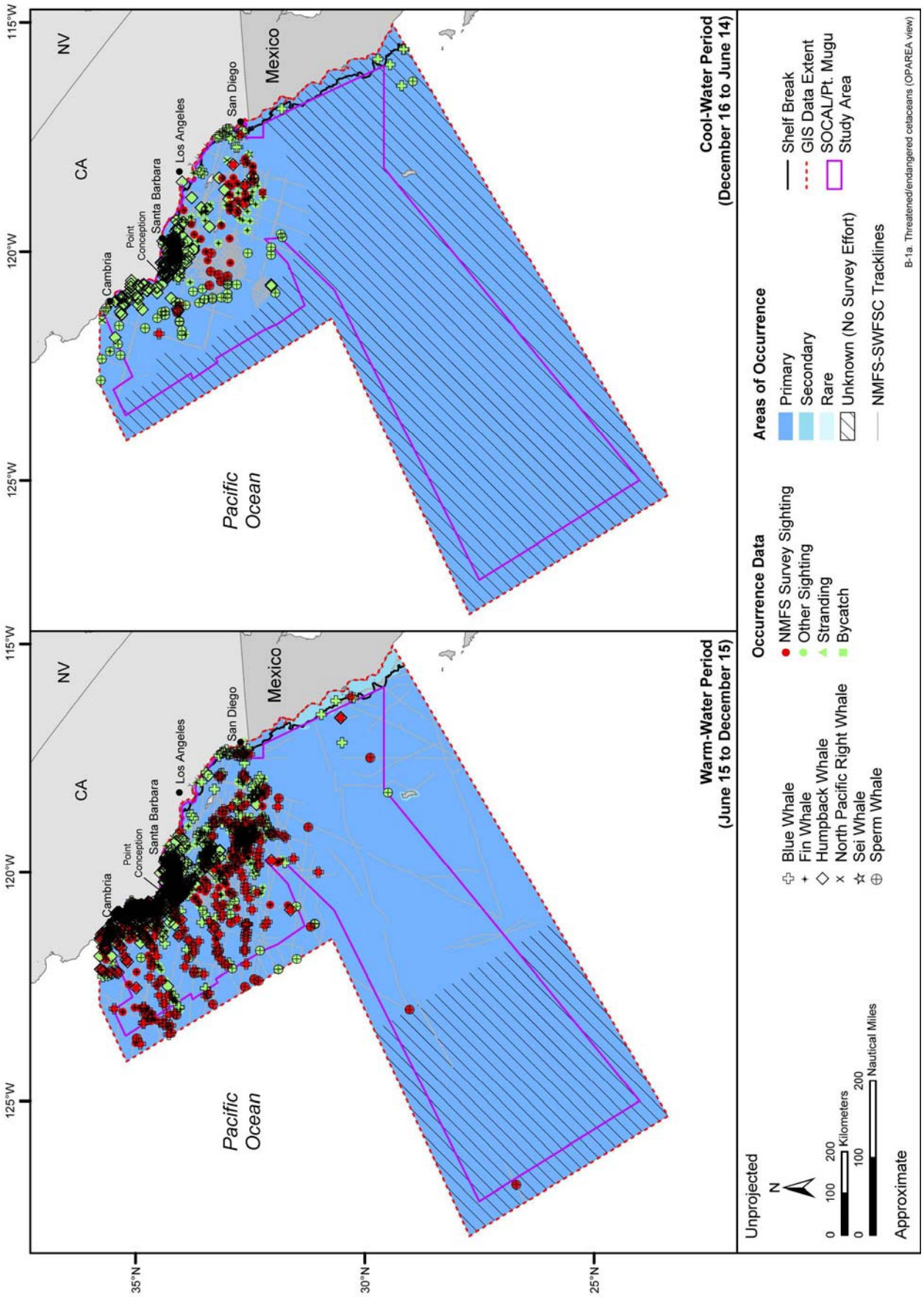

Figure B-1a. Areas of occurrence for threatened and endangered cetaceans in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

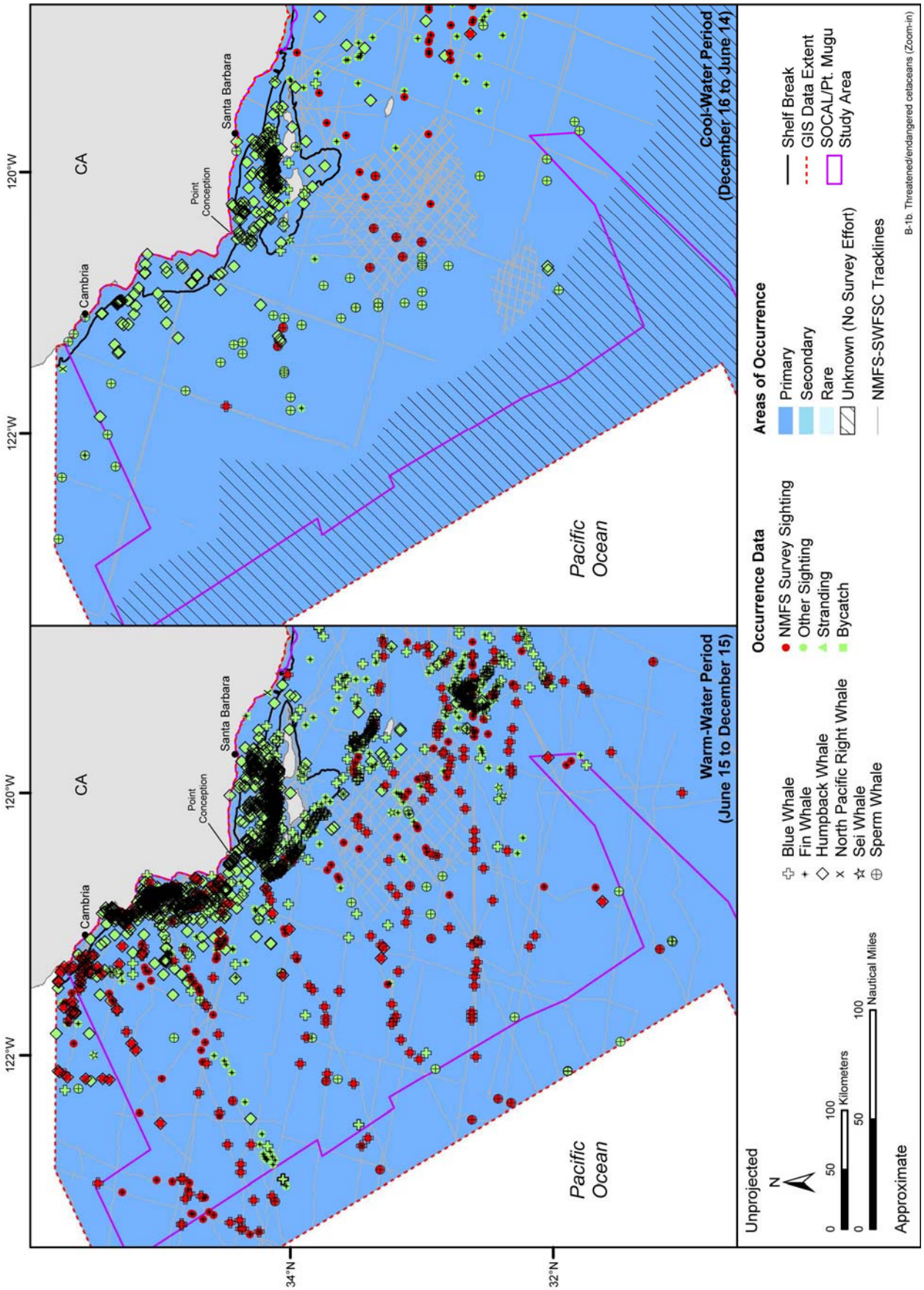

Figure B-1b. A zoom-in of the concentrated areas of occurrence for threatened and endangered cetaceans in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

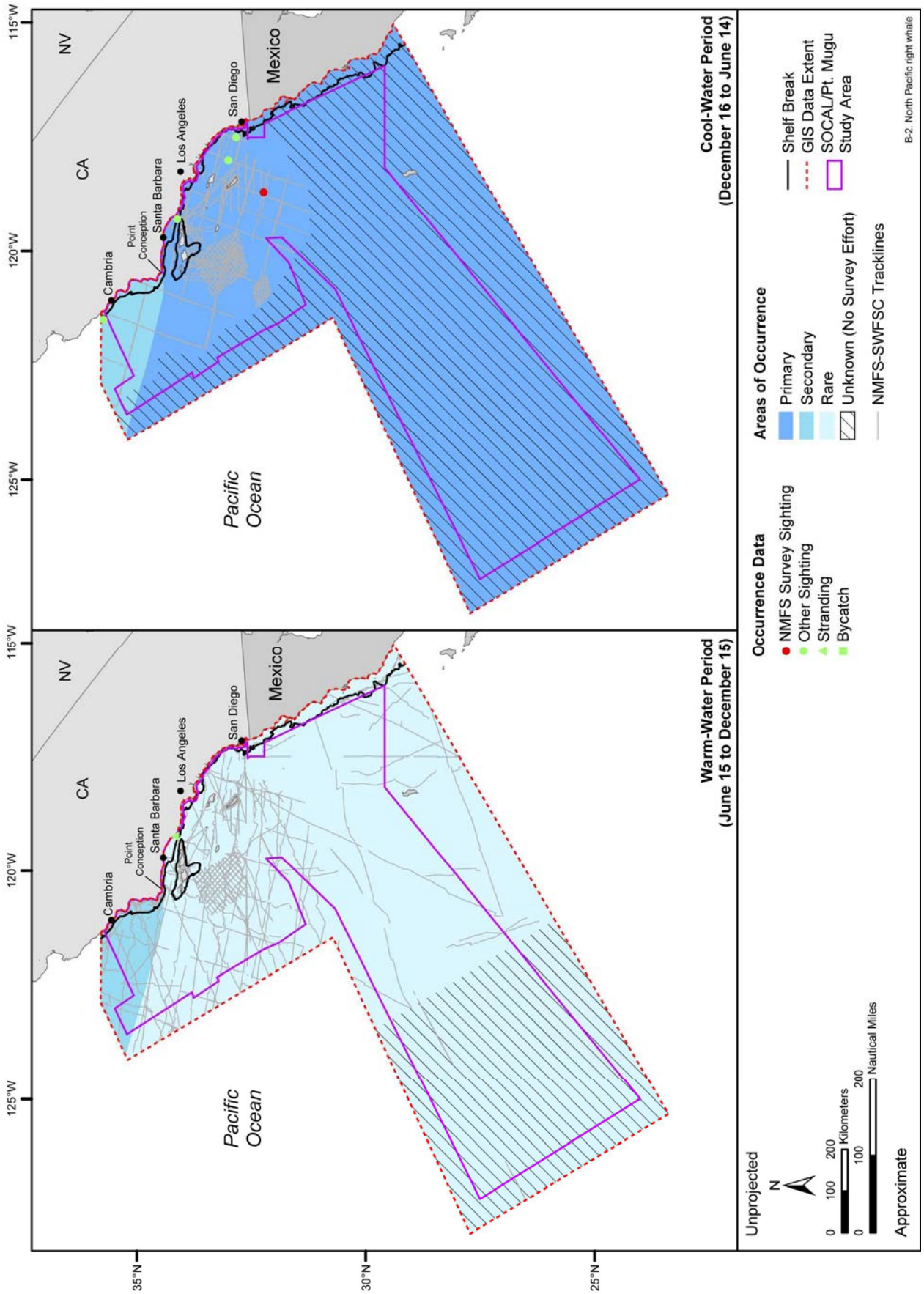

Figure B-2. Areas of occurrence for the North Pacific right whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

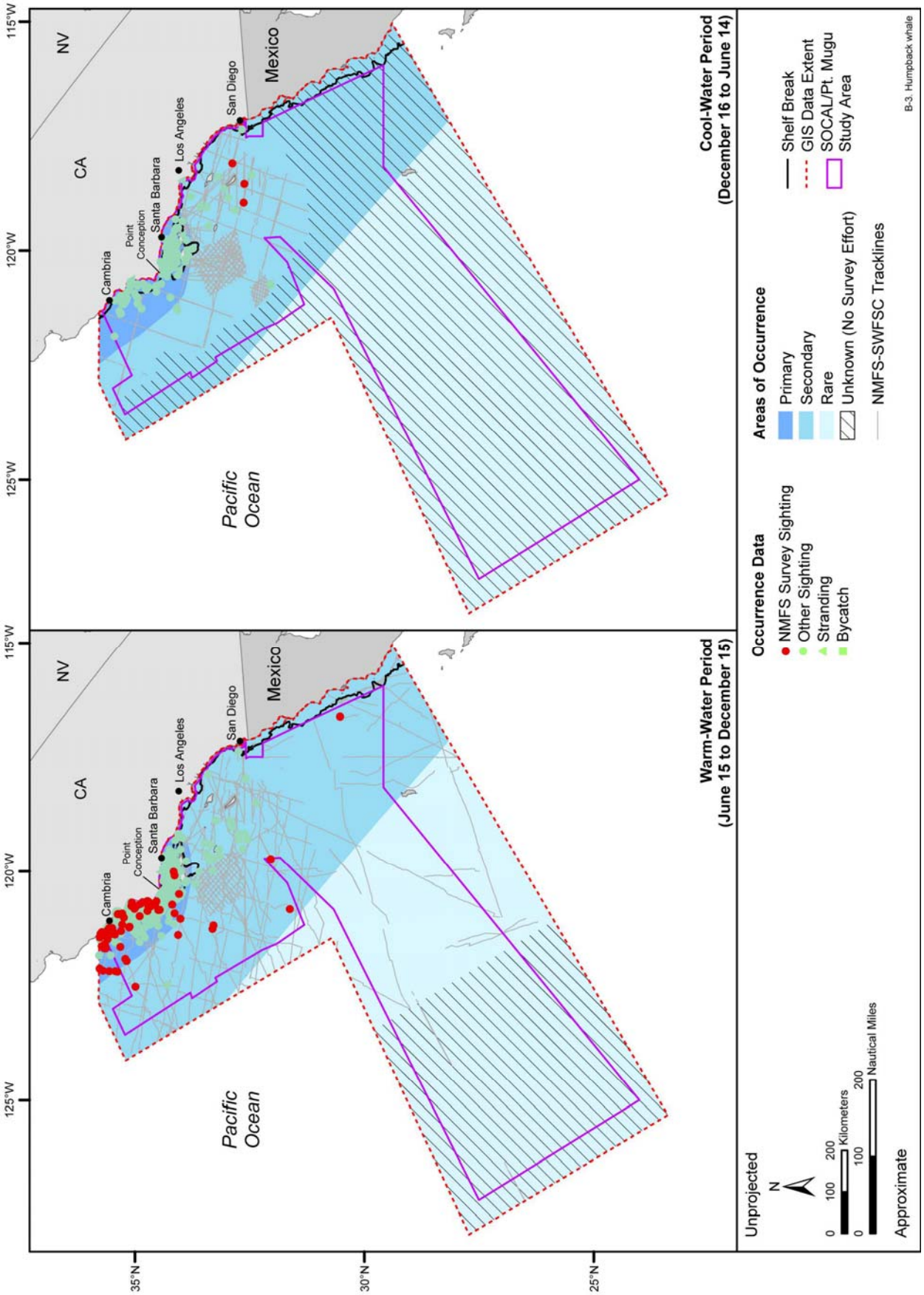

Figure B-3. Areas of occurrence for the humpback whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

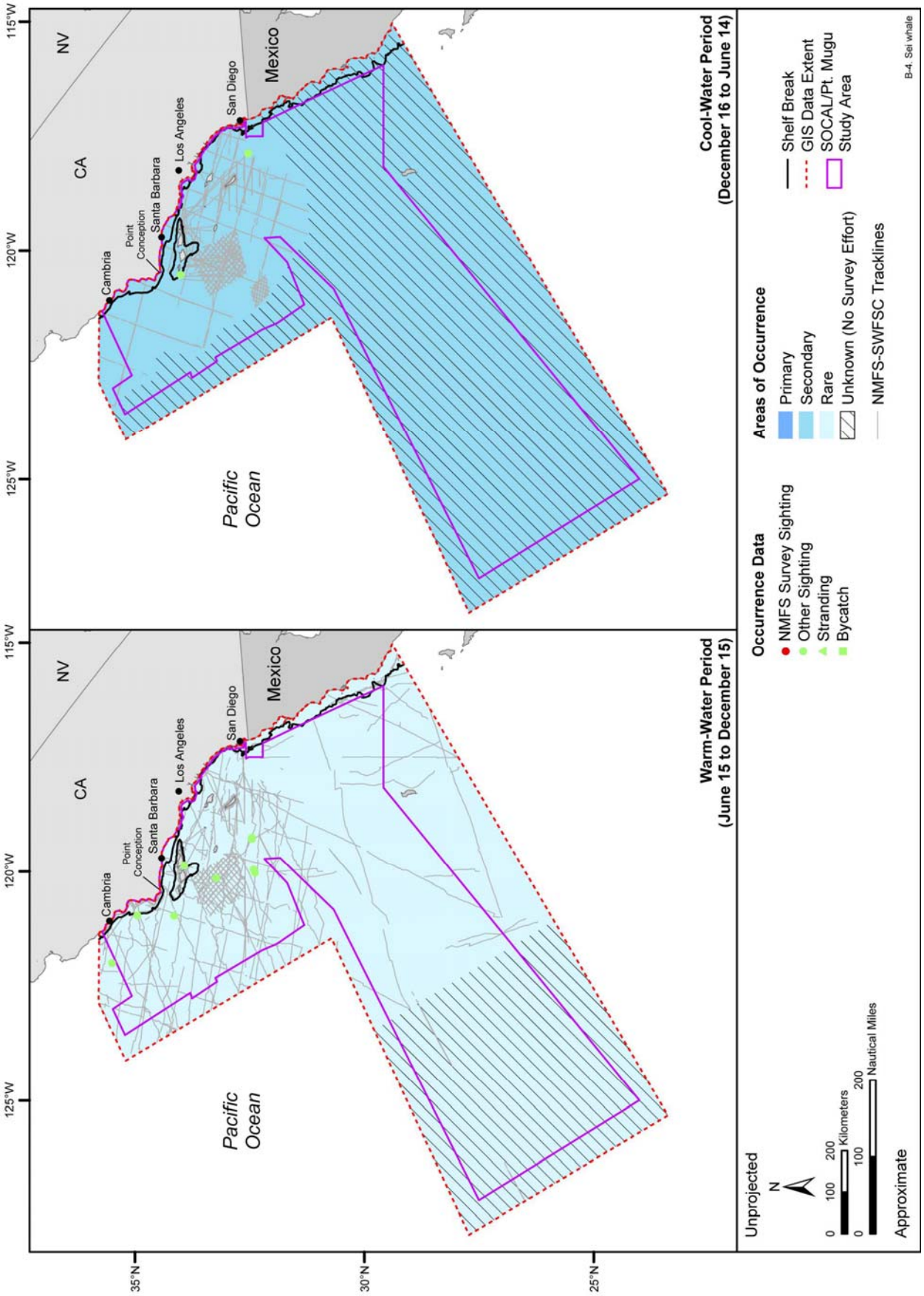

Figure B-4. Areas of occurrence for the sei whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

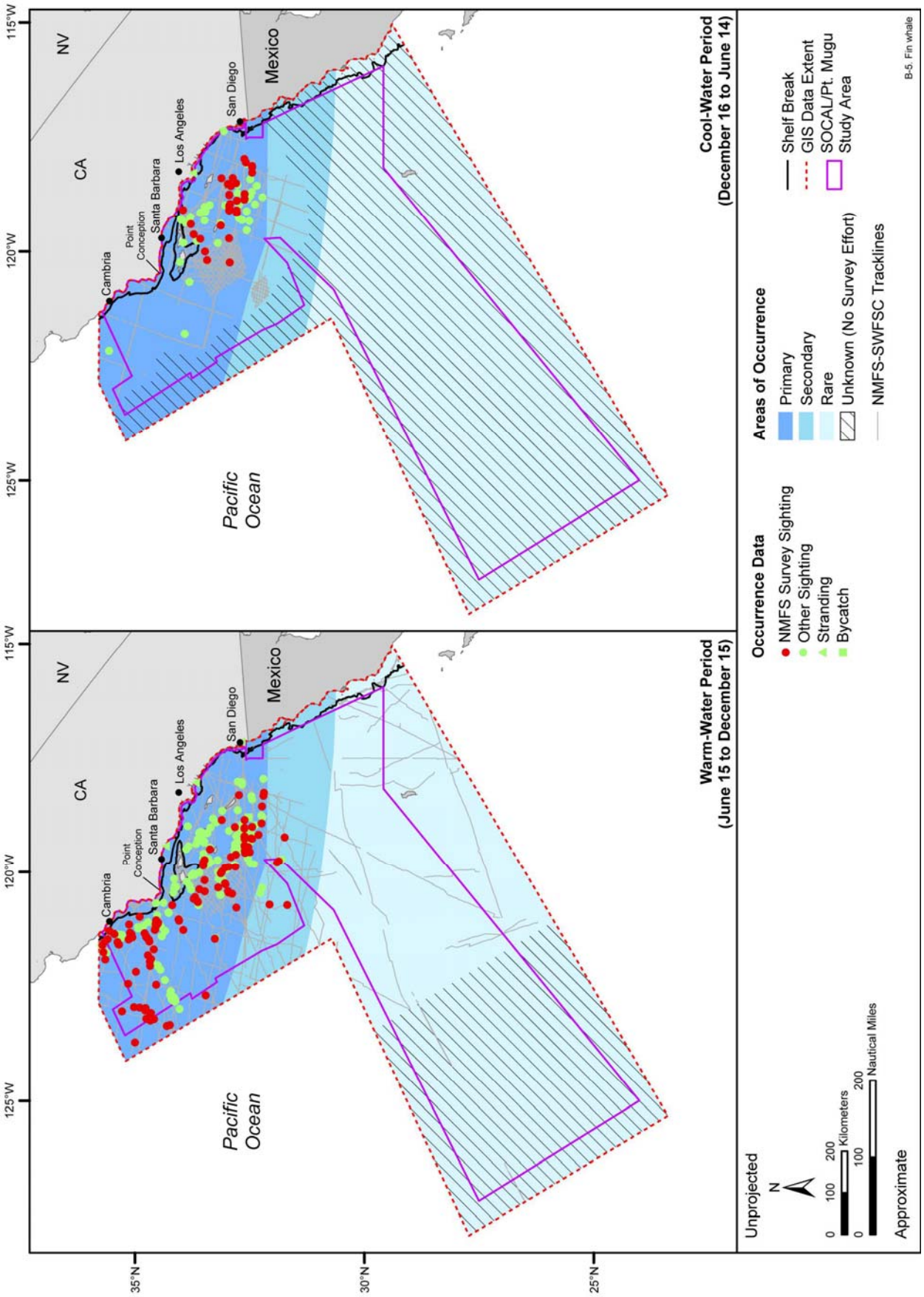

Figure B-5. Areas of occurrence for the fin whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

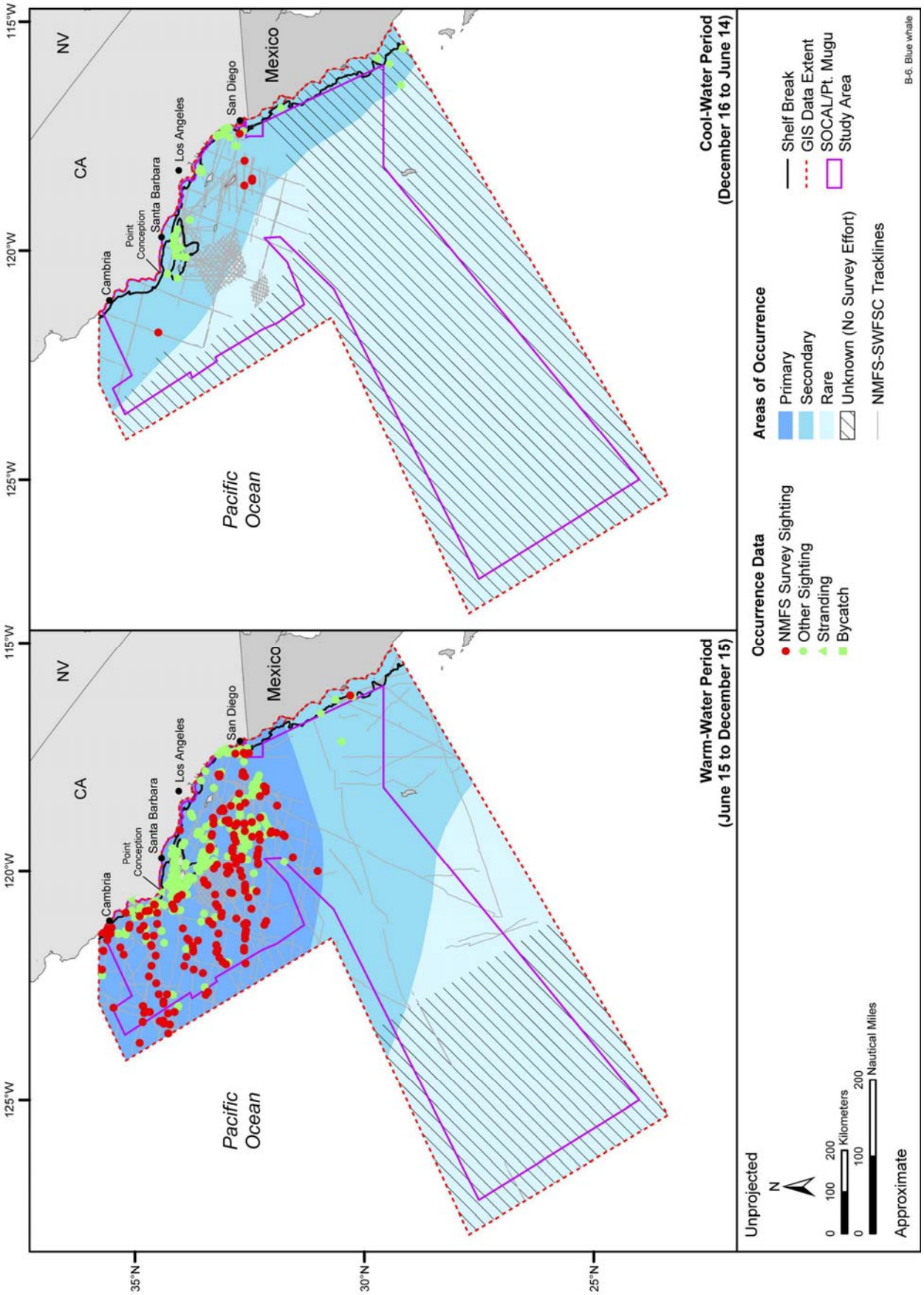

Figure B-6. Areas of occurrence for the blue whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

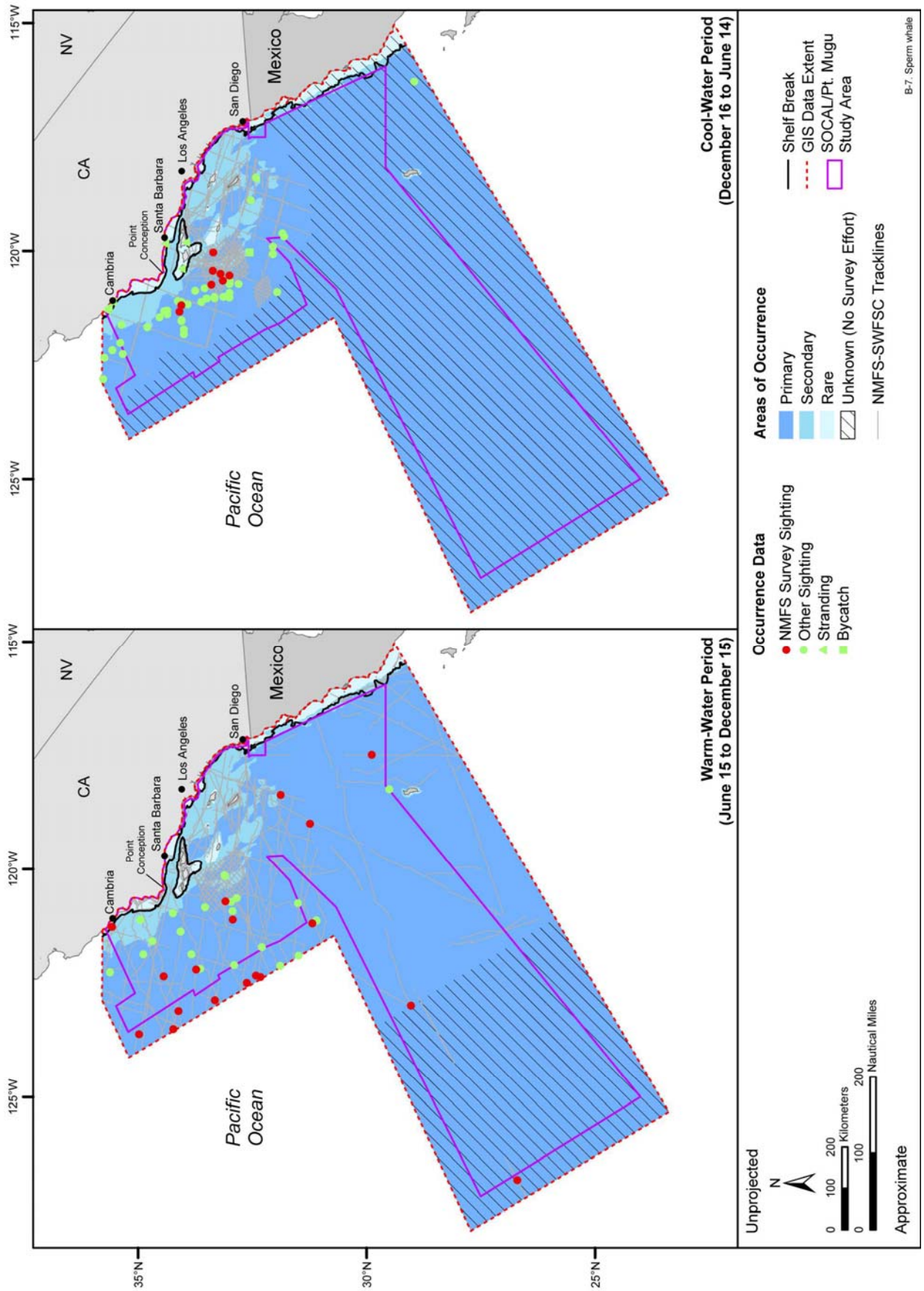

Figure B-7. Areas of occurrence for the sperm whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

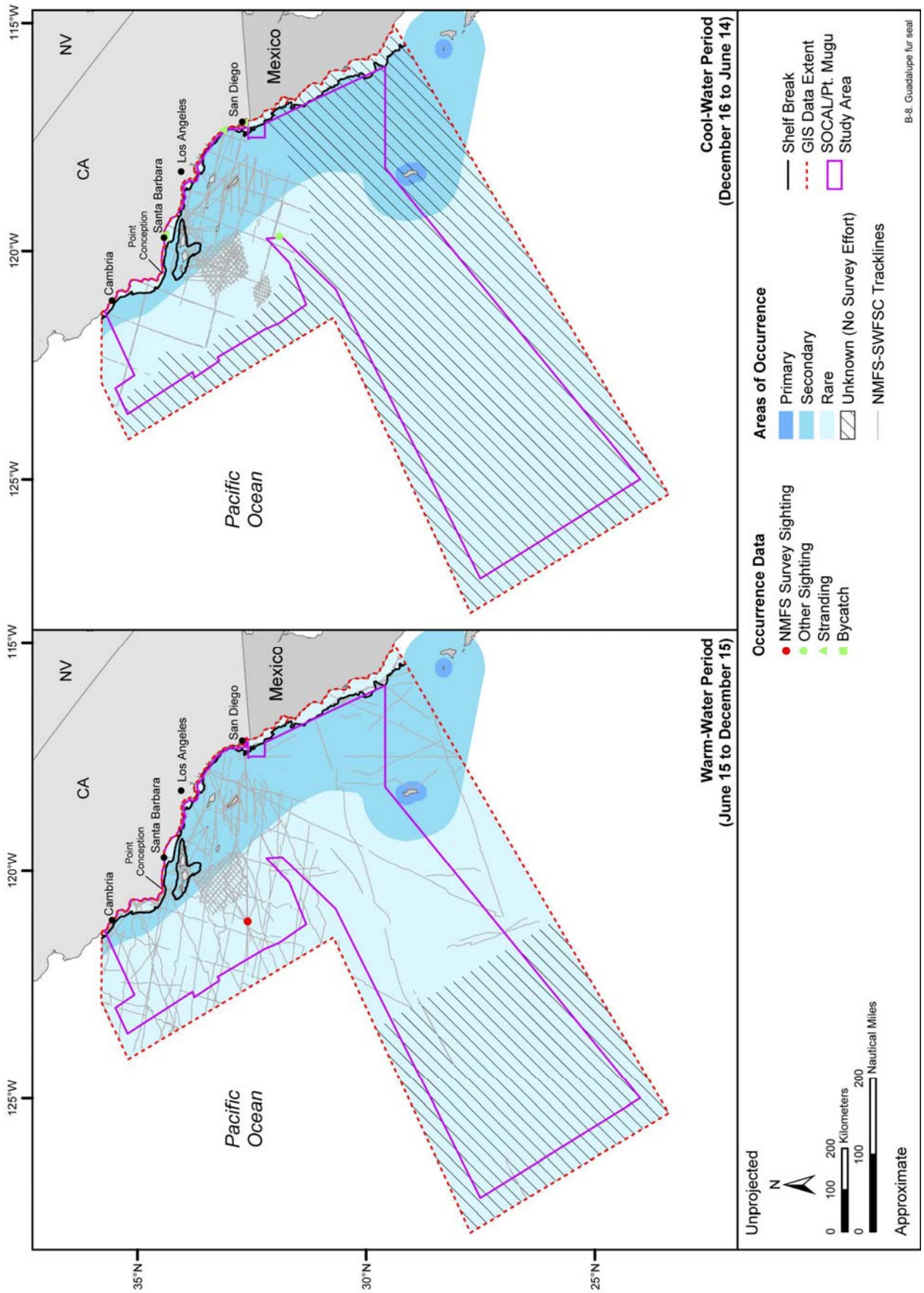

Figure B-8. Areas of occurrence for the Guadalupe fur seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

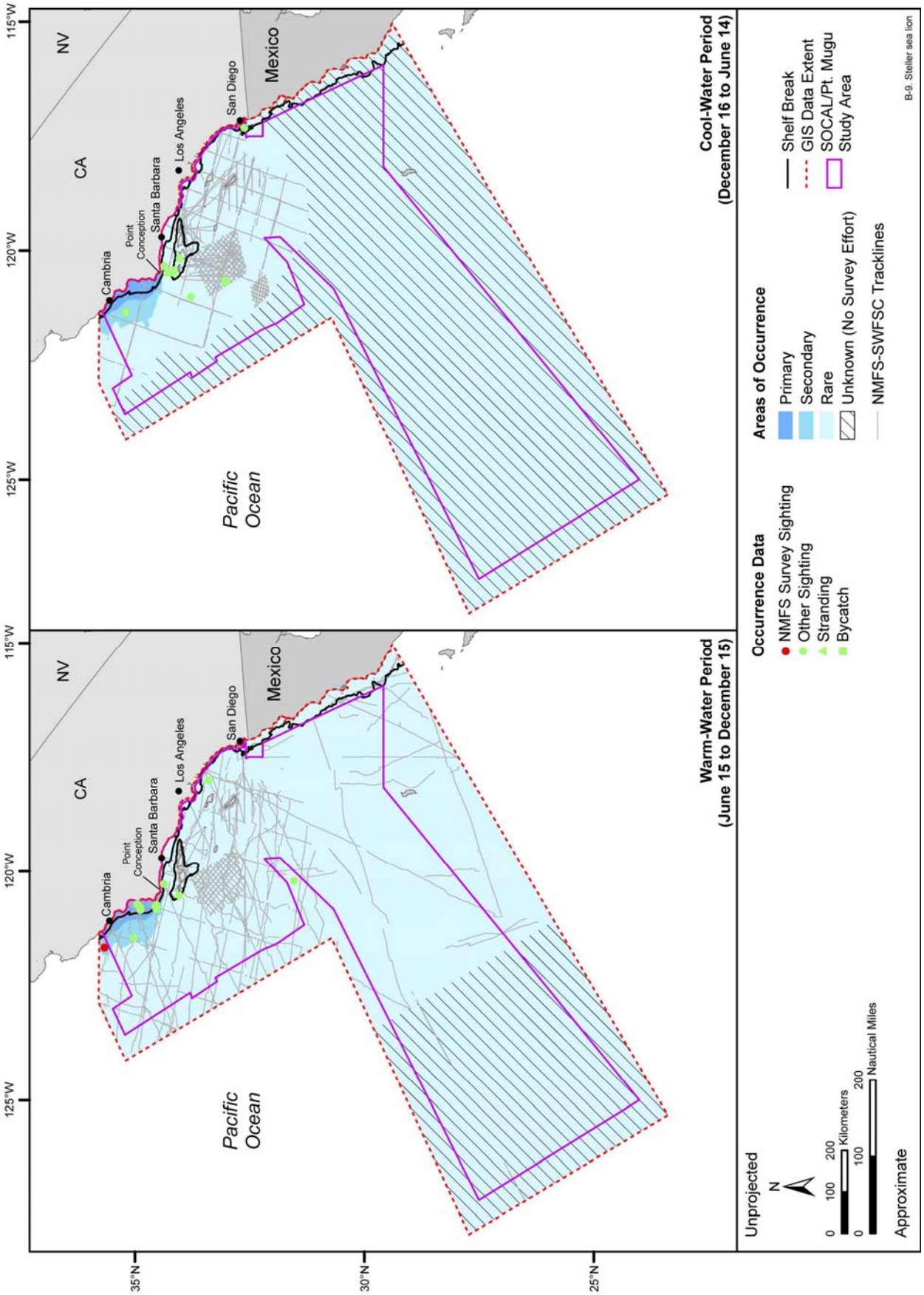

Figure B-9. Areas of occurrence for the Steller sea lion in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

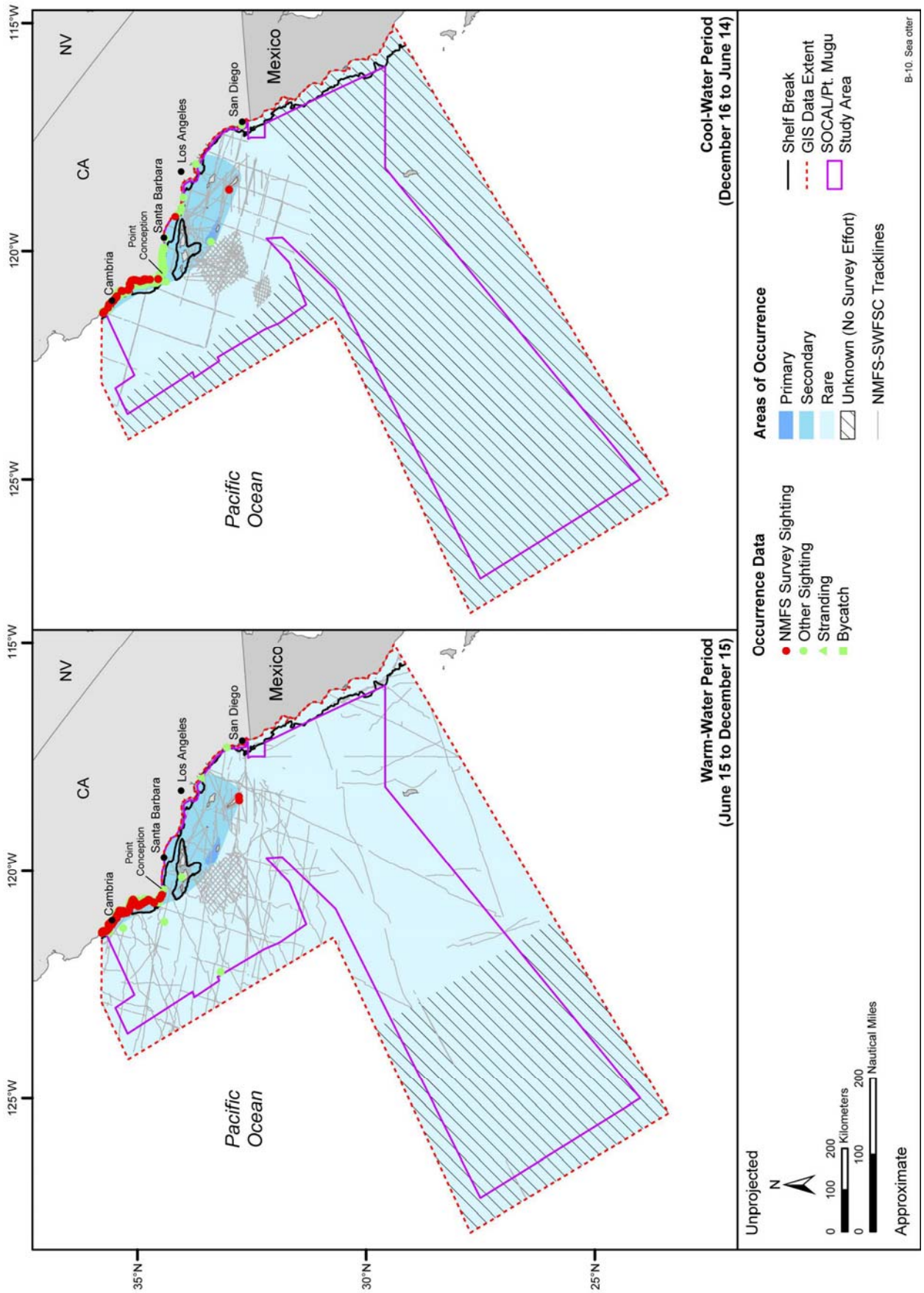

Figure B-10. Areas of occurrence for the sea otter in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

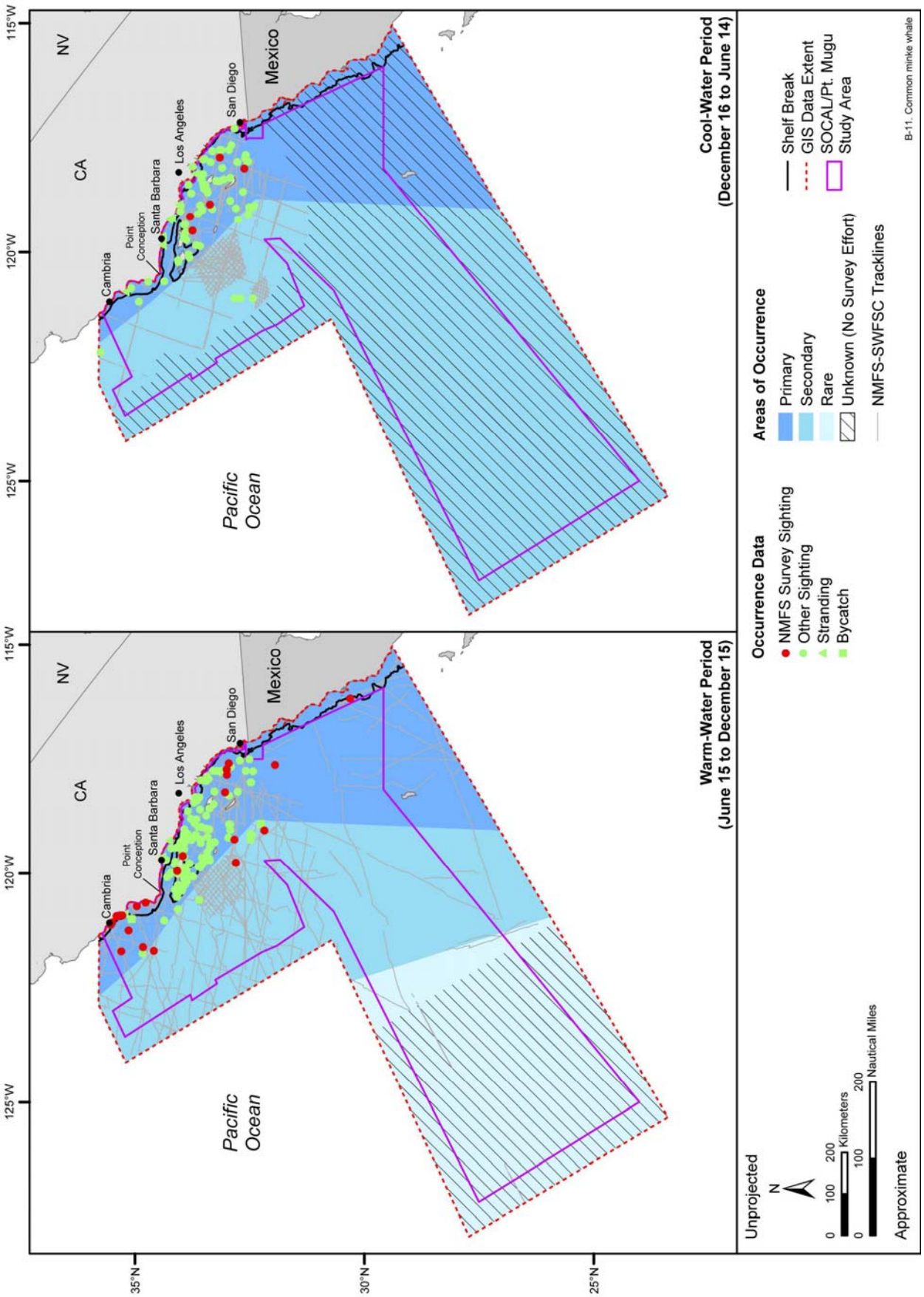

Figure B-11. Areas of occurrence for the common minke whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1

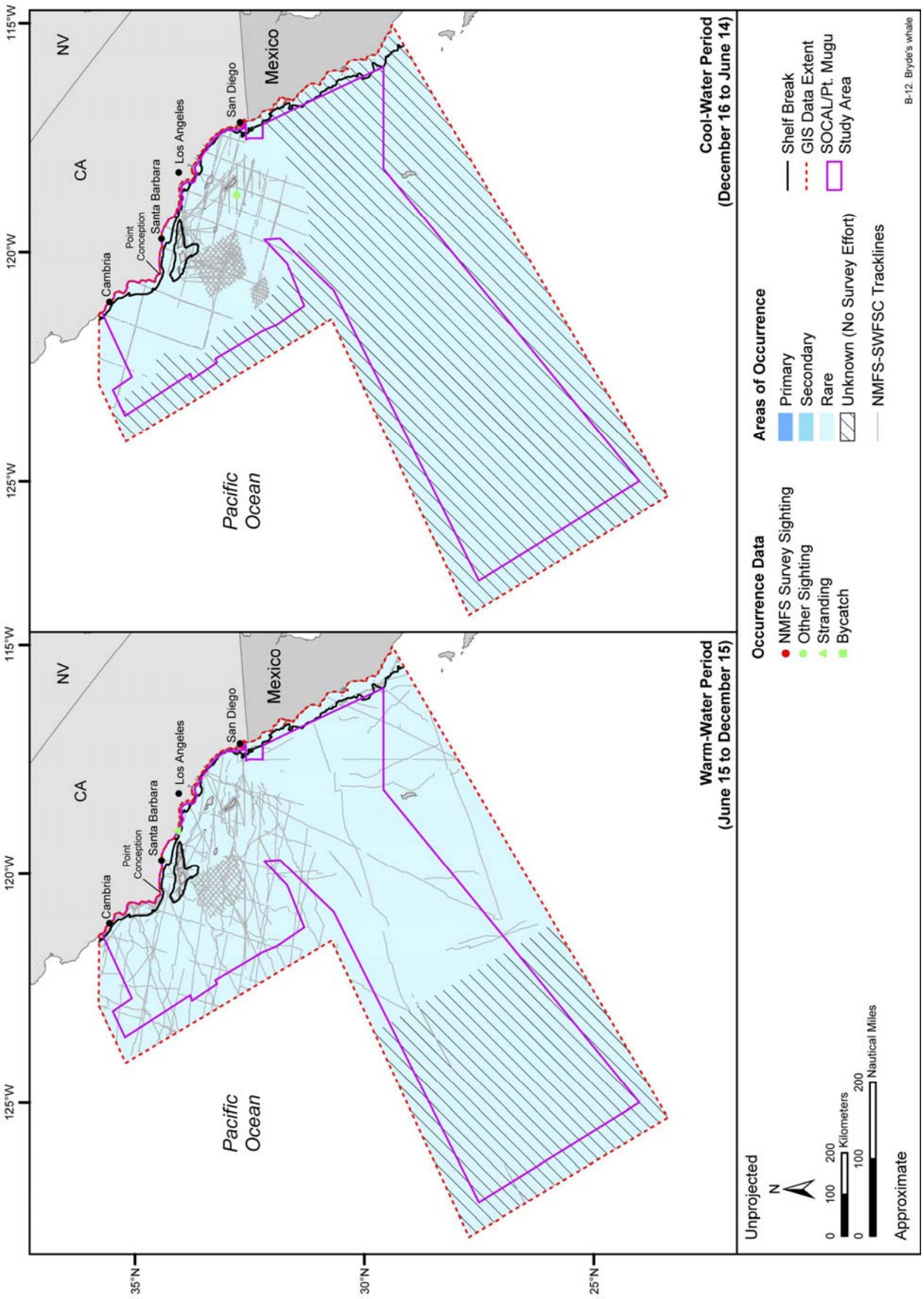

Figure B-12. Areas of occurrence for the Bryde's whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

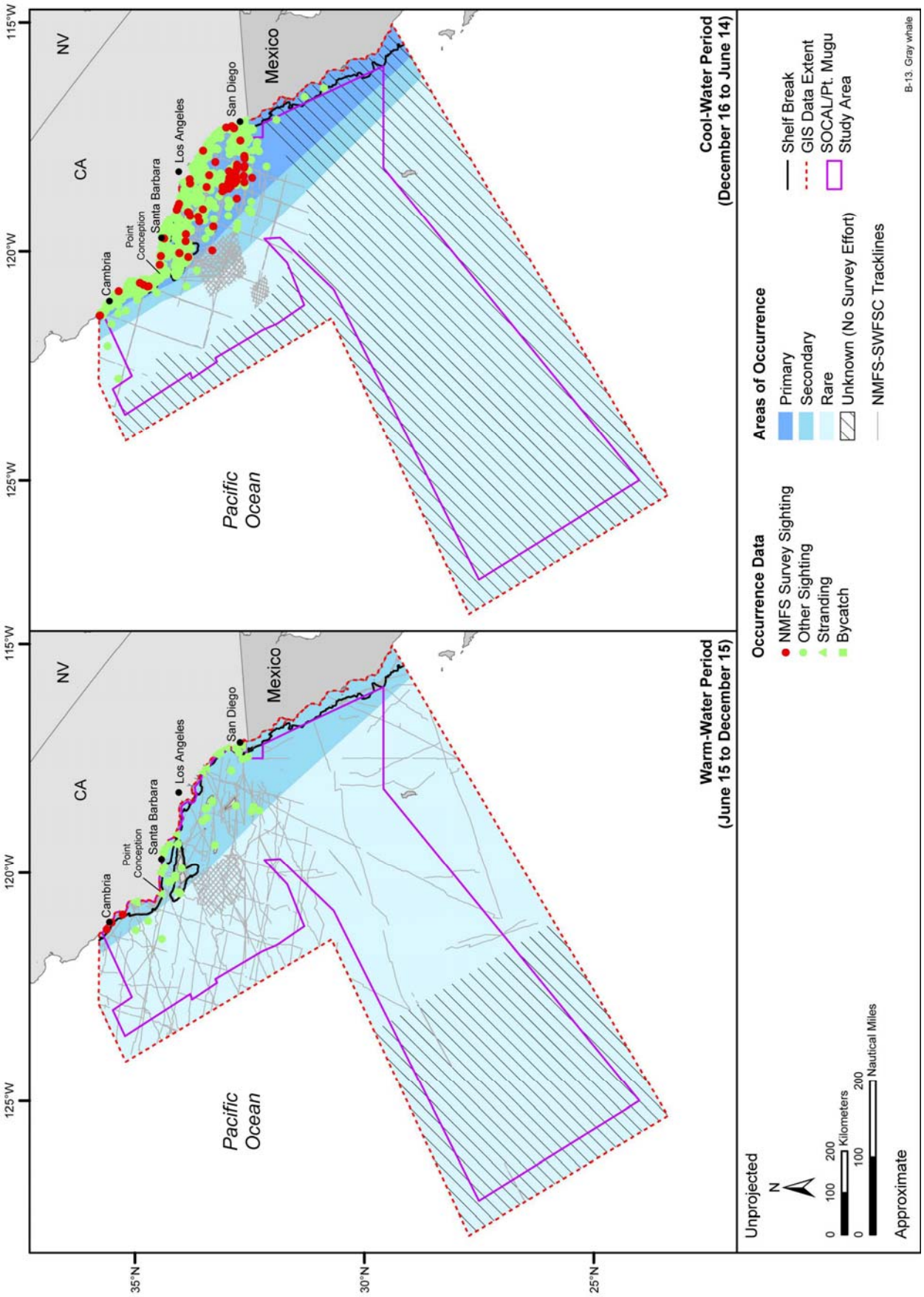

Figure B-13. Areas of occurrence for the gray whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

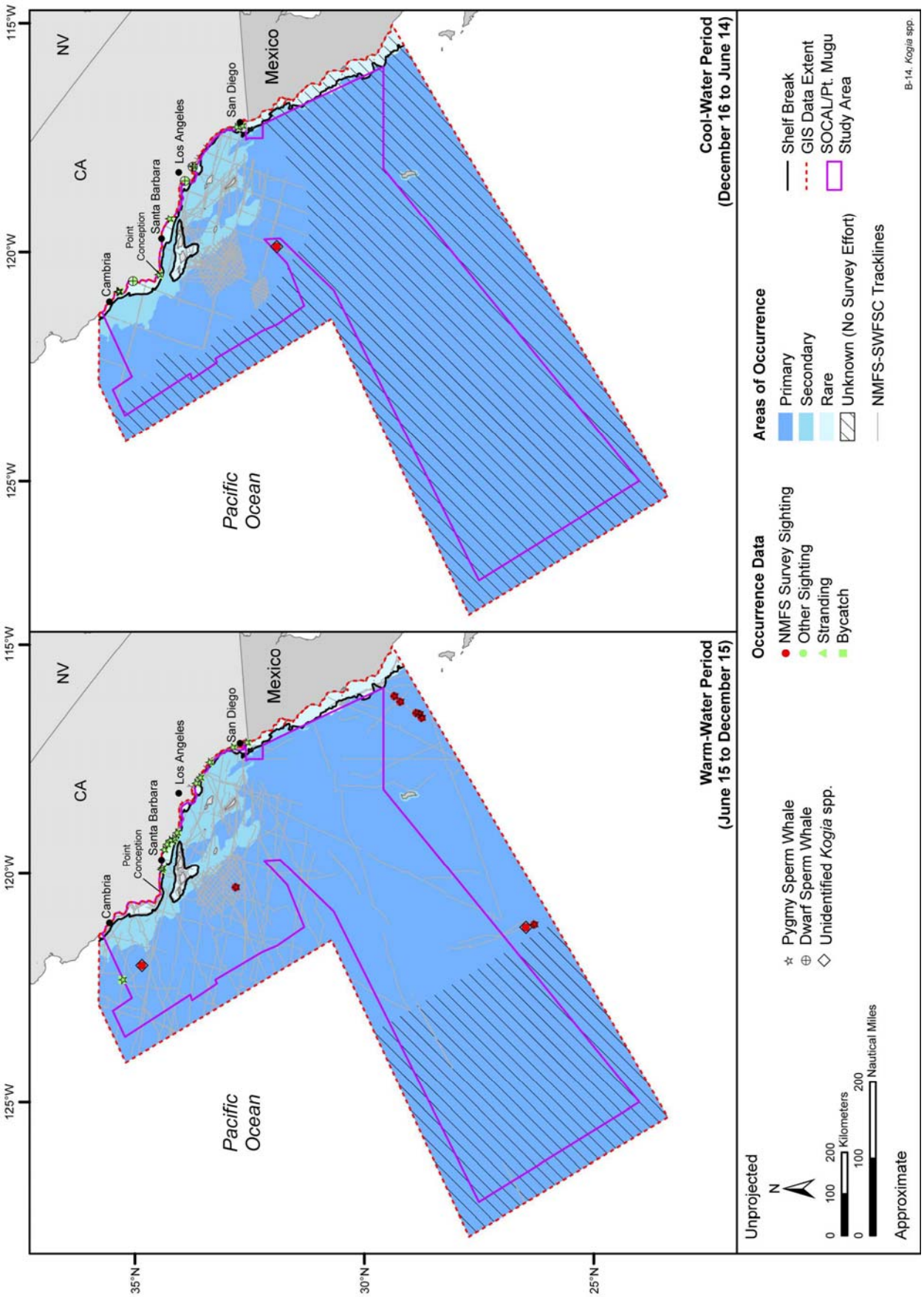

Figure B-14. Areas of occurrence for *Kogia* spp. in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

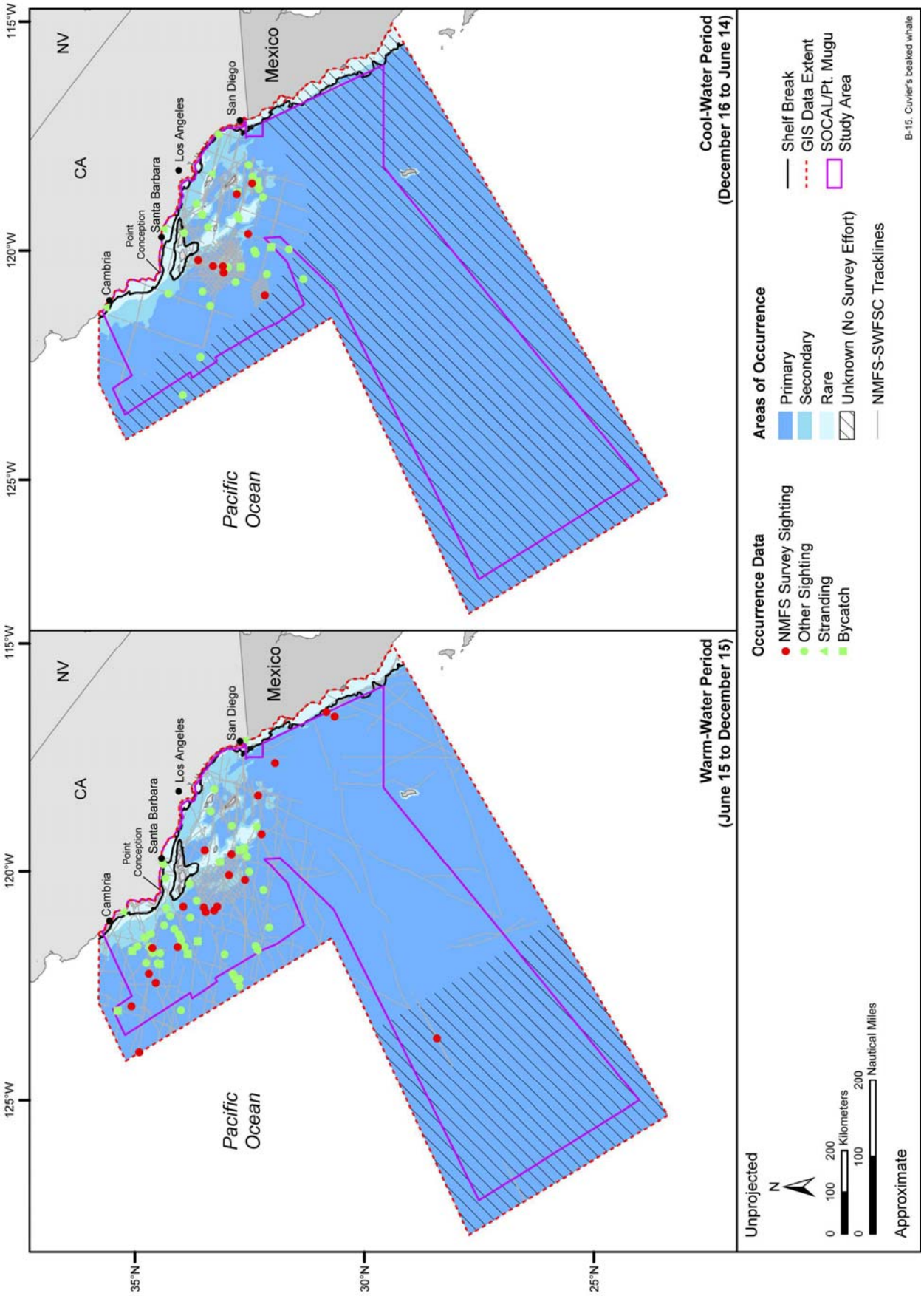

Figure B-15. Areas of occurrence for the Cuvier's beaked whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

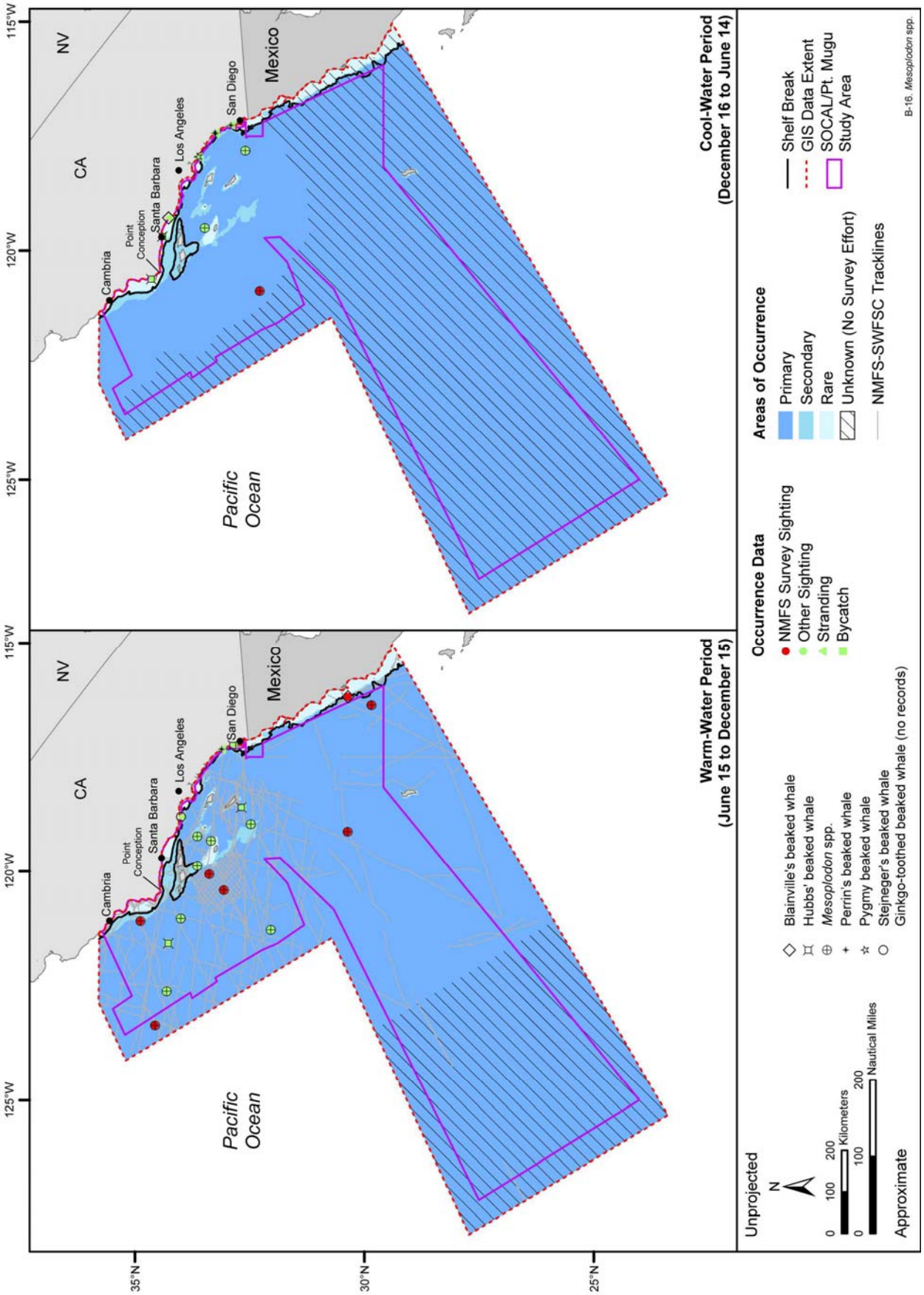

Figure B-16. Areas of occurrence for *Mesoplodon* spp. in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

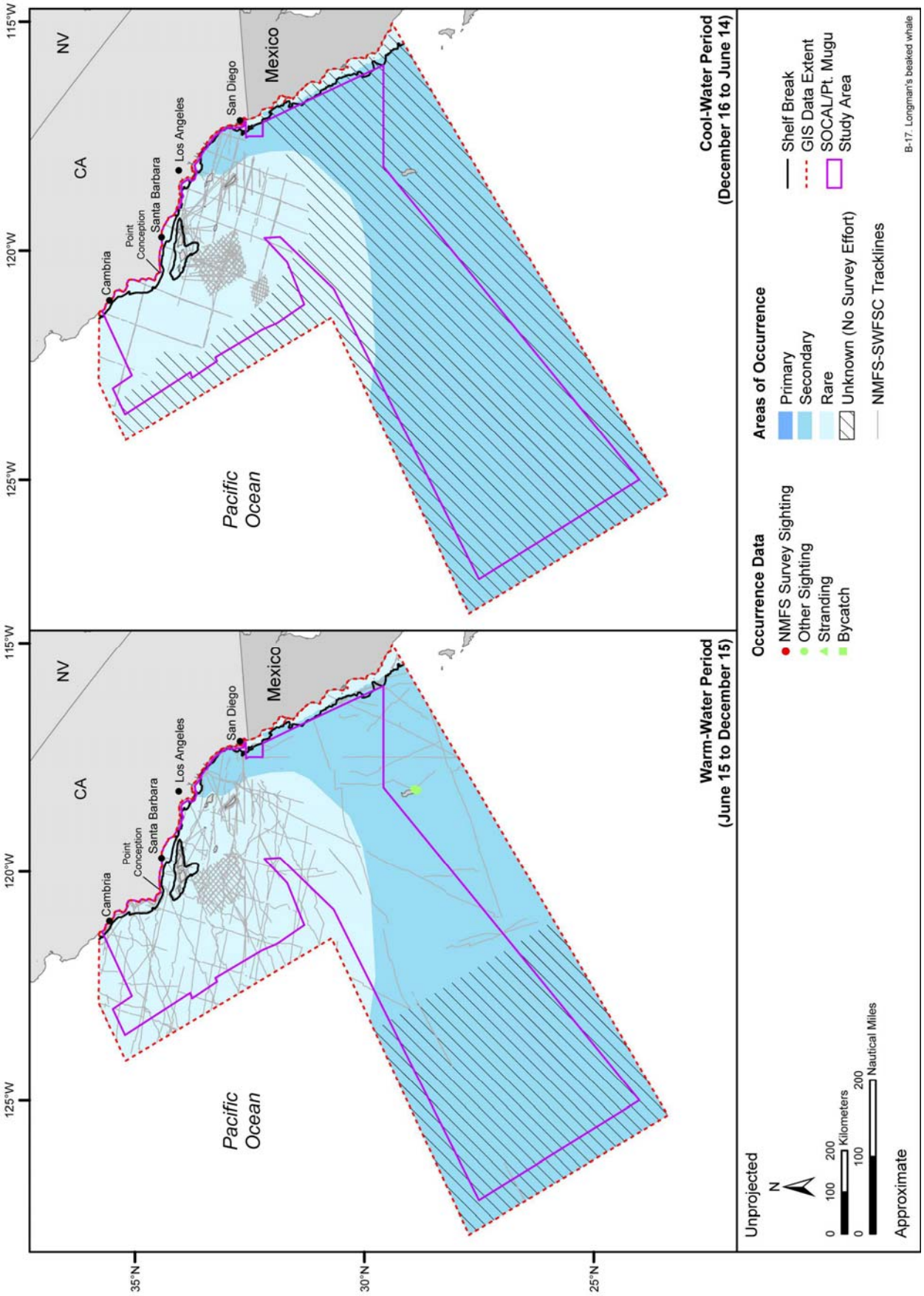

Figure B-17. Areas of occurrence for the Longman's beaked whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

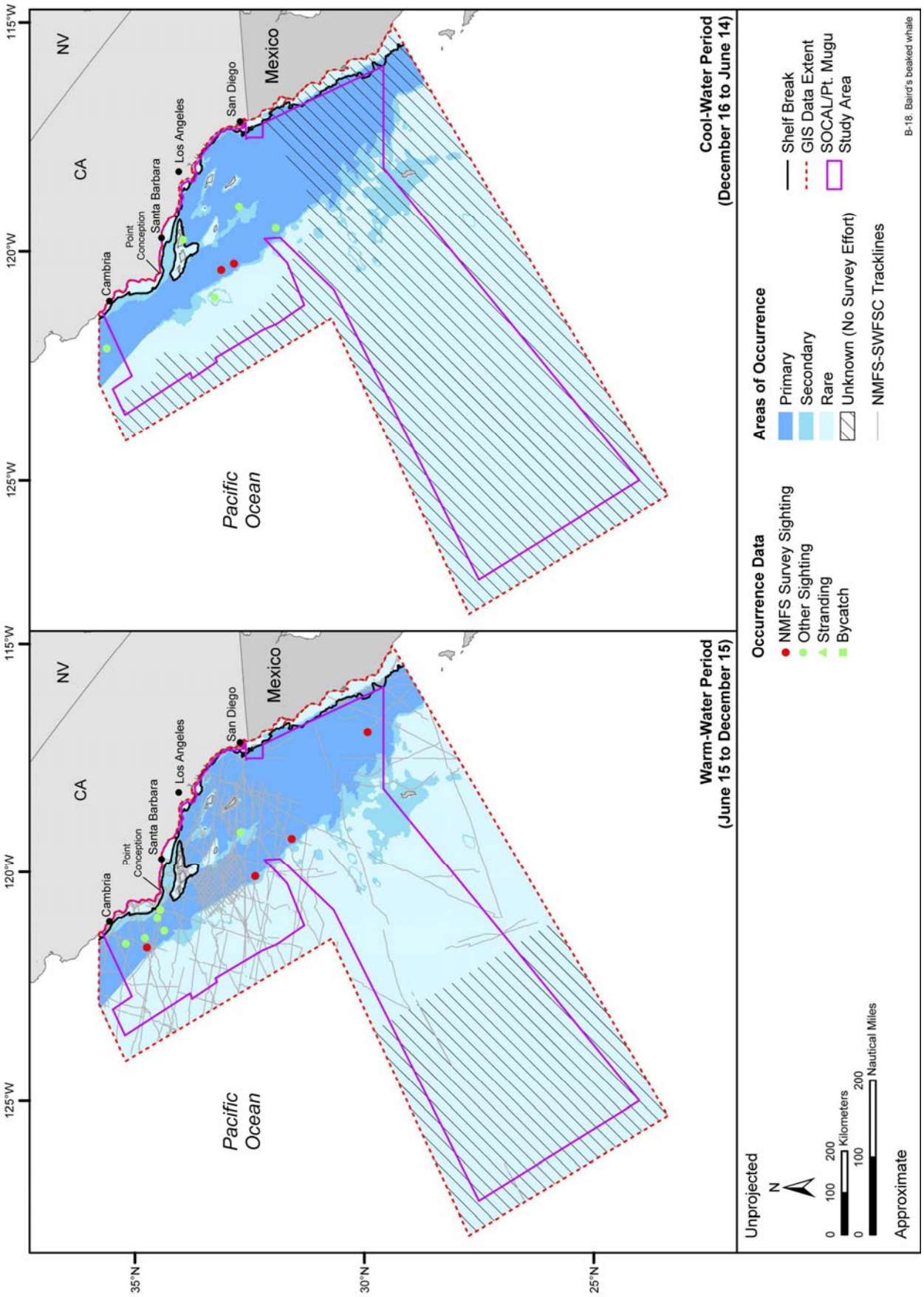

Figure B-18. Areas of occurrence for the Baird's beaked whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

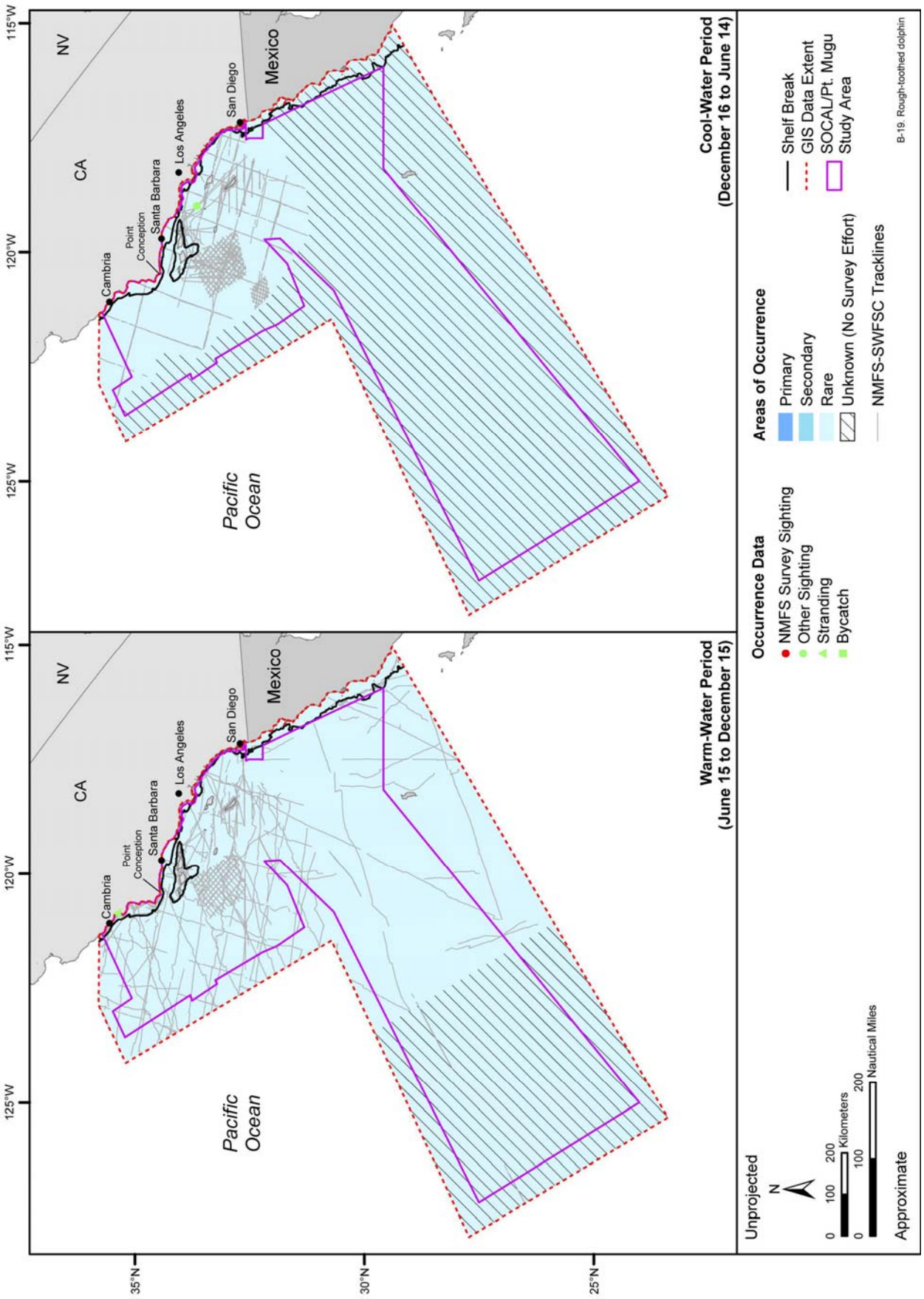

Figure B-19. Areas of occurrence for the rough-toothed dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

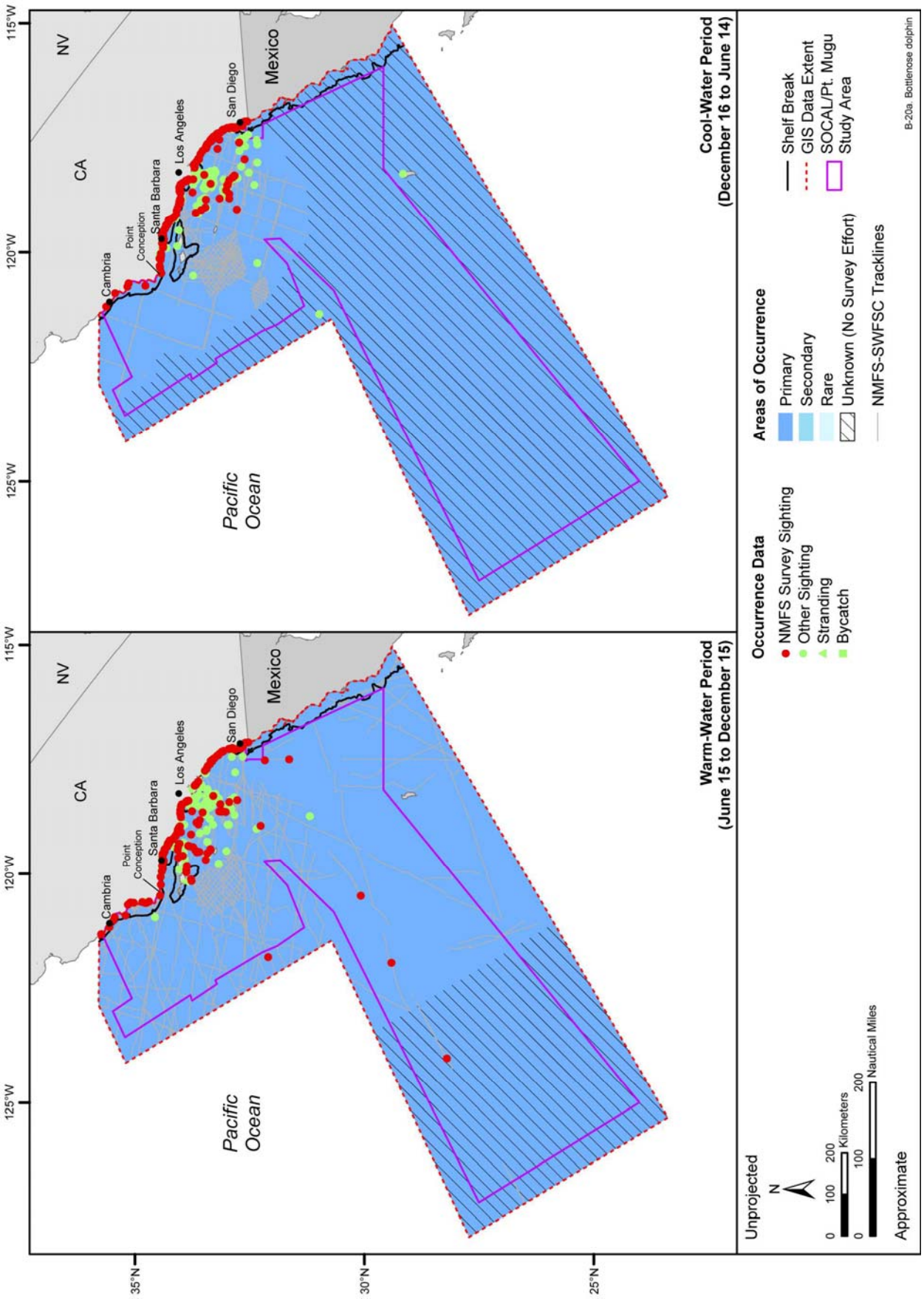

Figure B-20a. Areas of occurrence for the common bottlenose dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

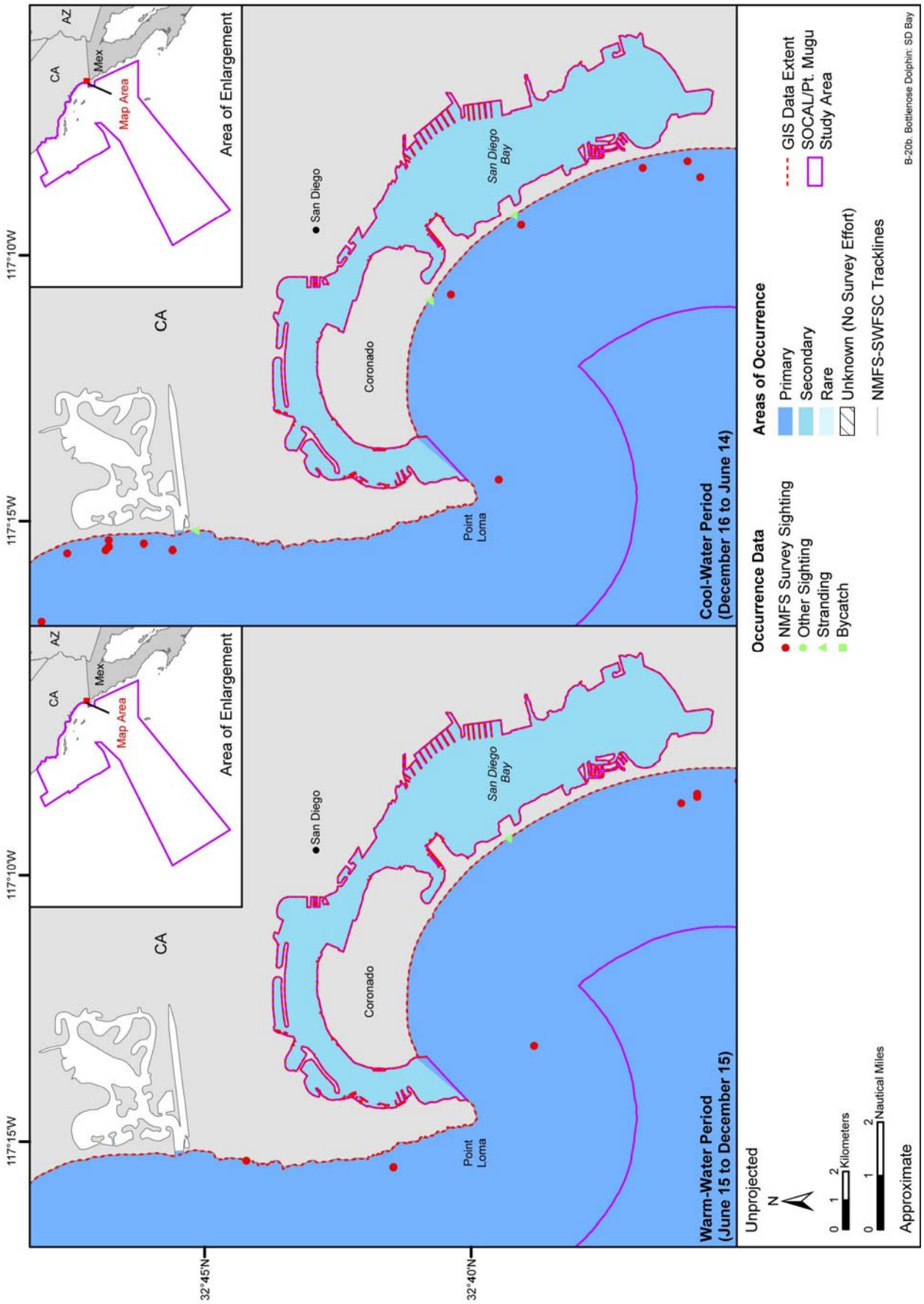

Figure B-20b. Areas of occurrence for the common bottlenose dolphin in San Diego Bay. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-1.

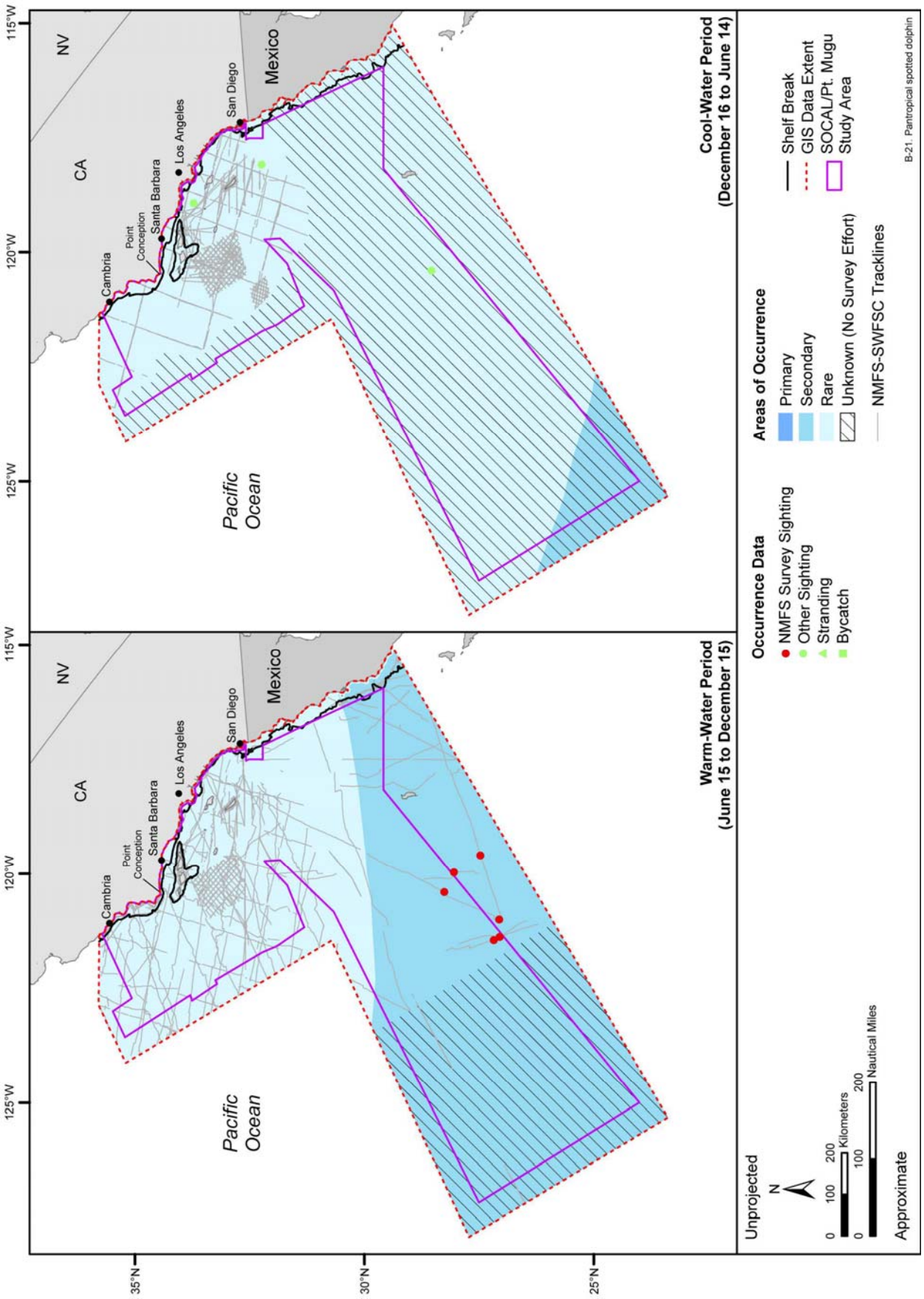

Figure B-21. Areas of occurrence for the pantropical spotted dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

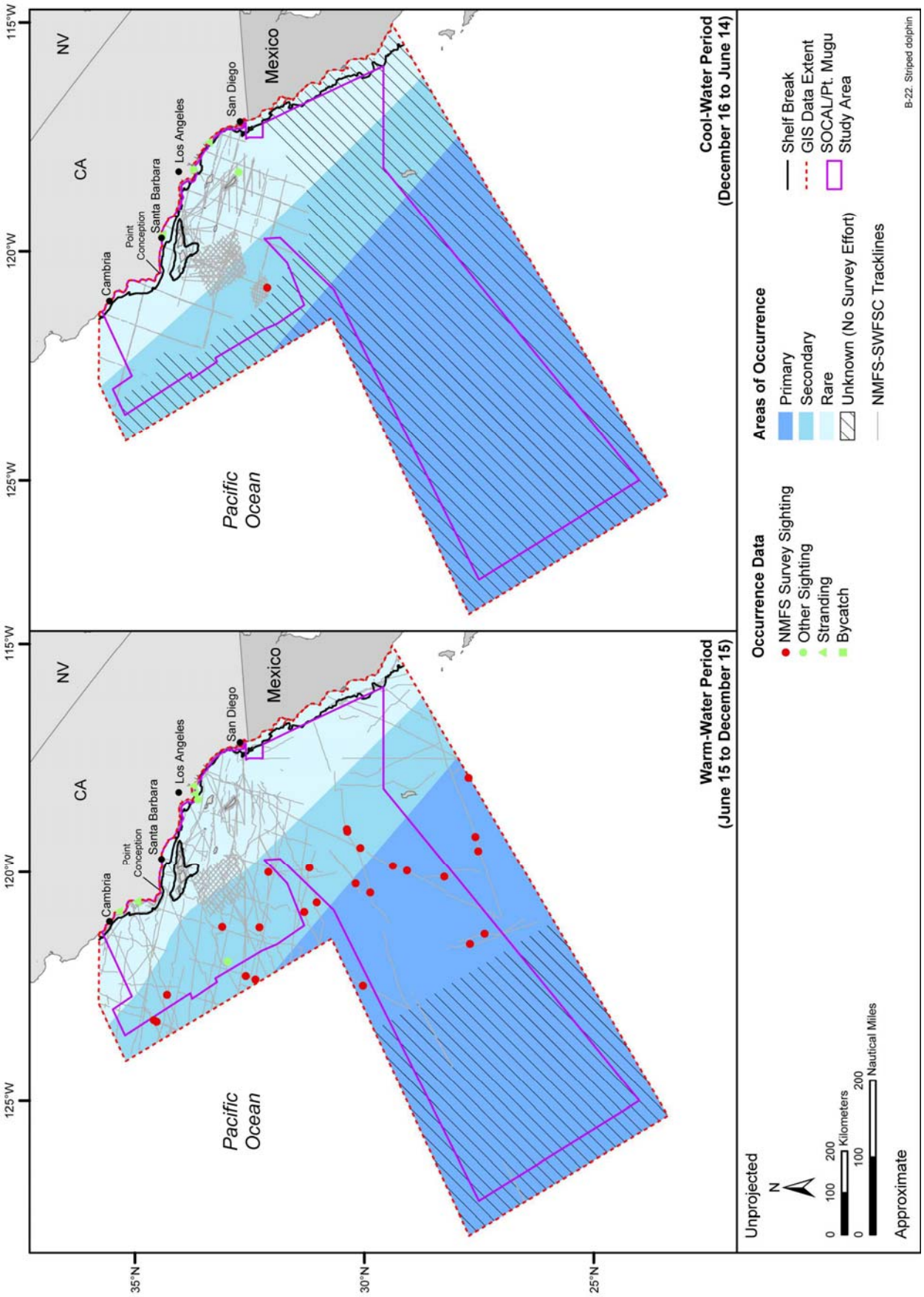

Figure B-22. Areas of occurrence for the striped dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

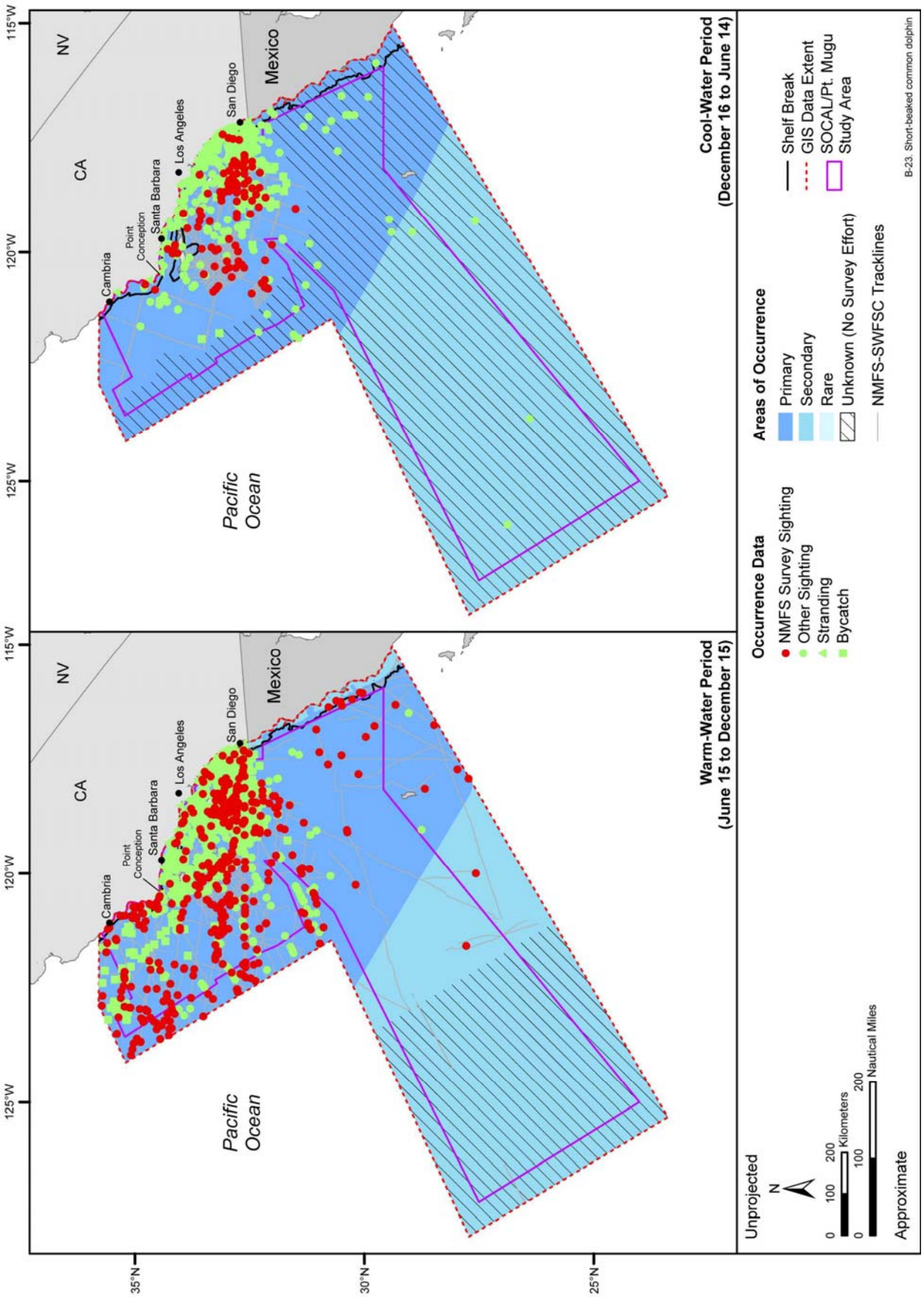

Figure B-23. Areas of occurrence for the short-beaked common dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

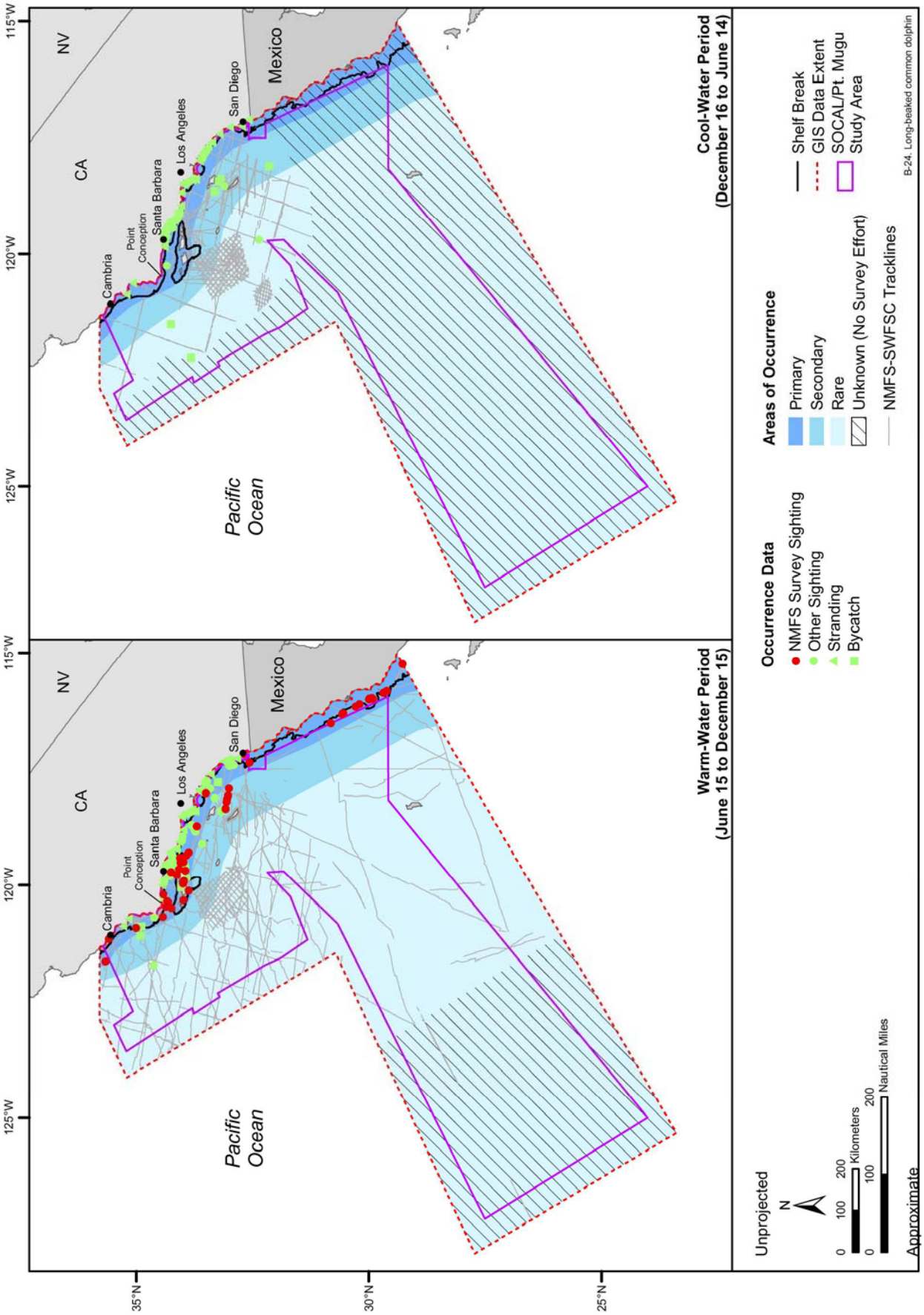

Figure B-24. Areas of occurrence for the long-beaked common dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

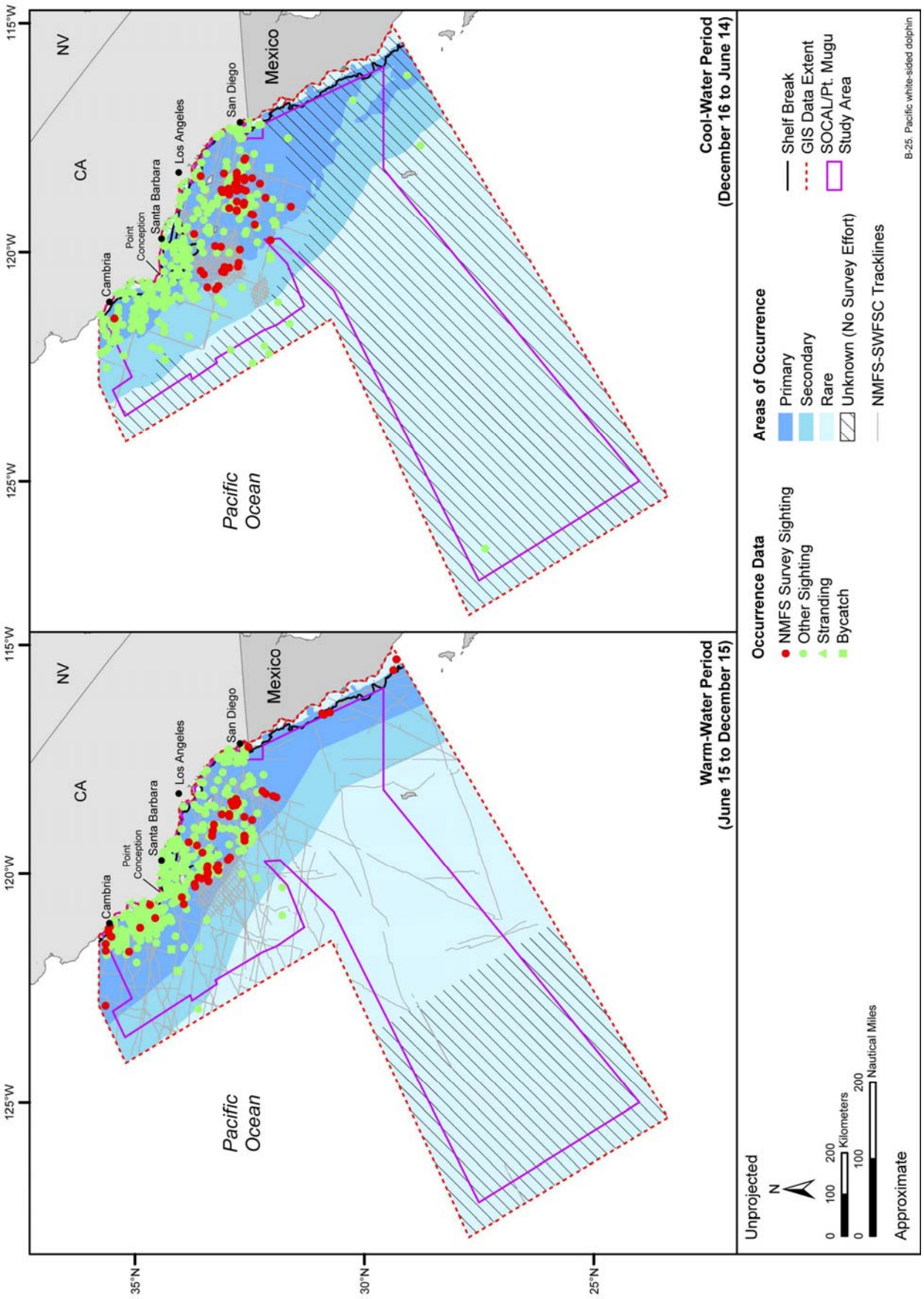

Figure B-25. Areas of occurrence for the Pacific white-sided dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

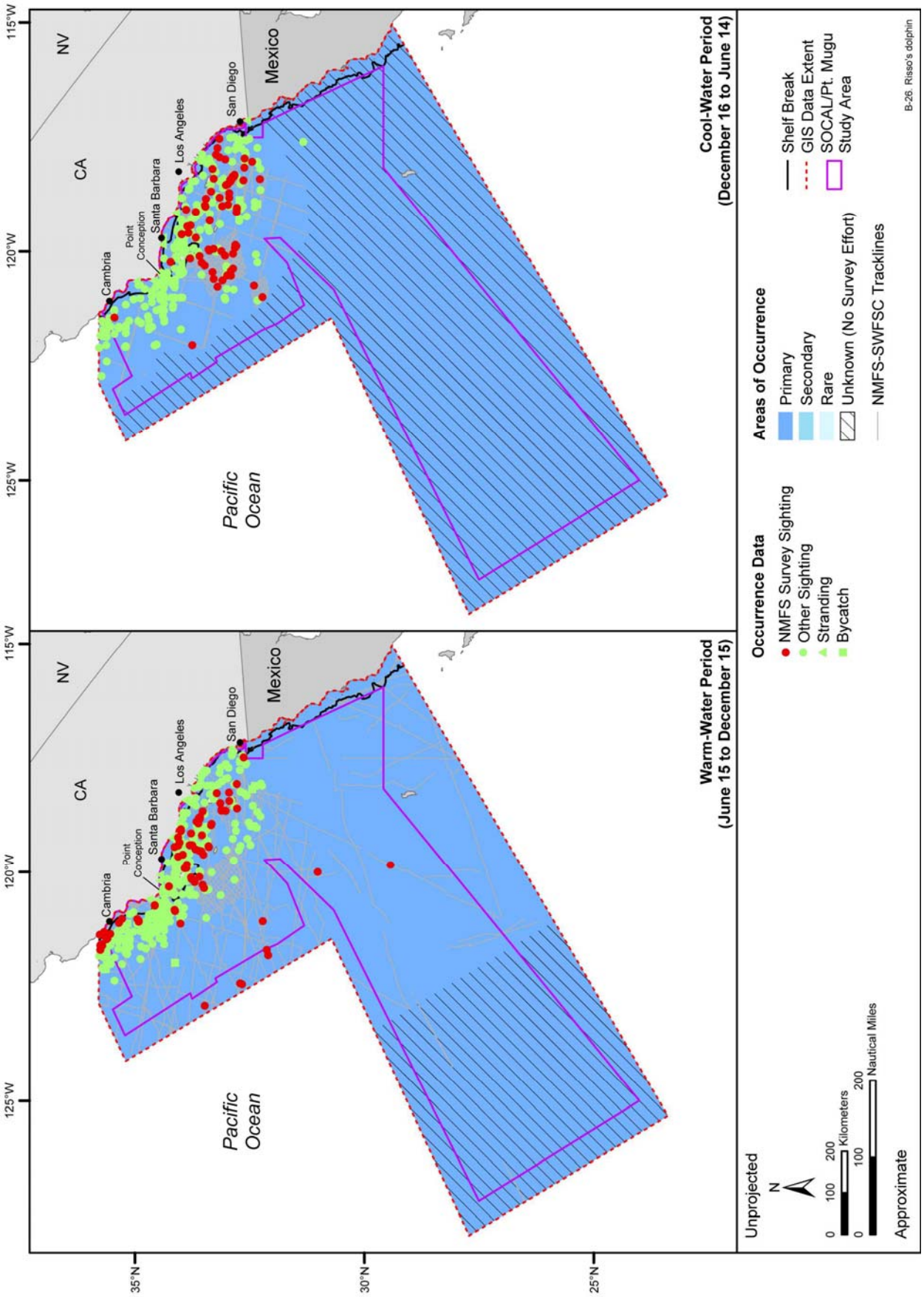

Figure B-26. Areas of occurrence for the Risso's dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

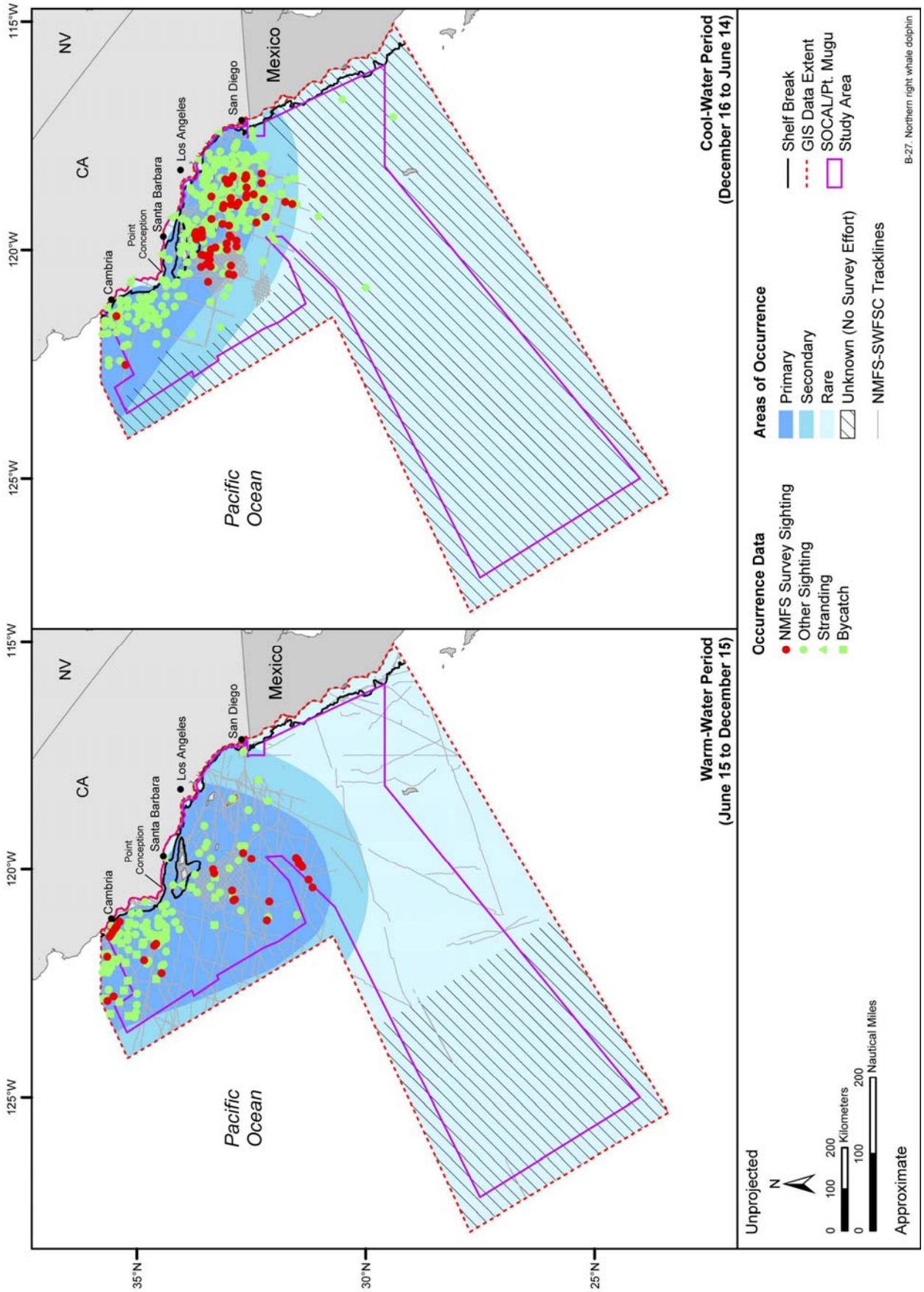

Figure B-27. Areas of occurrence for the northern right whale dolphin in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

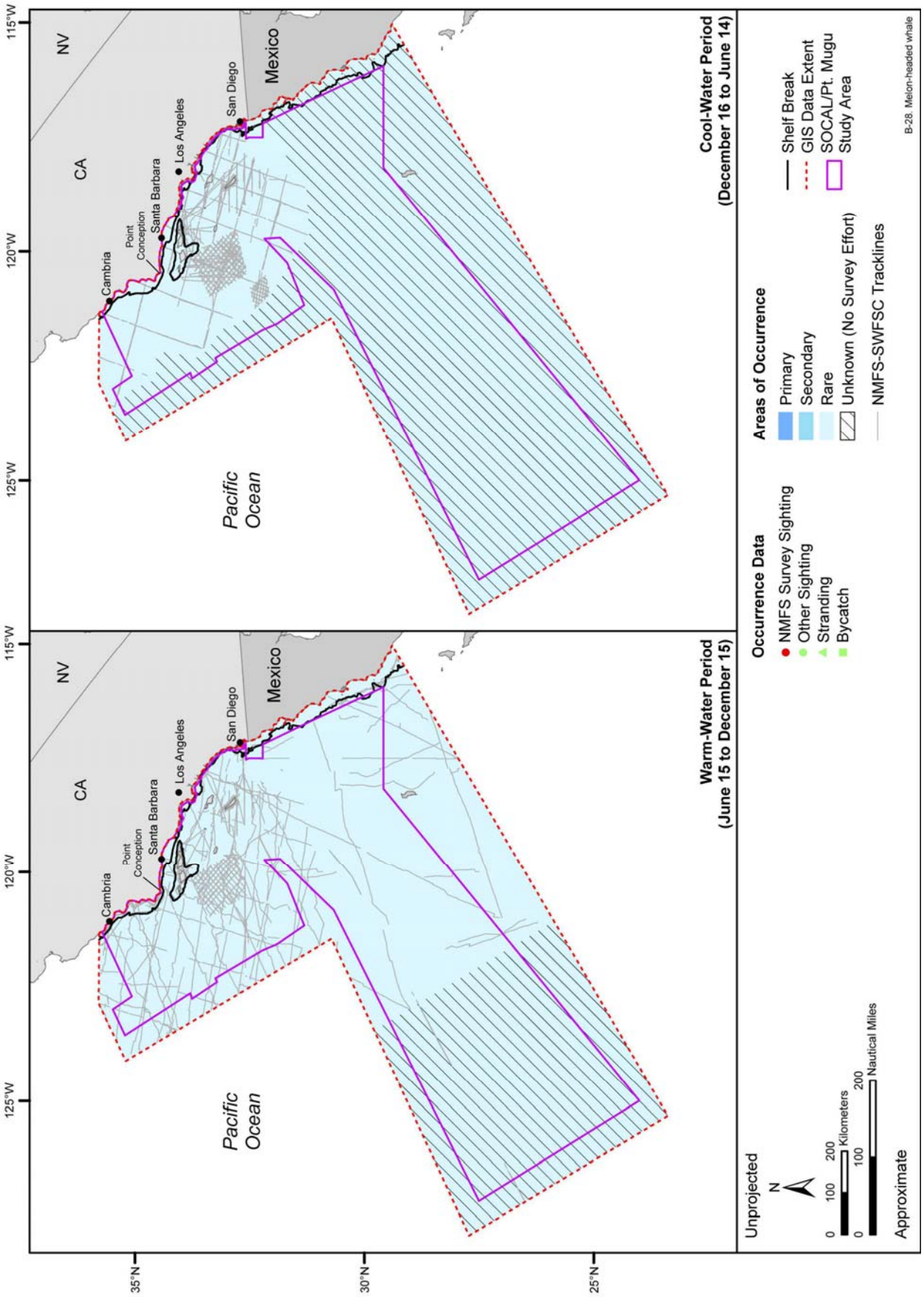

Figure B-28. Areas of occurrence for the melon-headed whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

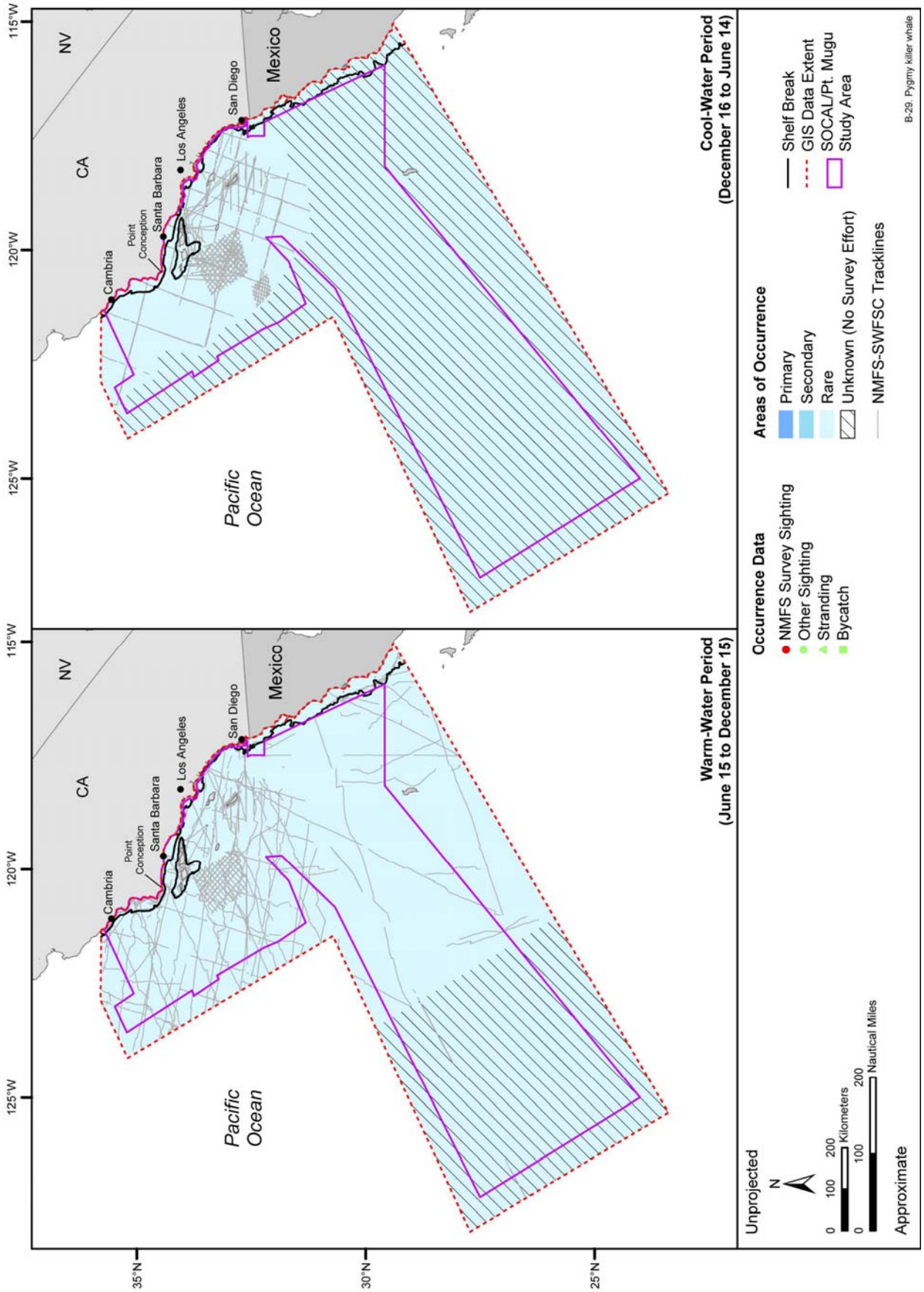

Figure B-29. Areas of occurrence for the pygmy killer whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

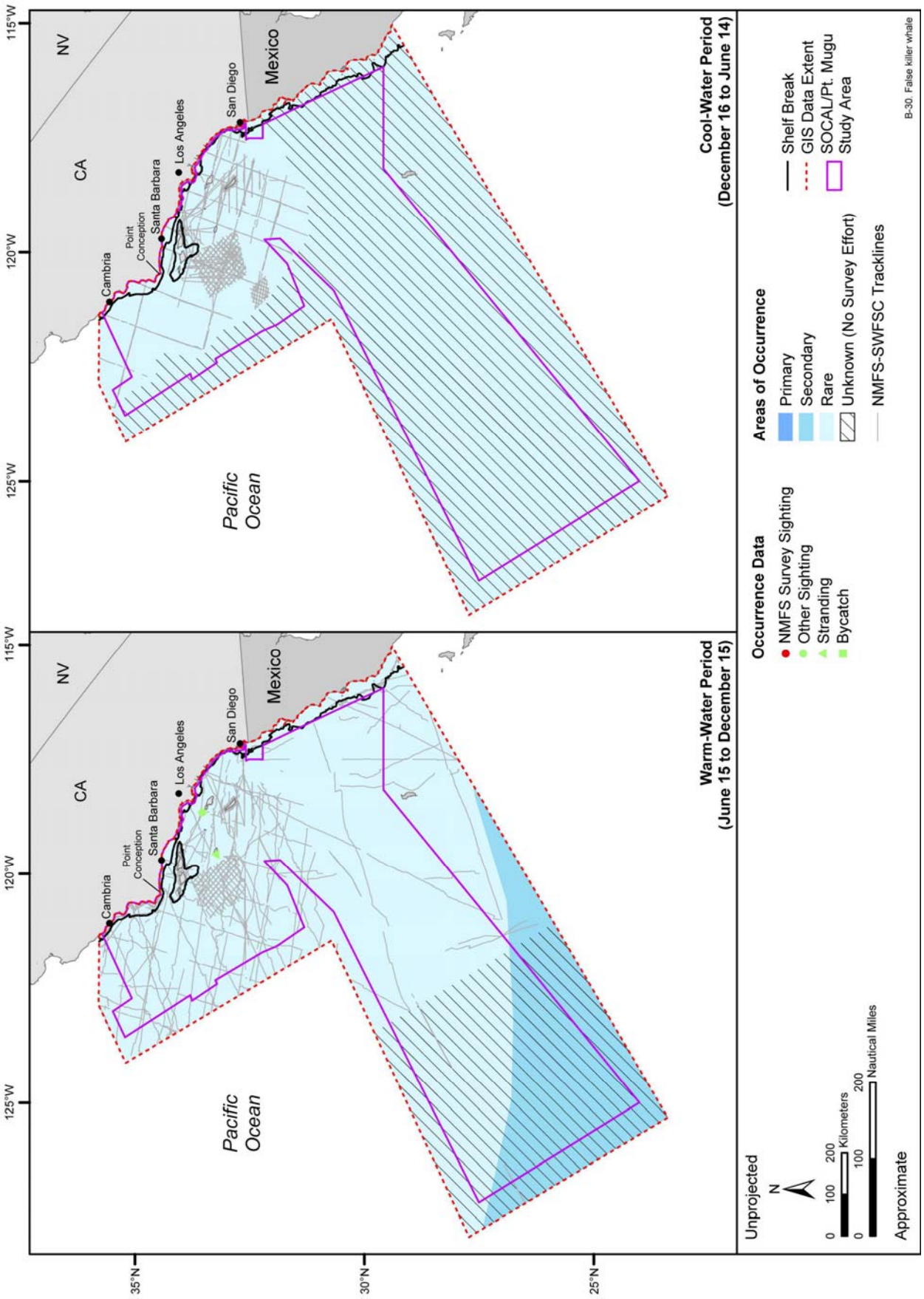

Figure B-30. Areas of occurrence for the false killer whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

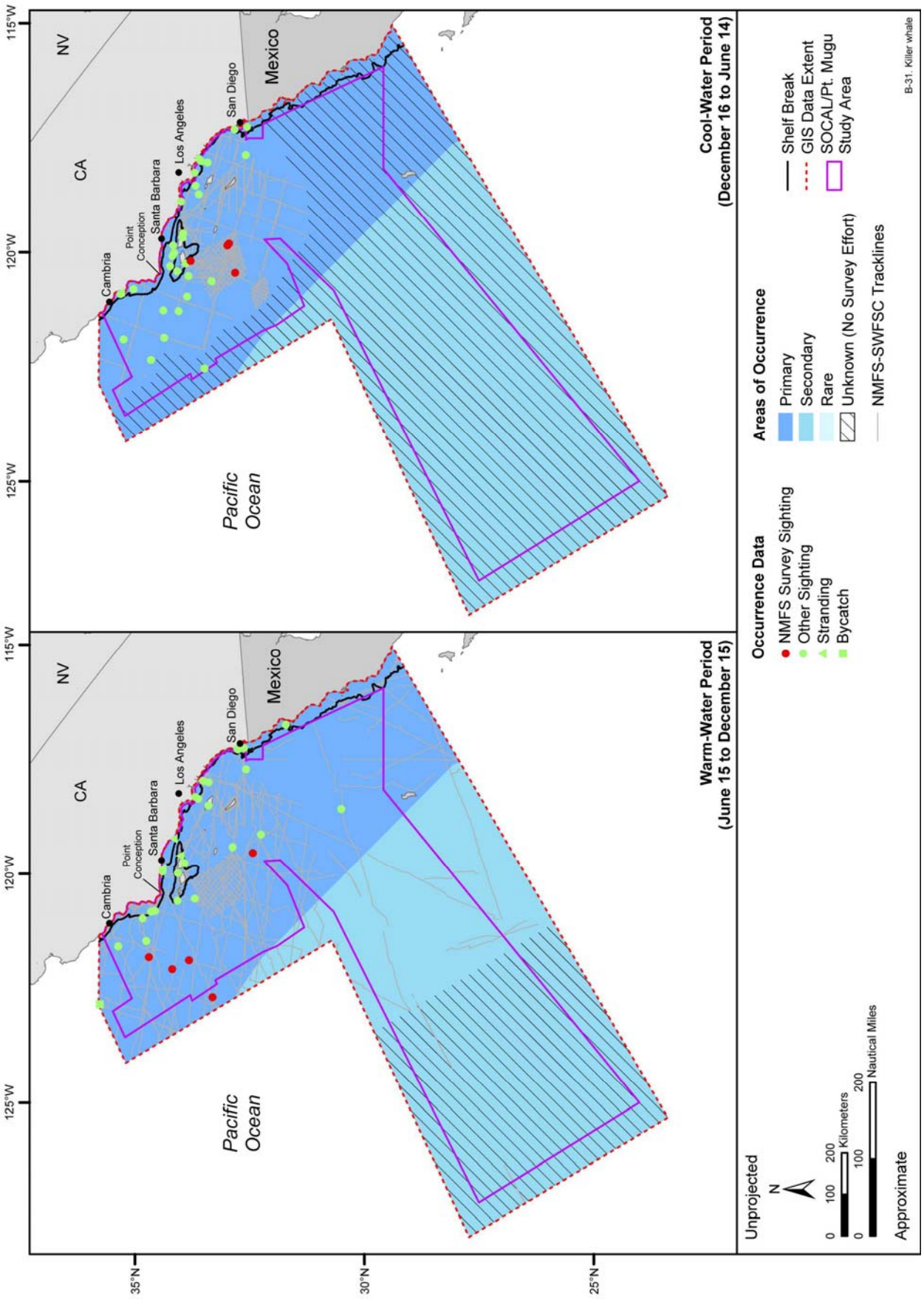

Figure B-31. Areas of occurrence for the killer whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

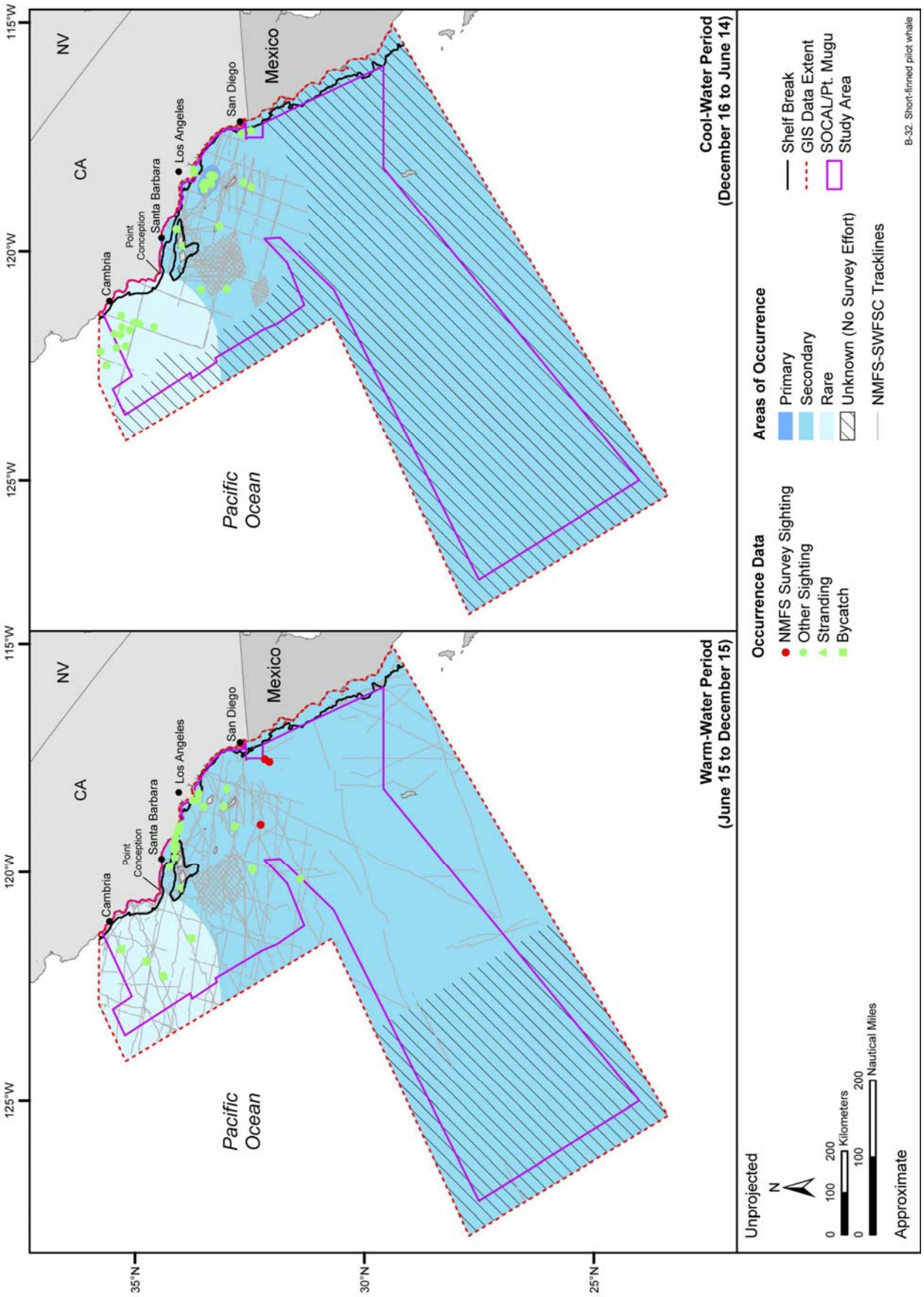

Figure B-32. Areas of occurrence for the short-finned pilot whale in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

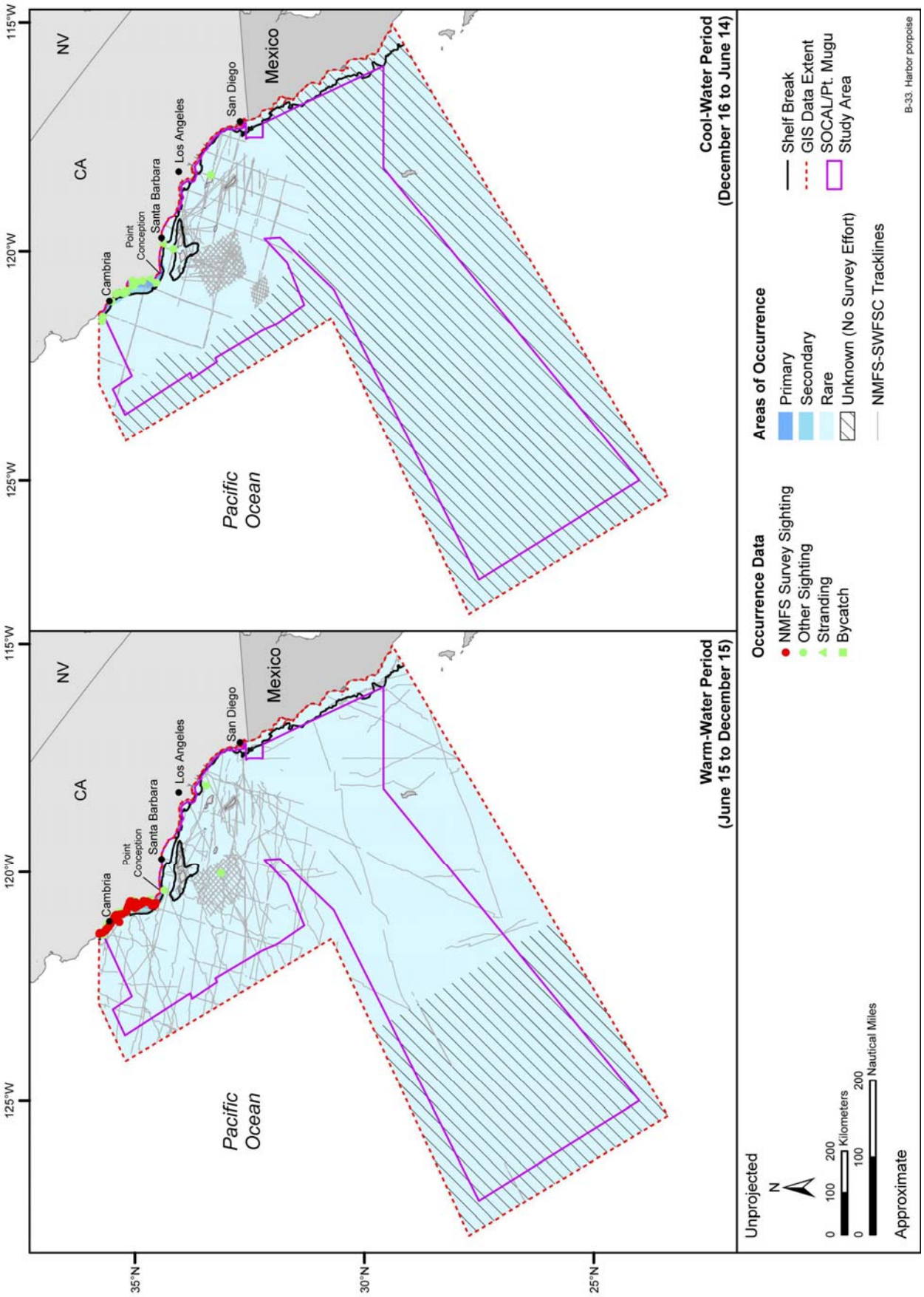

Figure B-33. Areas of occurrence for the harbor porpoise in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

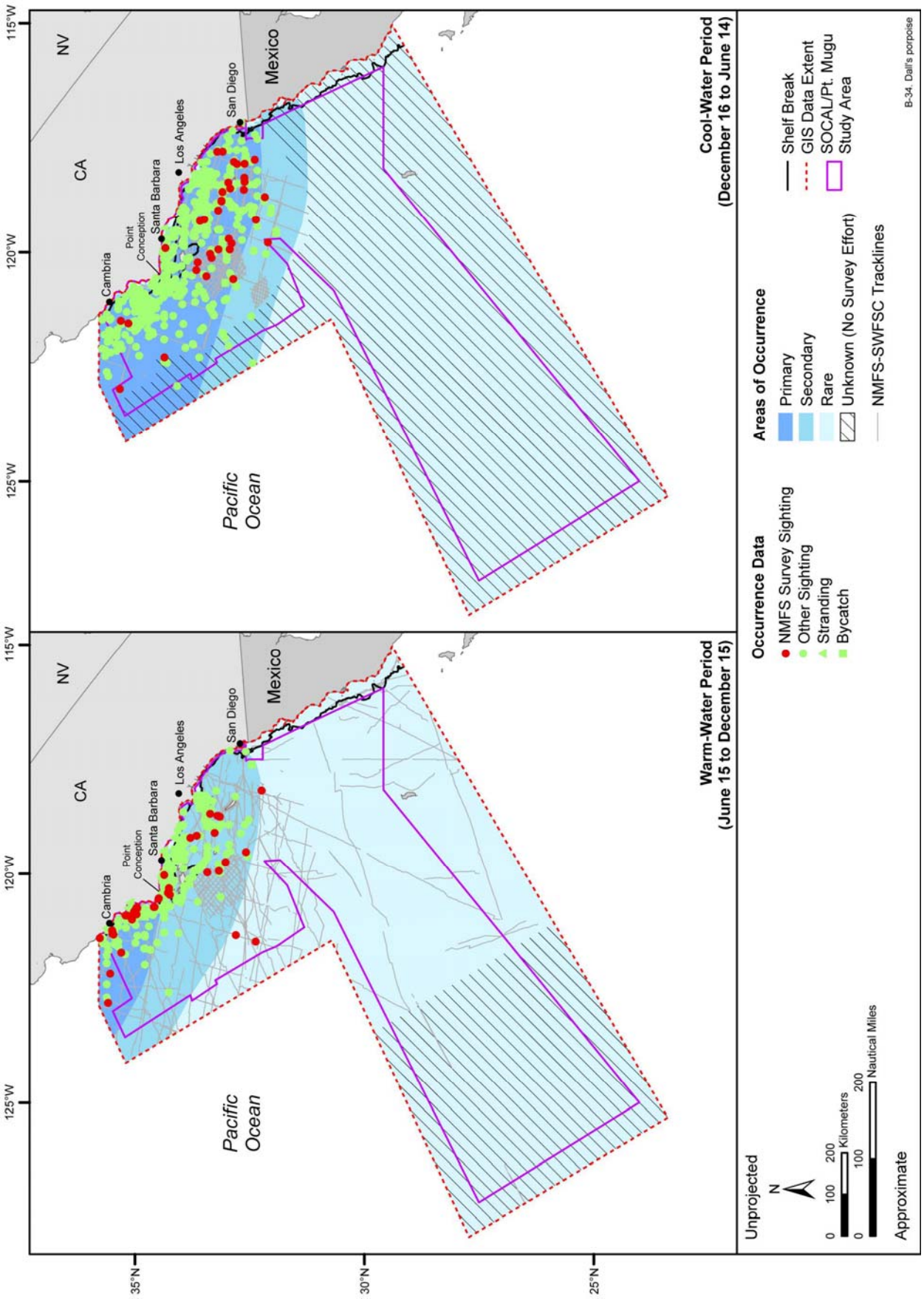

Figure B-34. Areas of occurrence for the Dall's porpoise in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

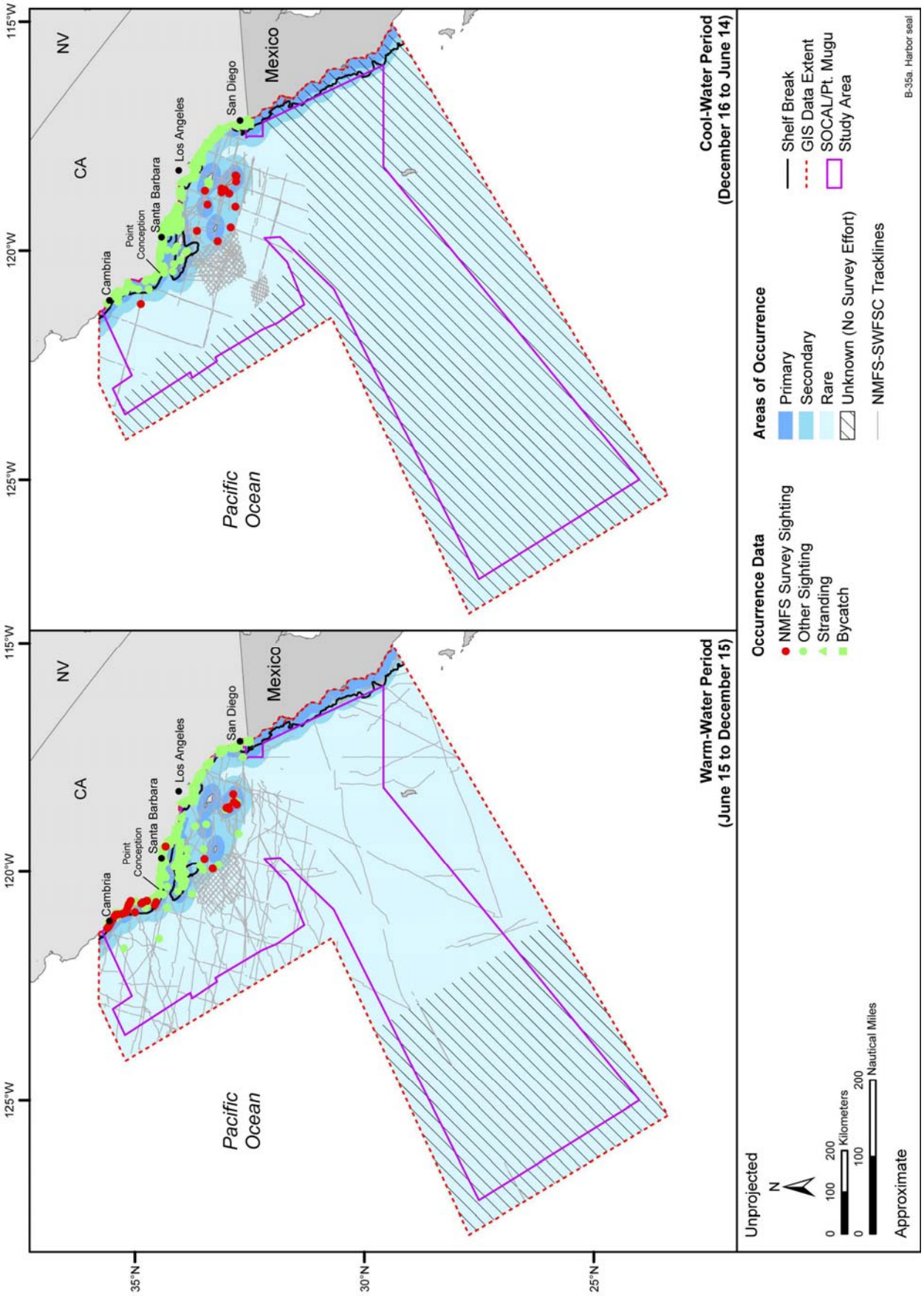

Figure B-35a. Areas of occurrence for the harbor seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

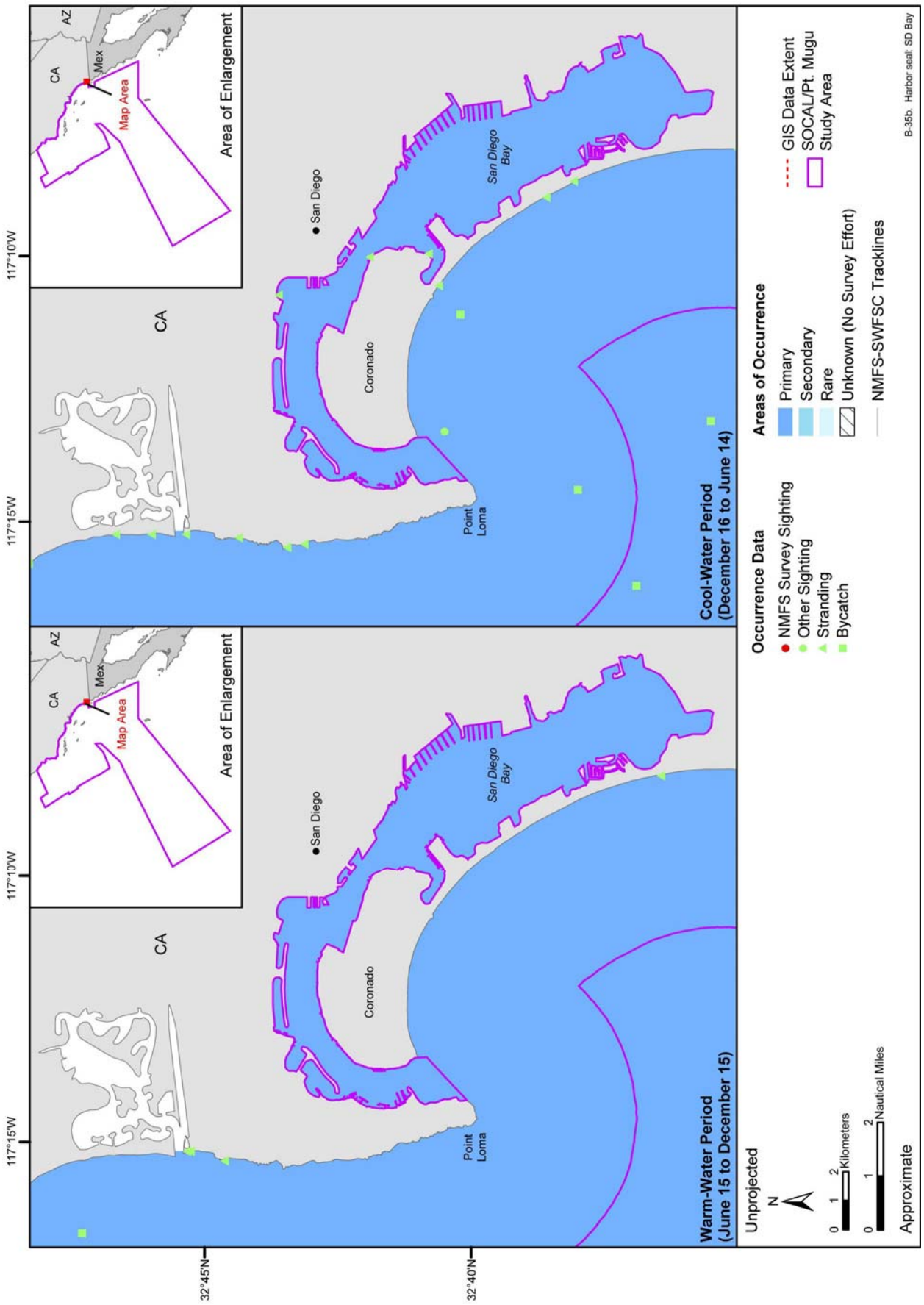

Figure B-35b. Areas of occurrence for the harbor seal in San Diego Bay. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-1.

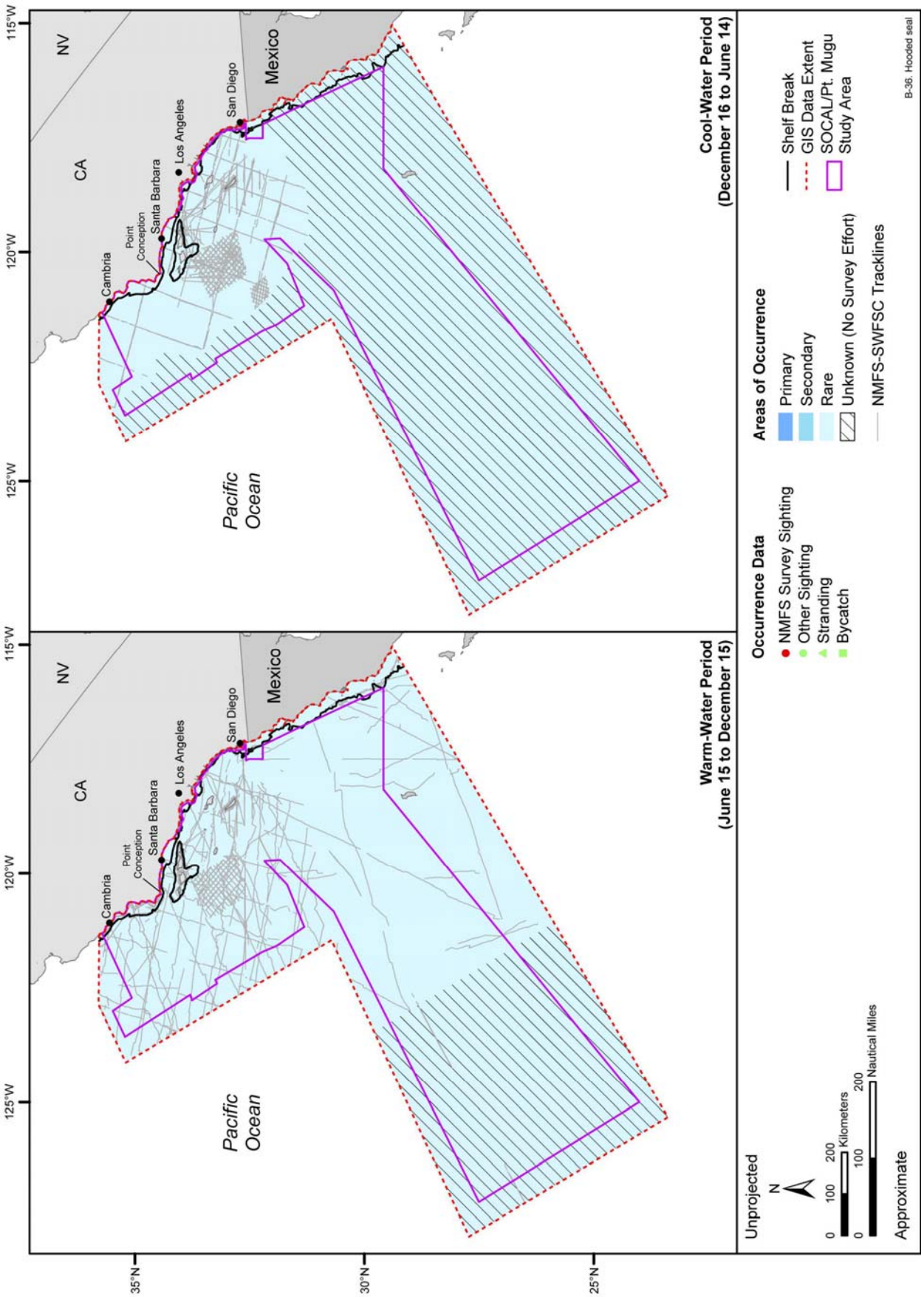

Figure B-36. Areas of occurrence for the hooded seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

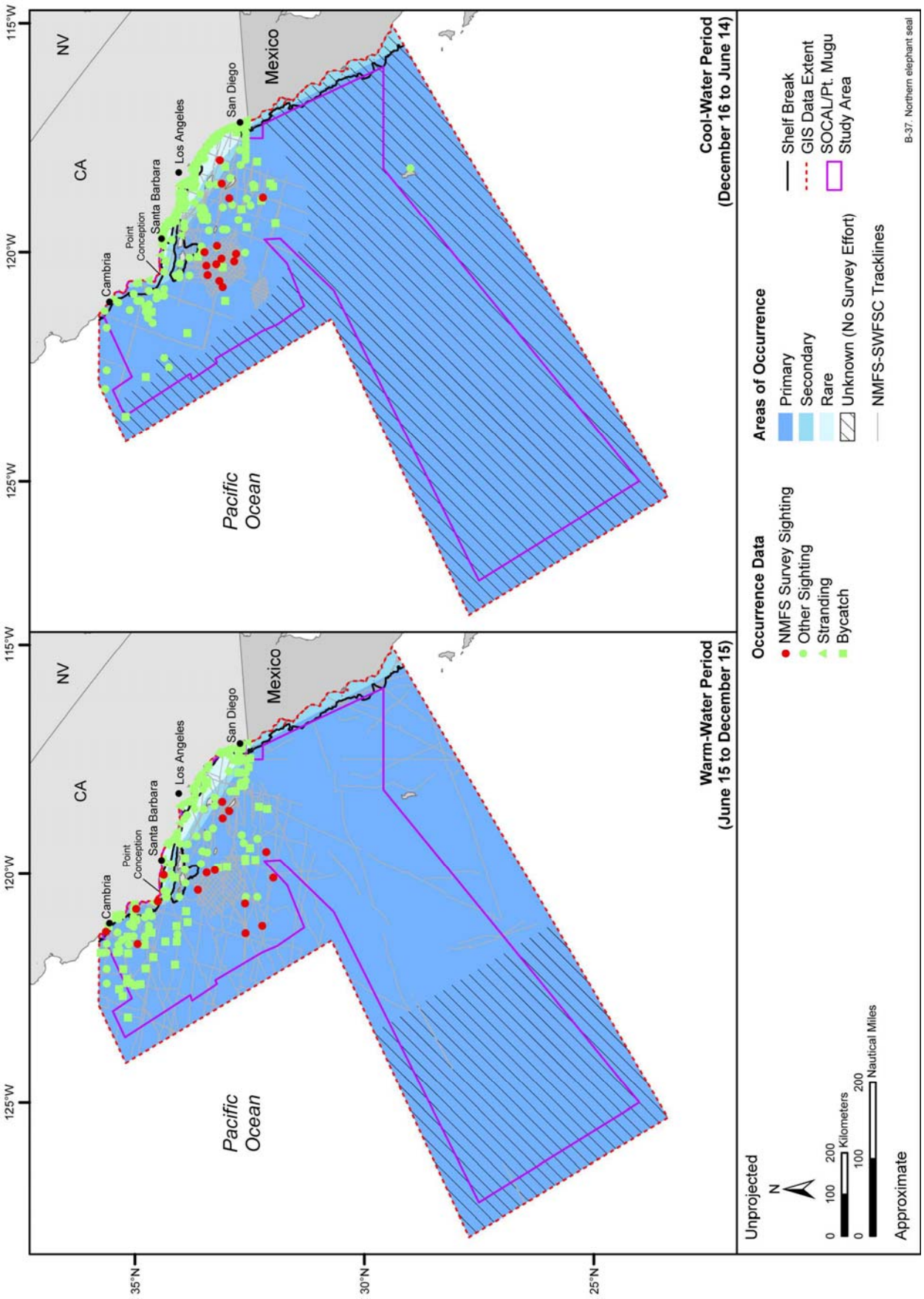

Figure B-37. Areas of occurrence for the northern elephant seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

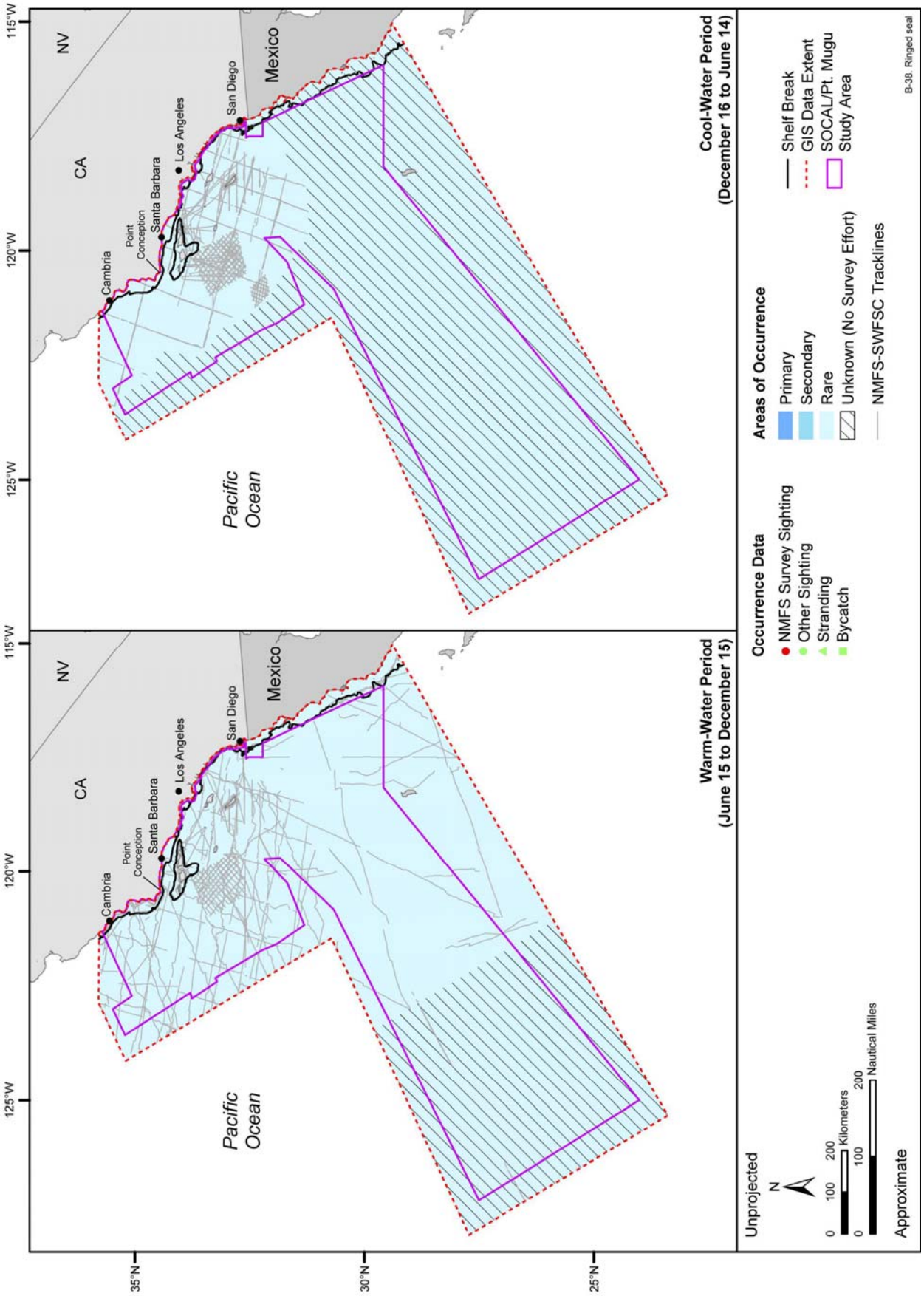

Figure B-38. Areas of occurrence for the ringed seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

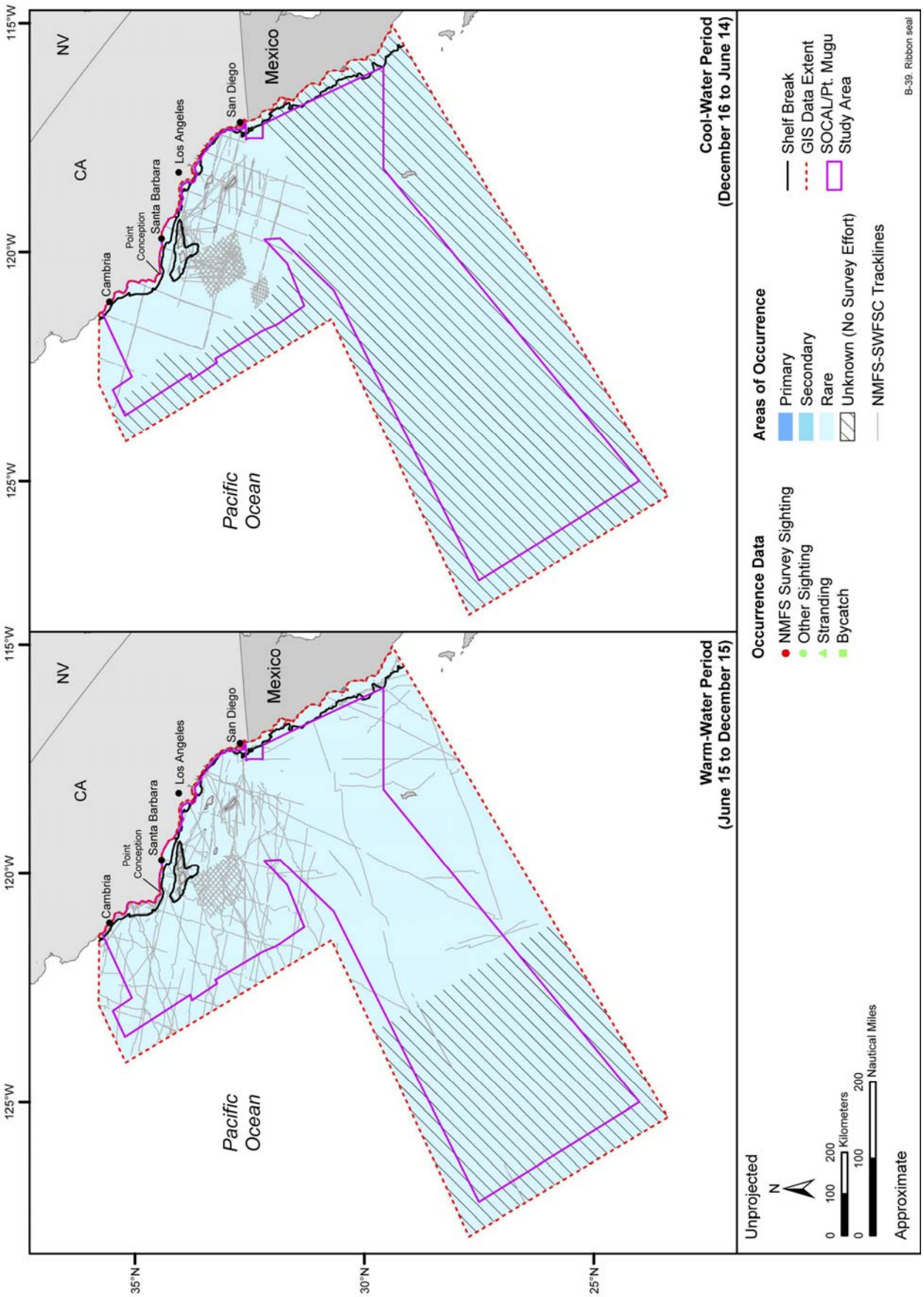

Figure B-39. Areas of occurrence for the ribbon seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

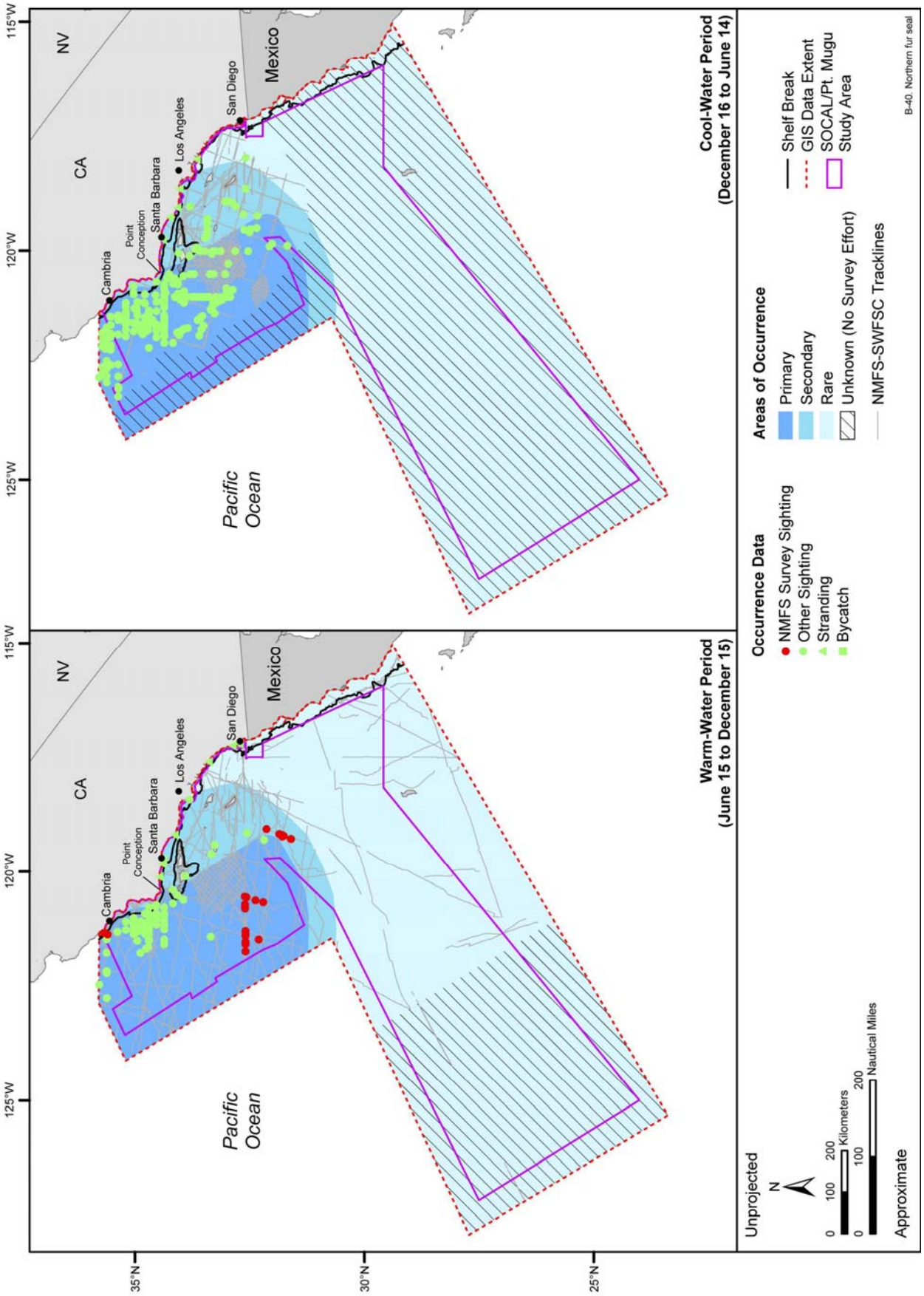

Figure B-40. Areas of occurrence for the northern fur seal in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

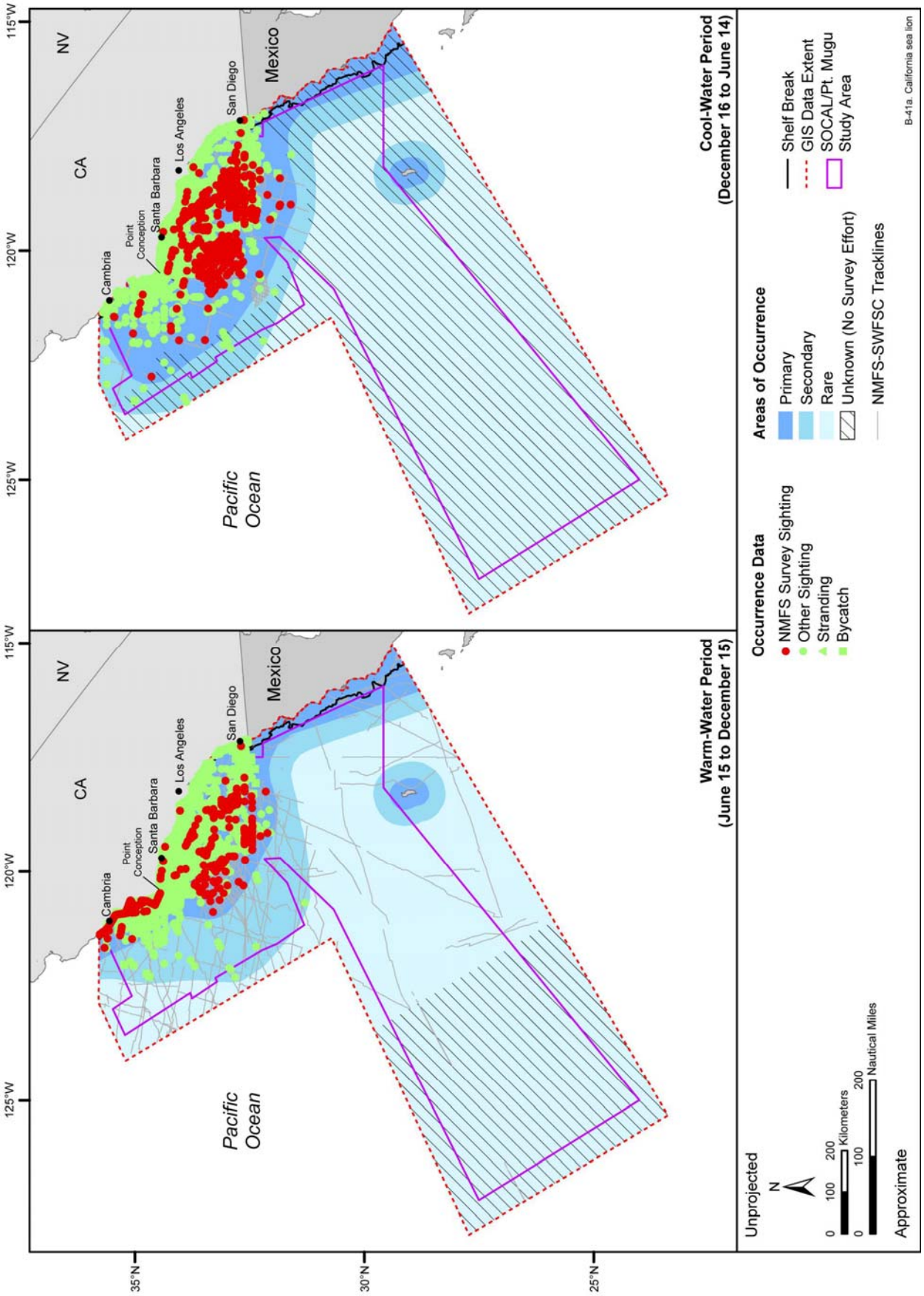

Figure B-41a. Areas of occurrence for the California sea lion in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

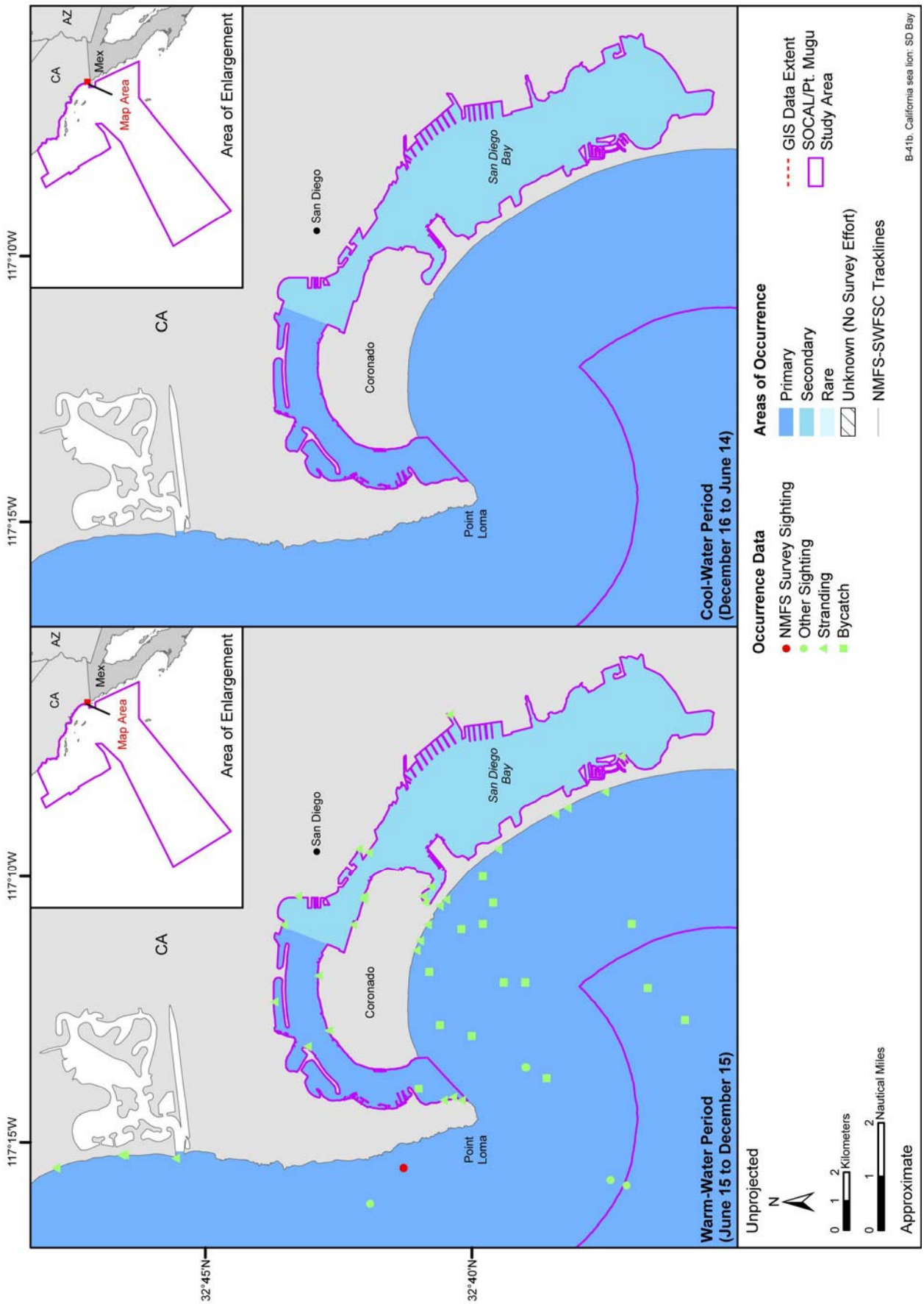

Figure B-41b. Areas of occurrence for the California sea lion in San Diego Bay. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-1.

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C-6	Areas of occurrence for the hawksbill turtle in the SOCAL/Pt. Mugu Study Area and vicinity.

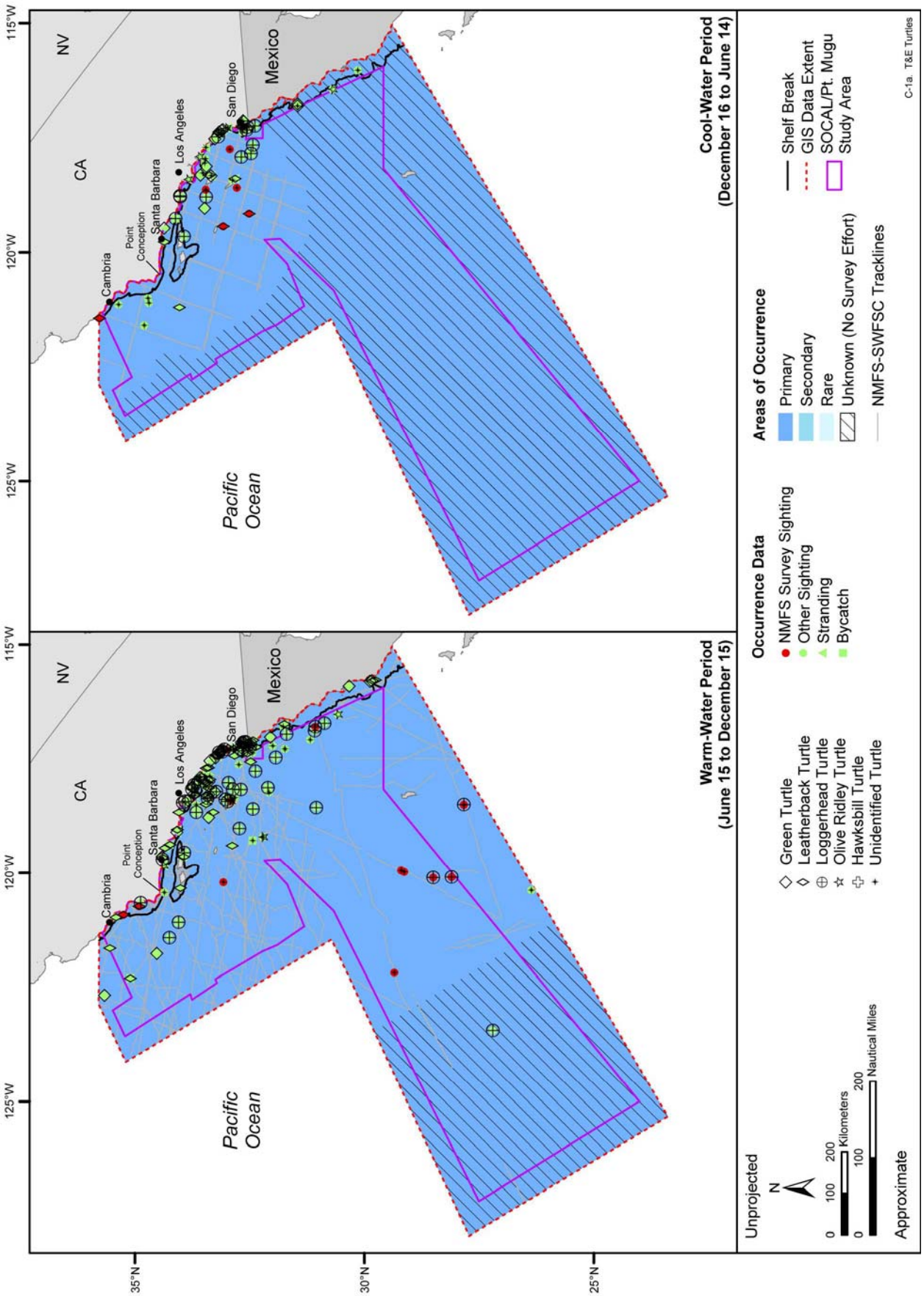

Figure C-1a. Areas of occurrence for all sea turtles in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

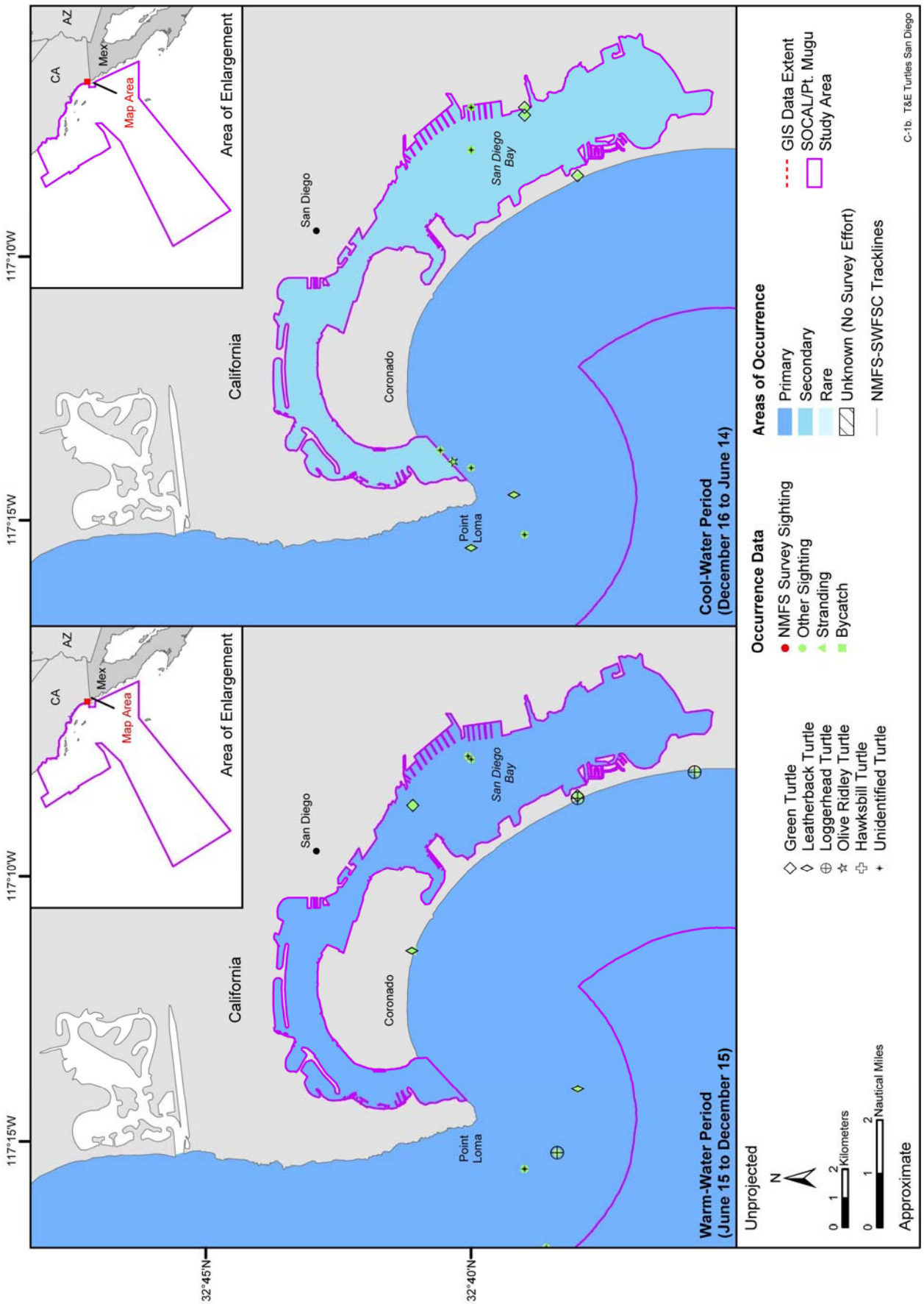

Figure C-1b. Areas of occurrence for all sea turtles in San Diego Bay. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Source data: refer to Table A-1.

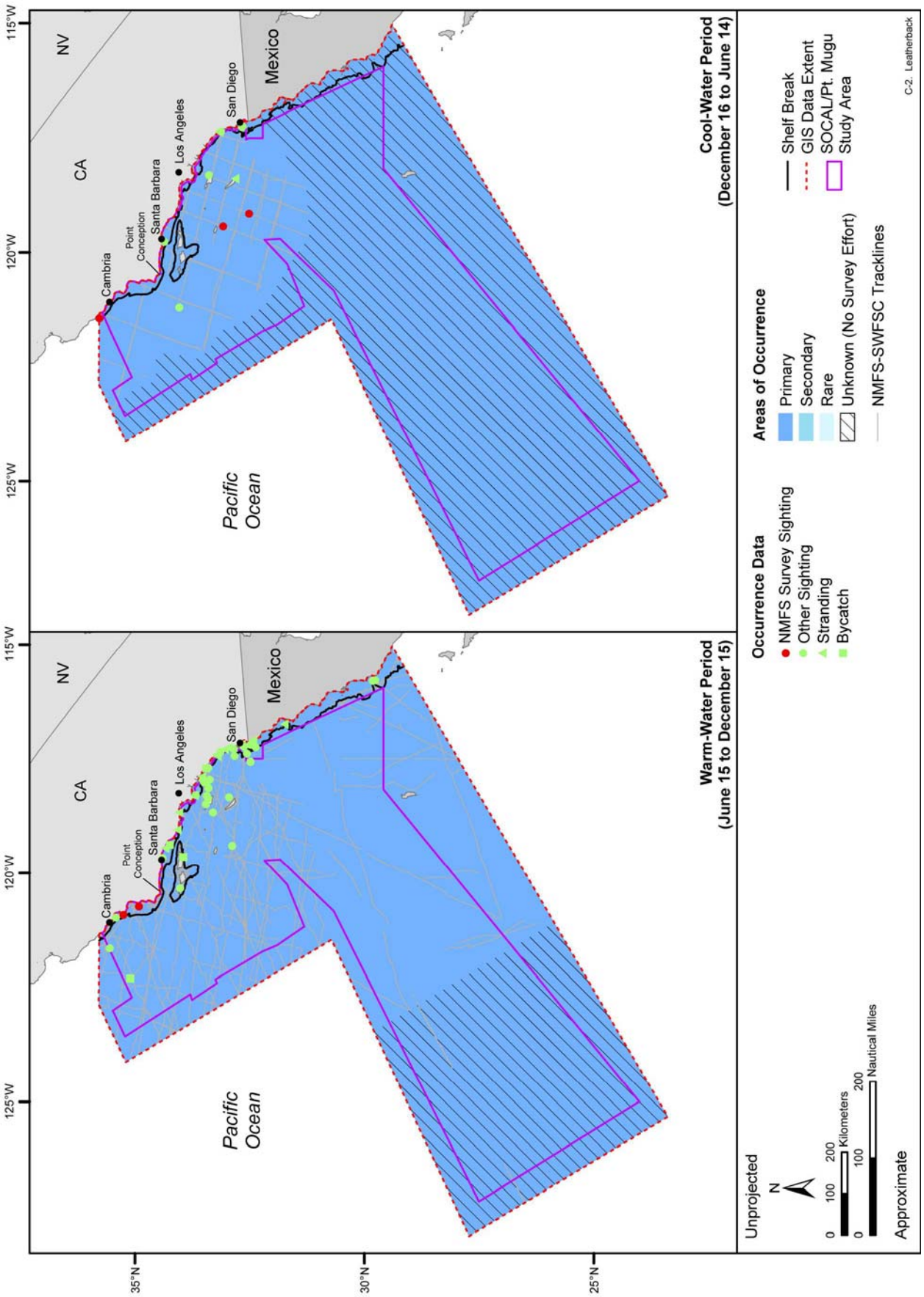

Figure C-2. Areas of occurrence for the leatherback turtle in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

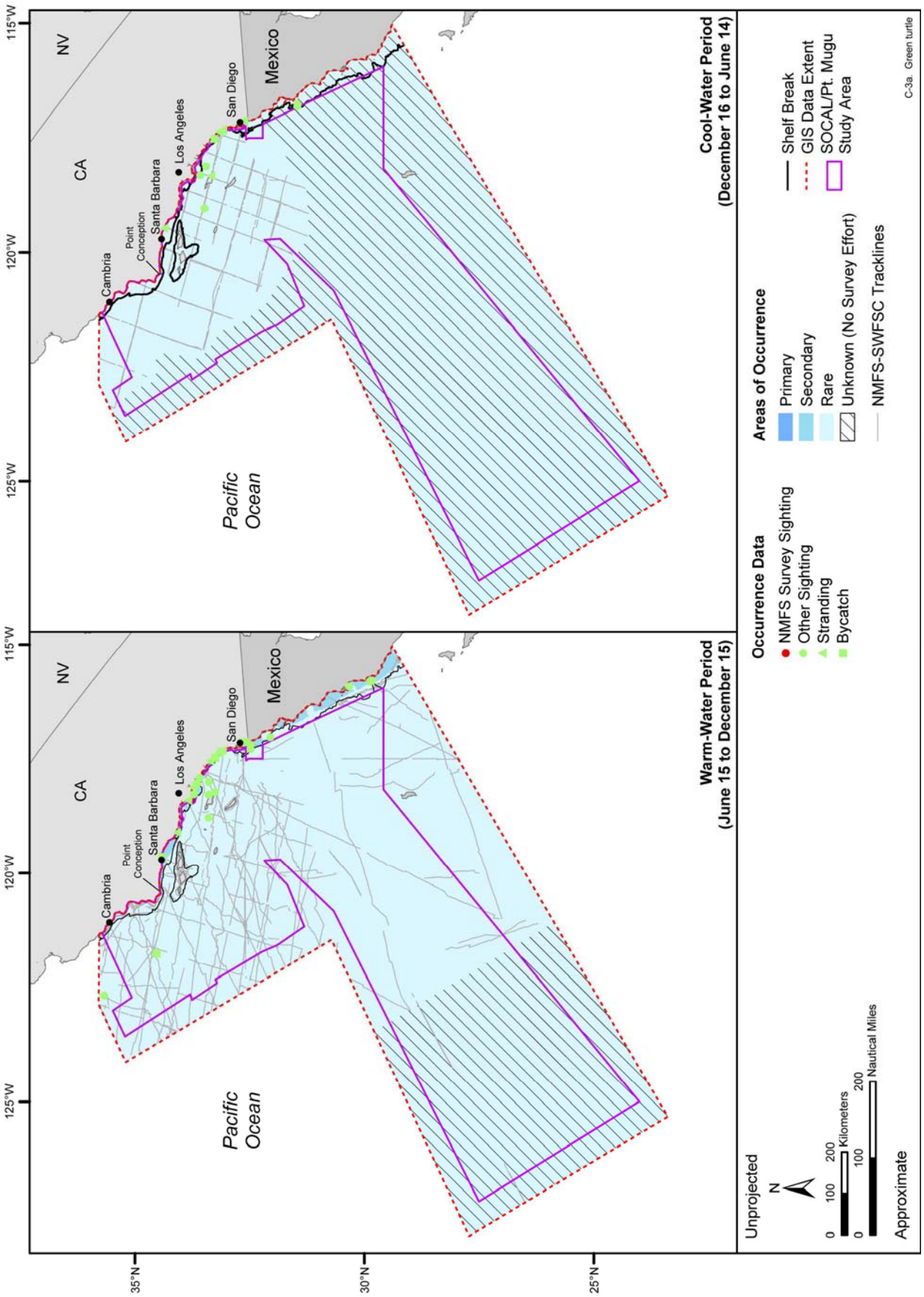

Figure C-3a. Areas of occurrence for the green turtle in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

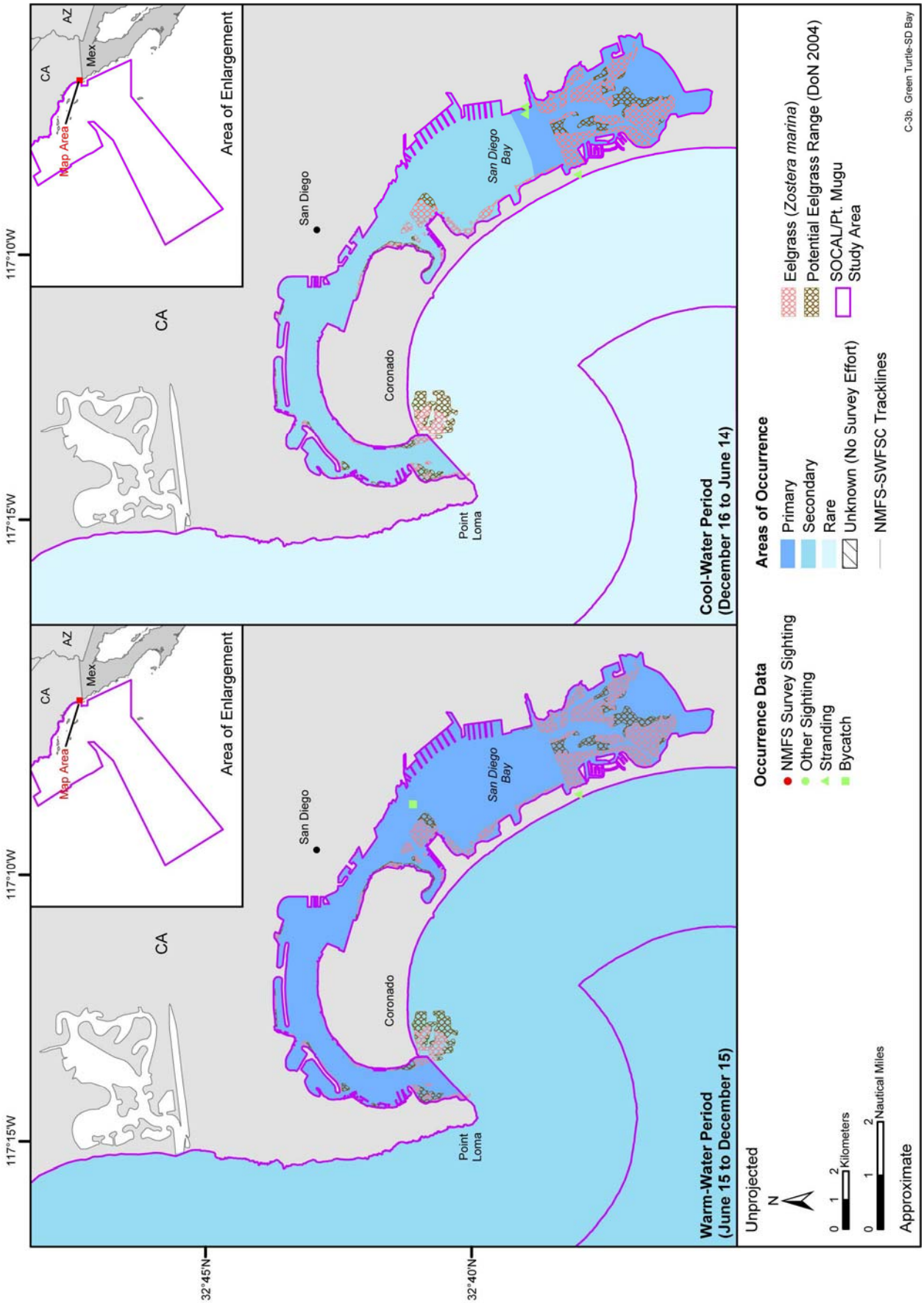

Figure C-3b. Areas of occurrence for the green turtle in San Diego Bay. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Also shown are the locations of seagrass beds within San Diego Bay. Source data: refer to Table A-1 and Figure 2-17.

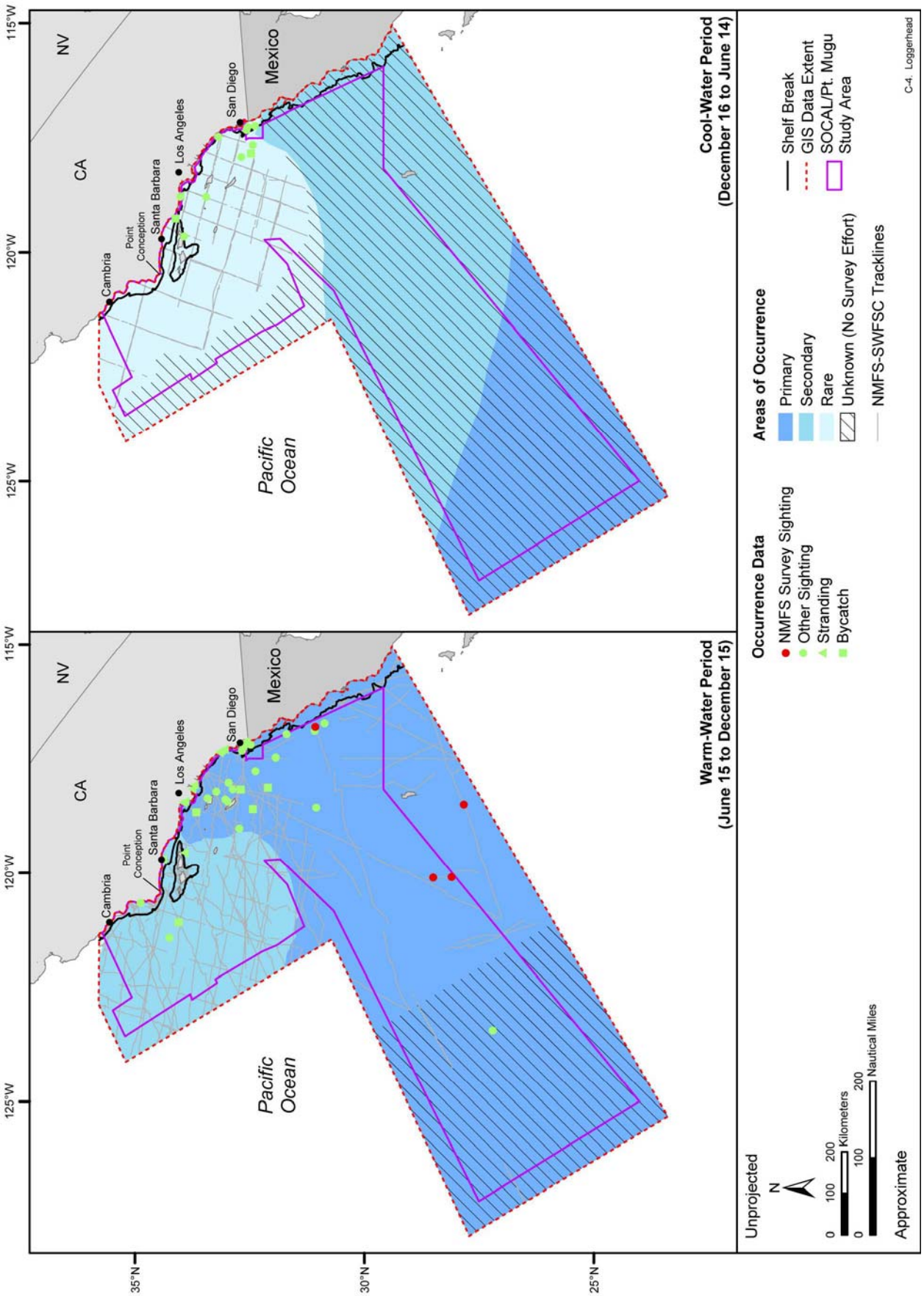

Figure C-4. Areas of occurrence for the loggerhead turtle in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

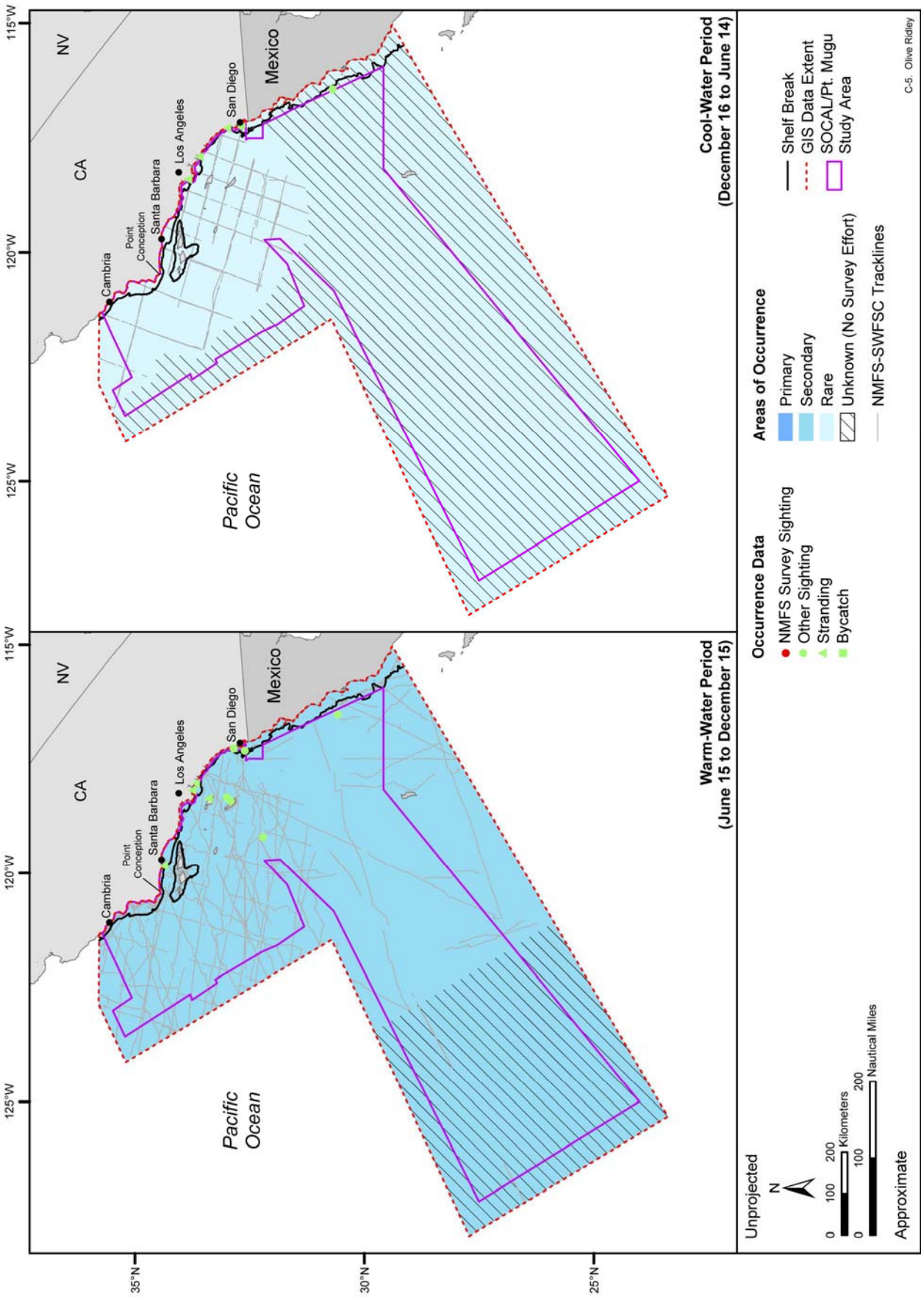

Figure C-5. Areas of occurrence for the olive ridley turtle in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

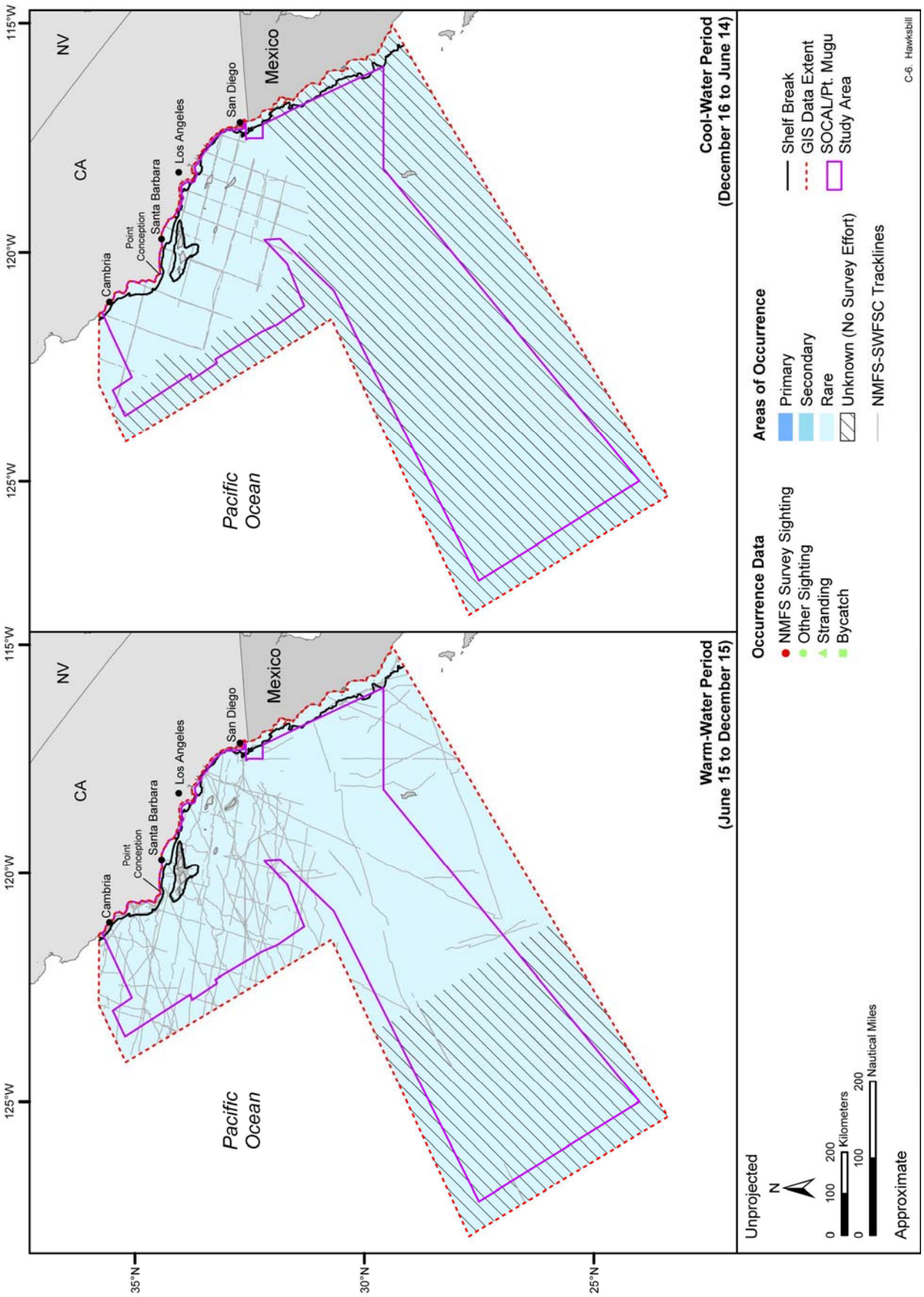

Figure C-6. Areas of occurrence for the hawksbill turtle in the SOCAL/Pt. Mugu Study Area and vicinity. Available sighting, stranding, and incidental fisheries bycatch records are represented by season. Sightings from NMFS-sponsored aerial and shipboard surveys are recorded along pre-determined tracklines, which also are depicted on the map. Source data: refer to Table A-1.

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D-10	EFH for juvenile/adult (183 m to EEZ) lifestages of albacore tuna designated in the SOCAL/Pt. Mugu Study Area and vicinity.
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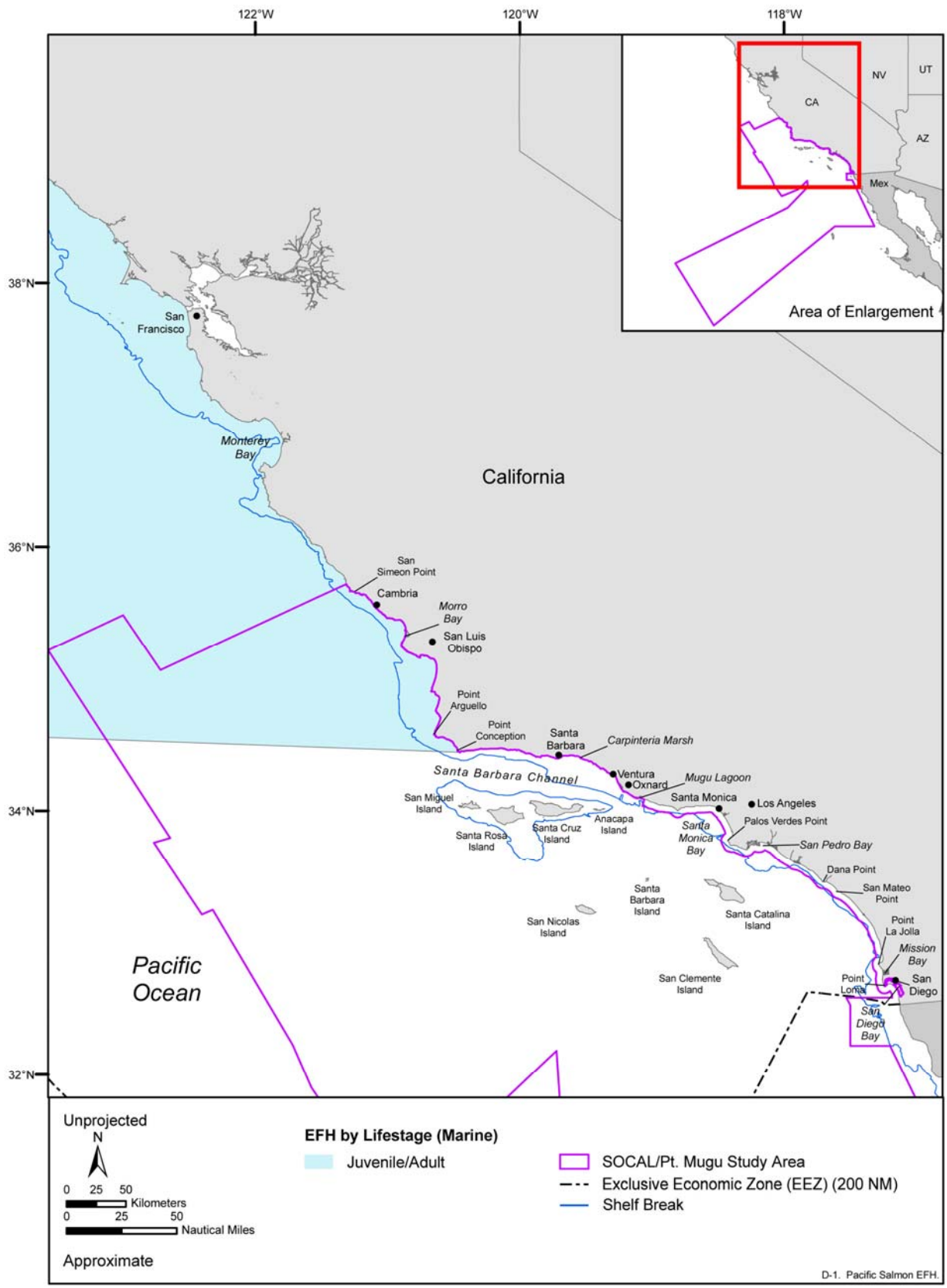

Figure D-1. EFH for all marine lifestages of Pacific salmon designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2000).

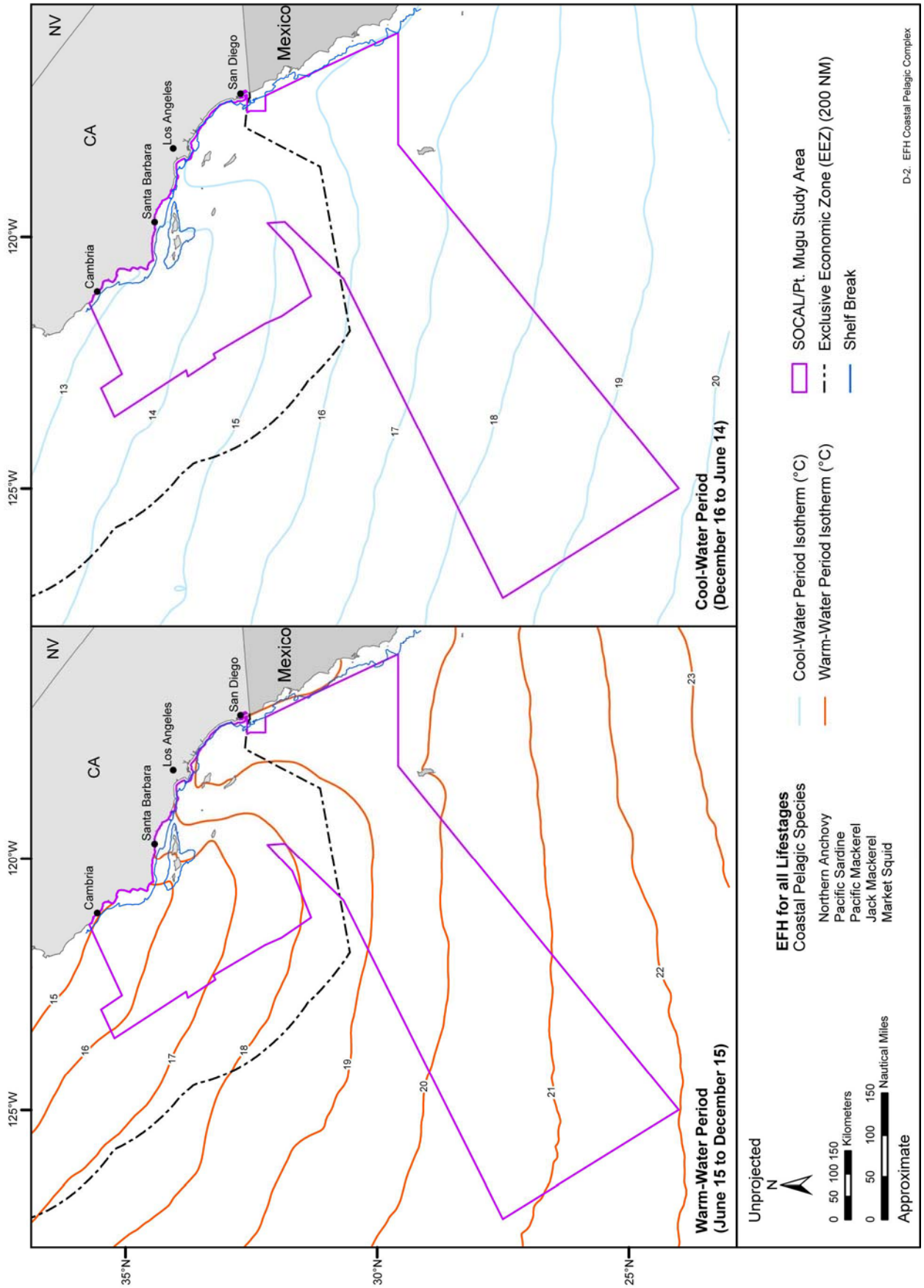

Figure D-2. Estimated EFH for all lifestages of coastal pelagic species designated in the SOCAL/Pt. Mugu Study Area and vicinity based on warmest and coldest year averages from 1985 through 2004. Source data: PODAAC (2004). Source information: PFMC (1998a).

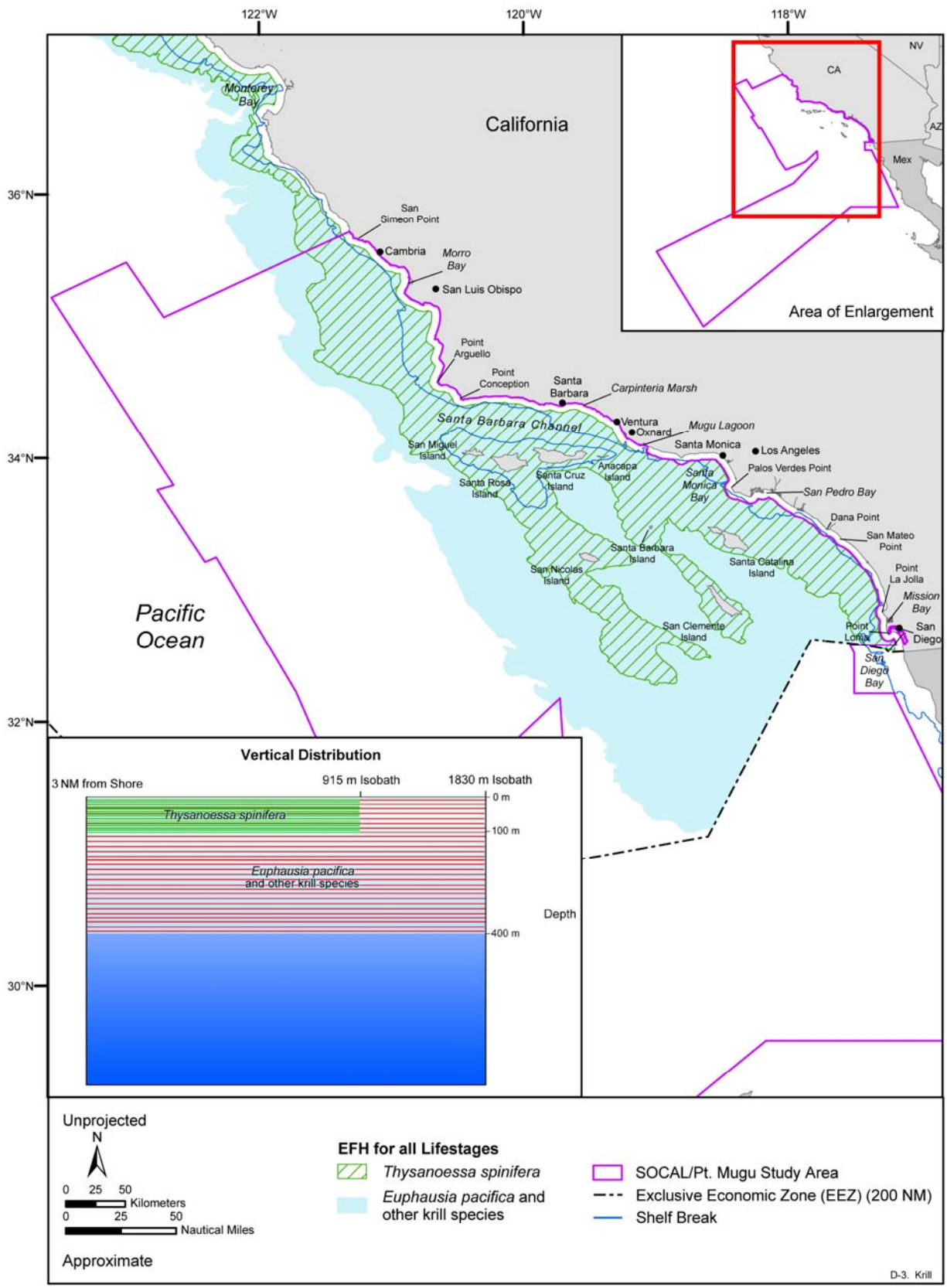

Figure D-3. Estimated EFH for *Euphasia pacifica*, *Thysanoessa spinferaall*, and other krill species in the SOCAL/Pt. Mugu Study Area and vicinity. Source information: NMFS-SWR (2006).

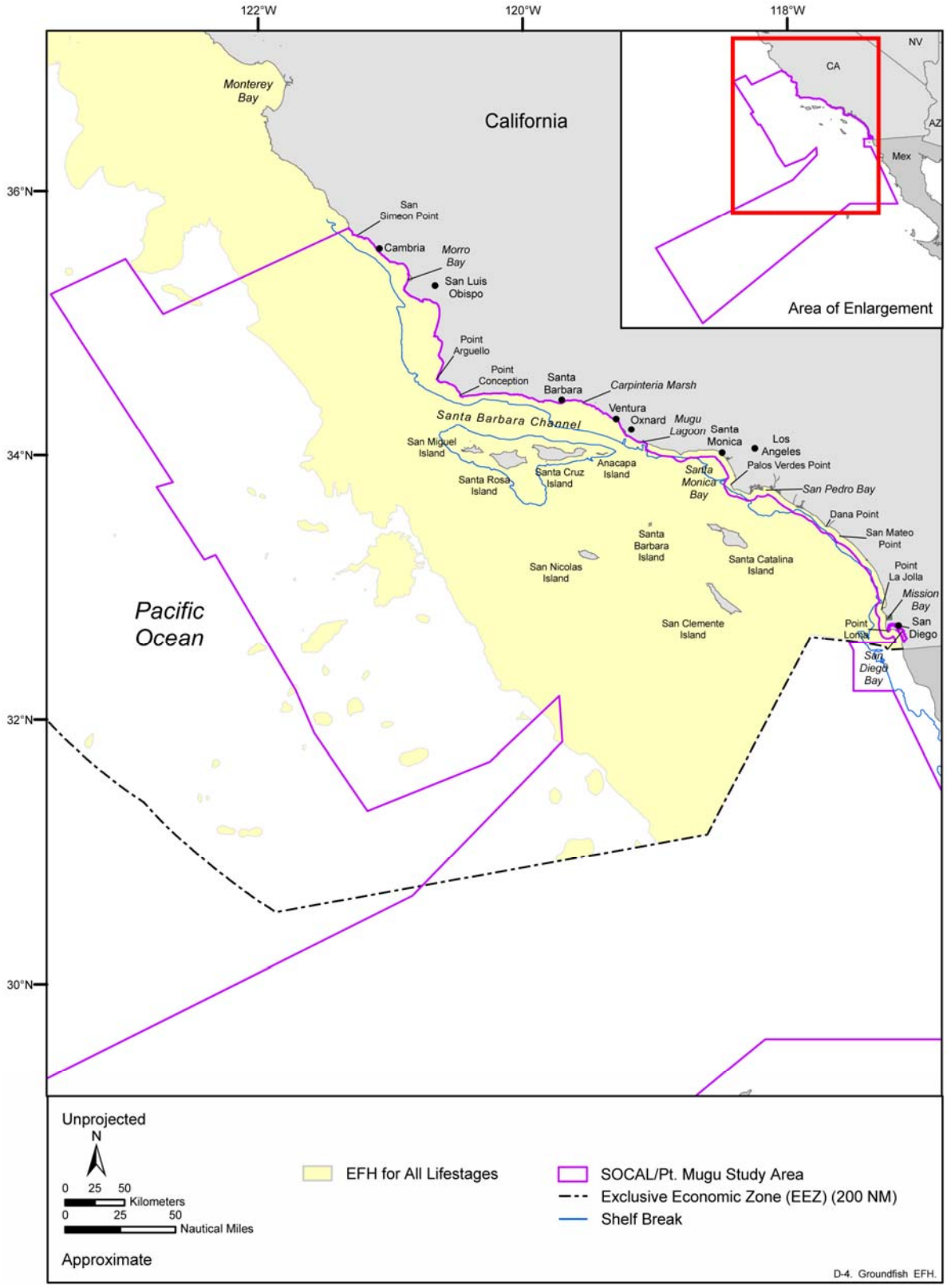

Figure D-4. EFH designated for areas with 100% of the area with an HSP greater than zero and any additional areas with seafloor depths of 3,500 m or less in the SOCAL/Pt. Mugu Study Area and vicinity. Source data: Terralogic GIS, Inc. (2005a).

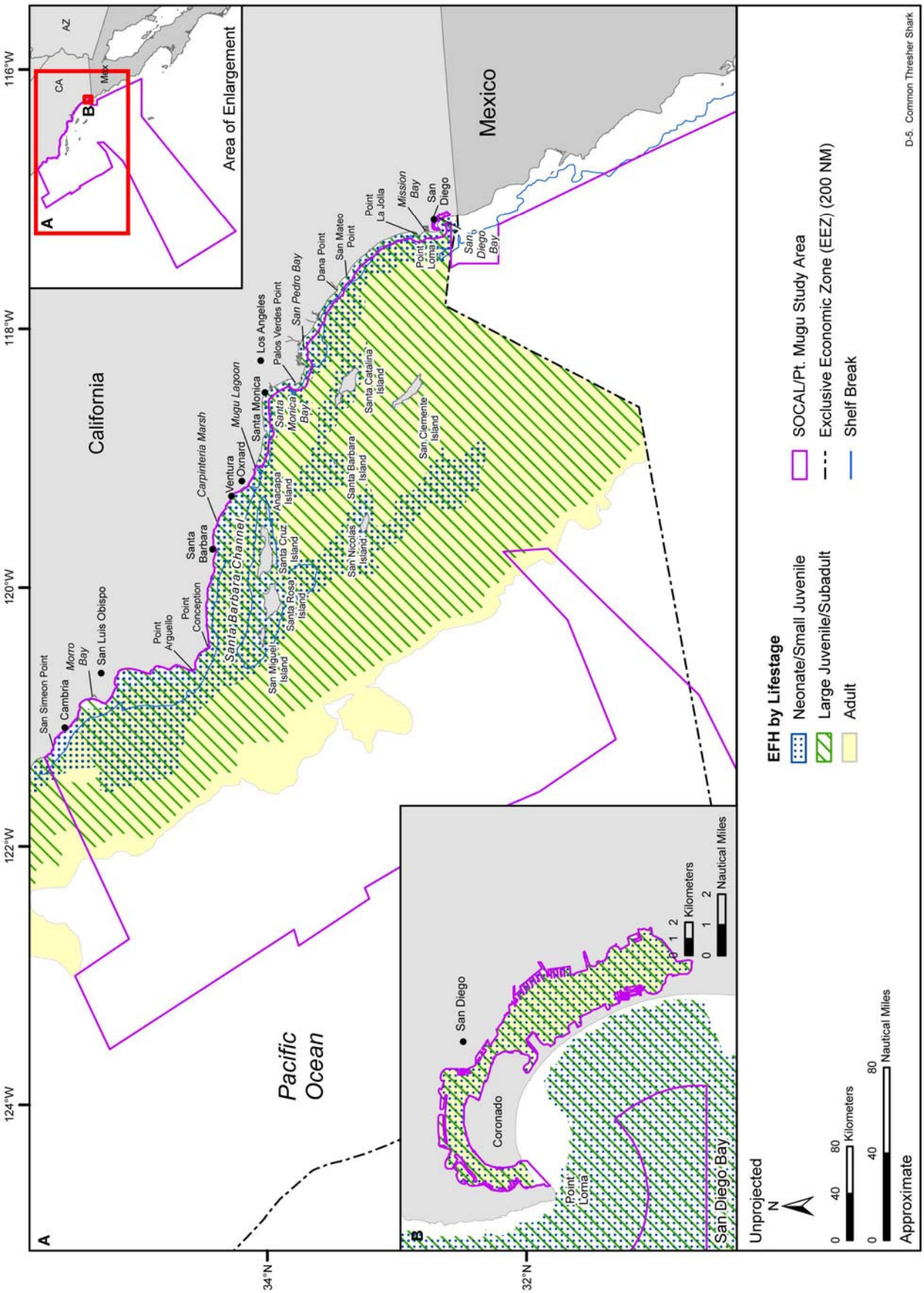

Figure D-5. EFH for neonate/small juvenile (11 to 732 m), large juvenile/subadult (11 to 2,560 m), and adult (73 to 3,475 m) lifestages of common thresher shark designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

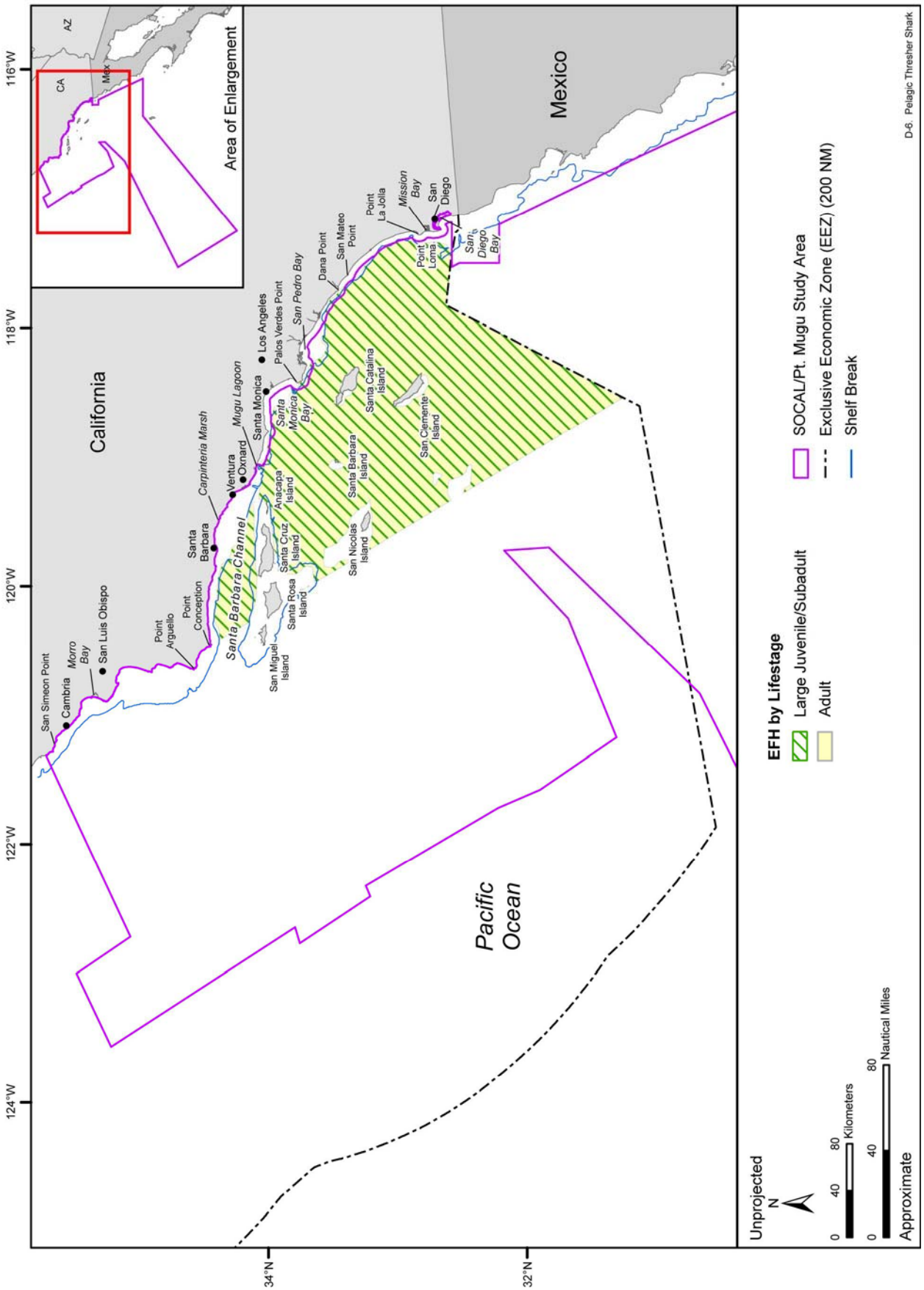

Figure D-6. EFH for large juvenile/subadult/adult (183 m to the Santa Rosa-Cortes Ridge) lifestages of pelagic thresher shark designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

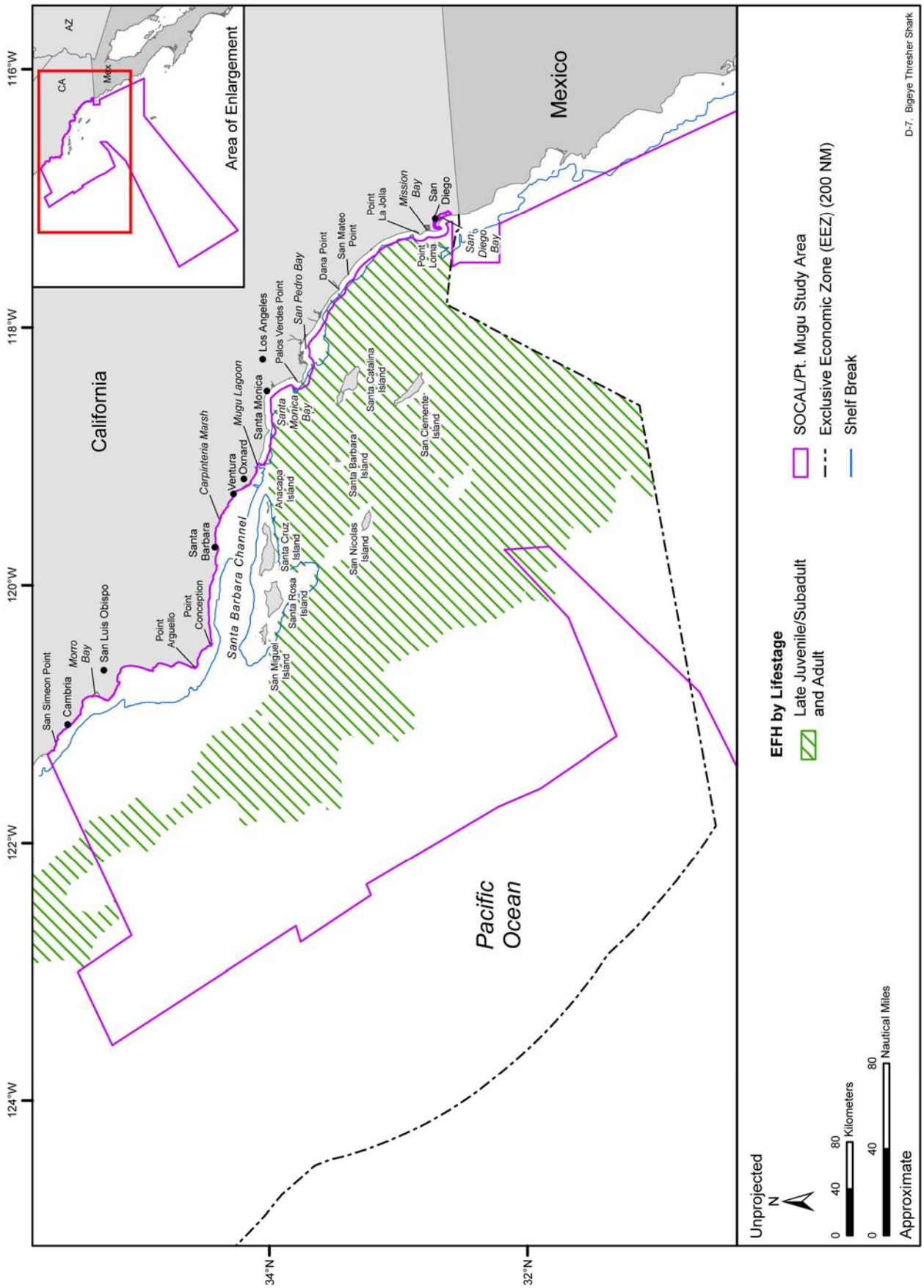

Figure D-7. EFH for large juvenile/subadult/adult (183 to 3,658 m) lifestages of bigeye thresher shark designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

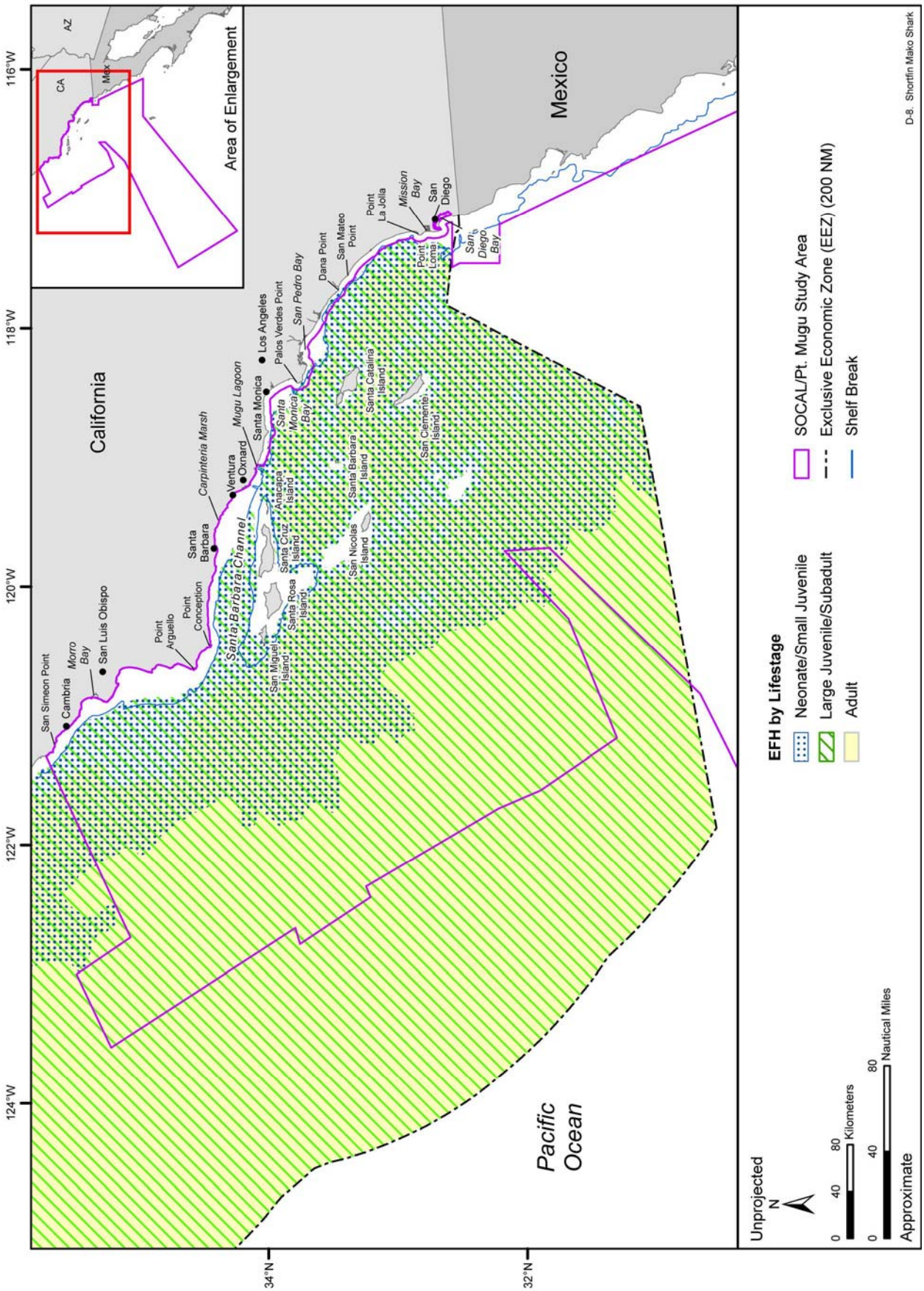

Figure D-8. EFH for neonate/small juvenile (183 to 3,658 m), large juvenile/subadult (183 m to EEZ), and adult (732 m to EEZ) lifestages of shortfin mako shark designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

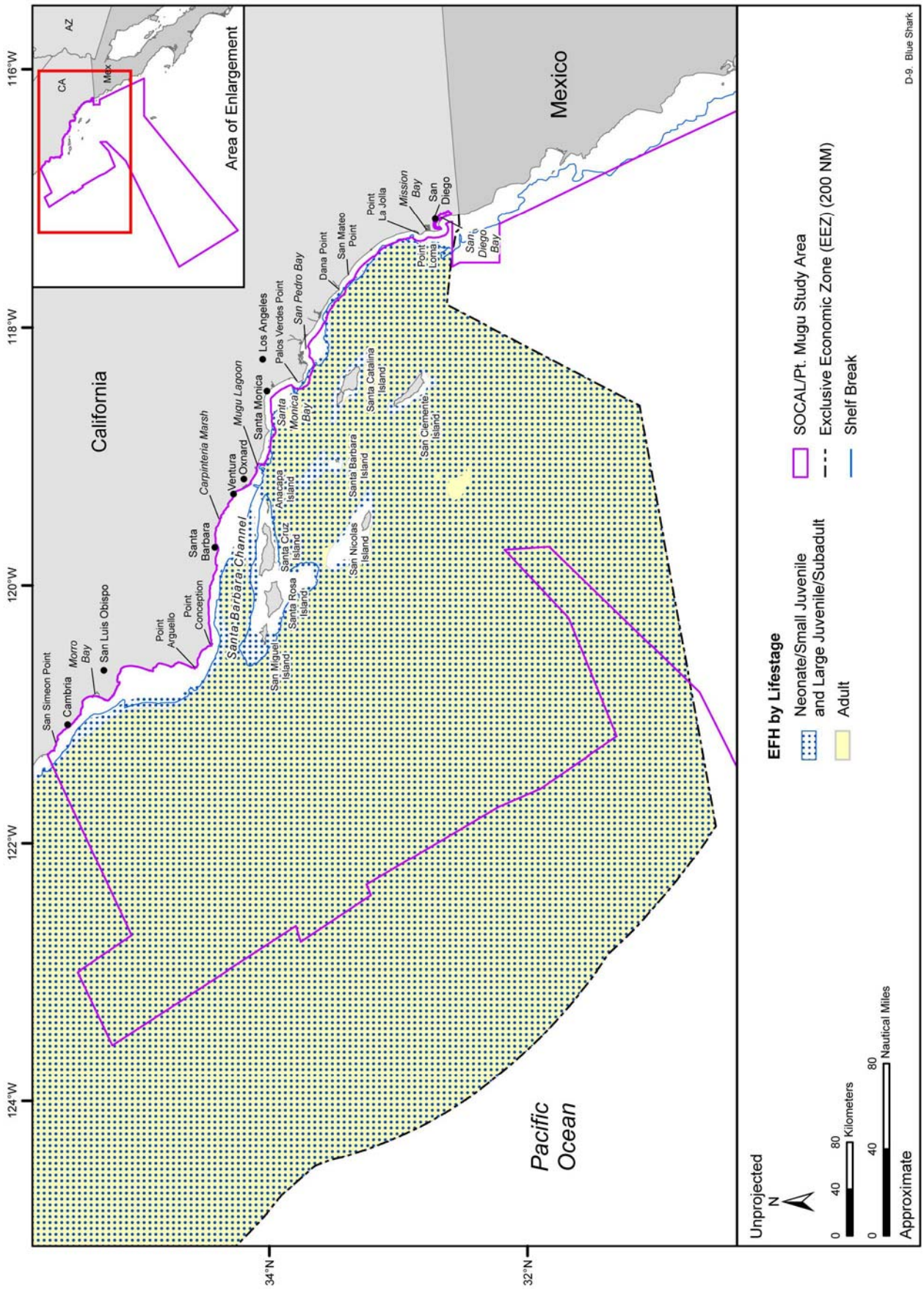

Figure D-9. EFH for neonate/small juvenile/large juvenile/subadult (183 m to EEZ) and adult (366 m to EEZ) lifestages of blue shark designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

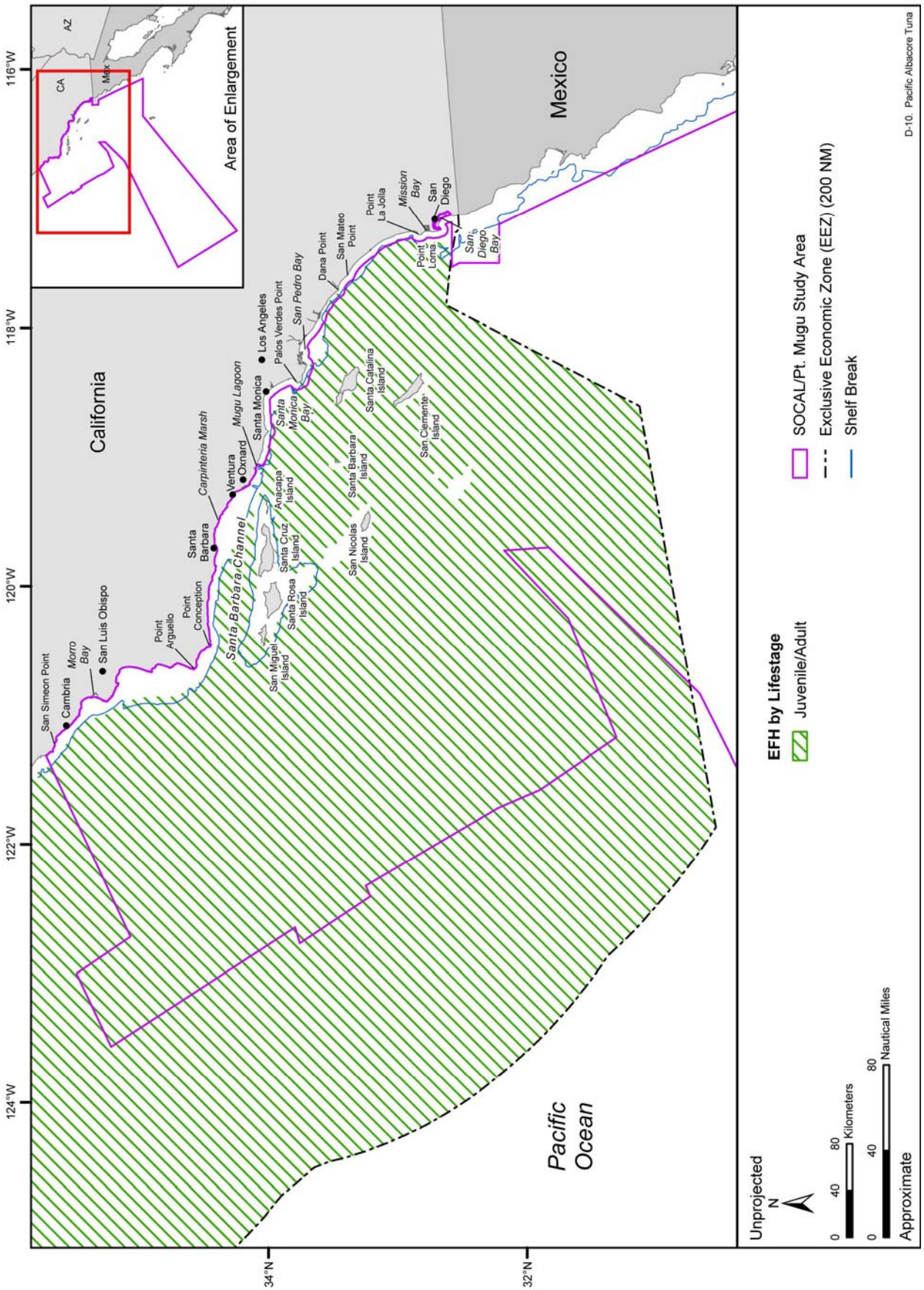

Figure D-10. EFH for juvenile/adult (183 m to EEZ) lifestages of albacore tuna designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

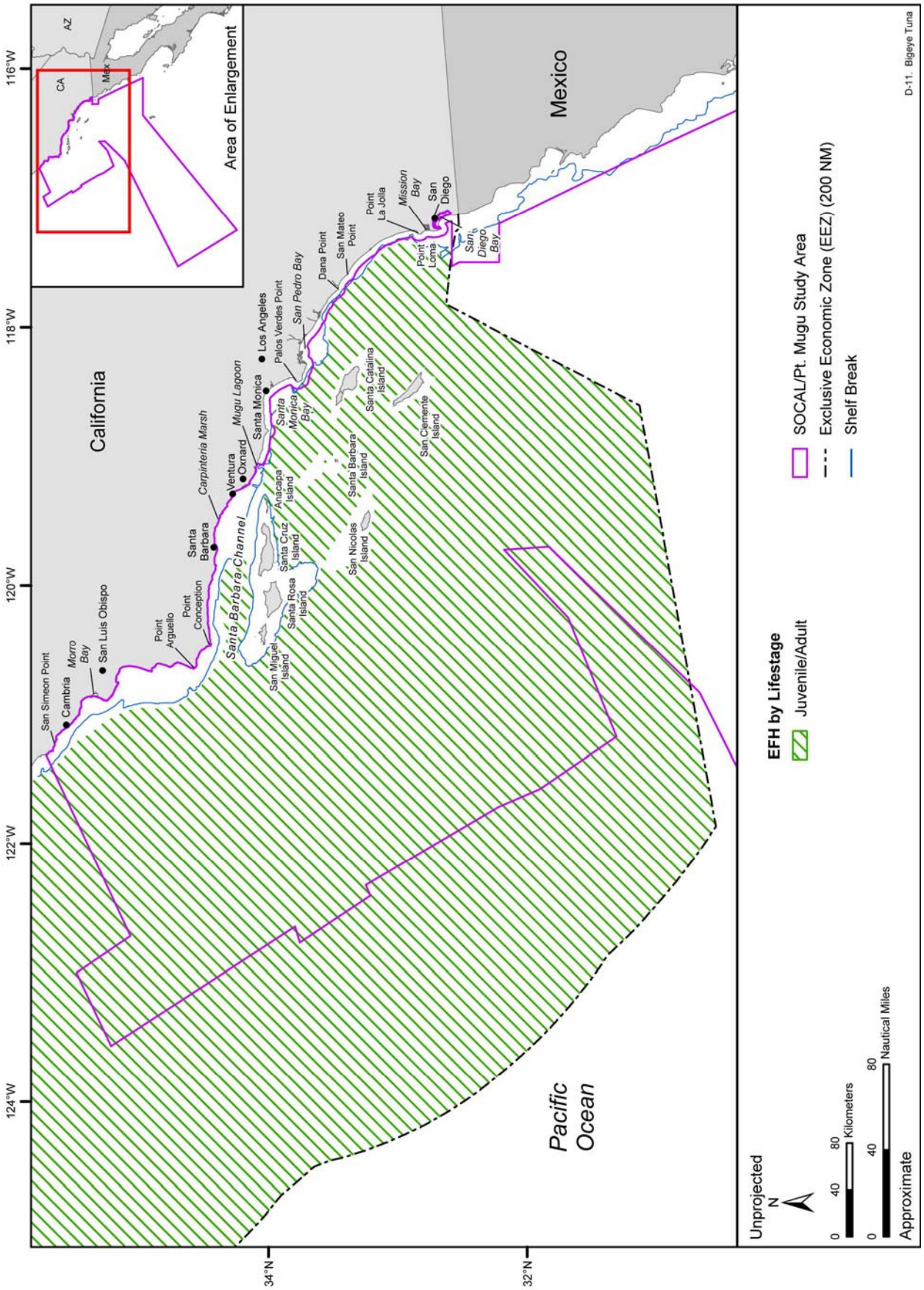

Figure D-11. EFH for juvenile/adult (336 m to EEZ) lifestages of bigeye tuna designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

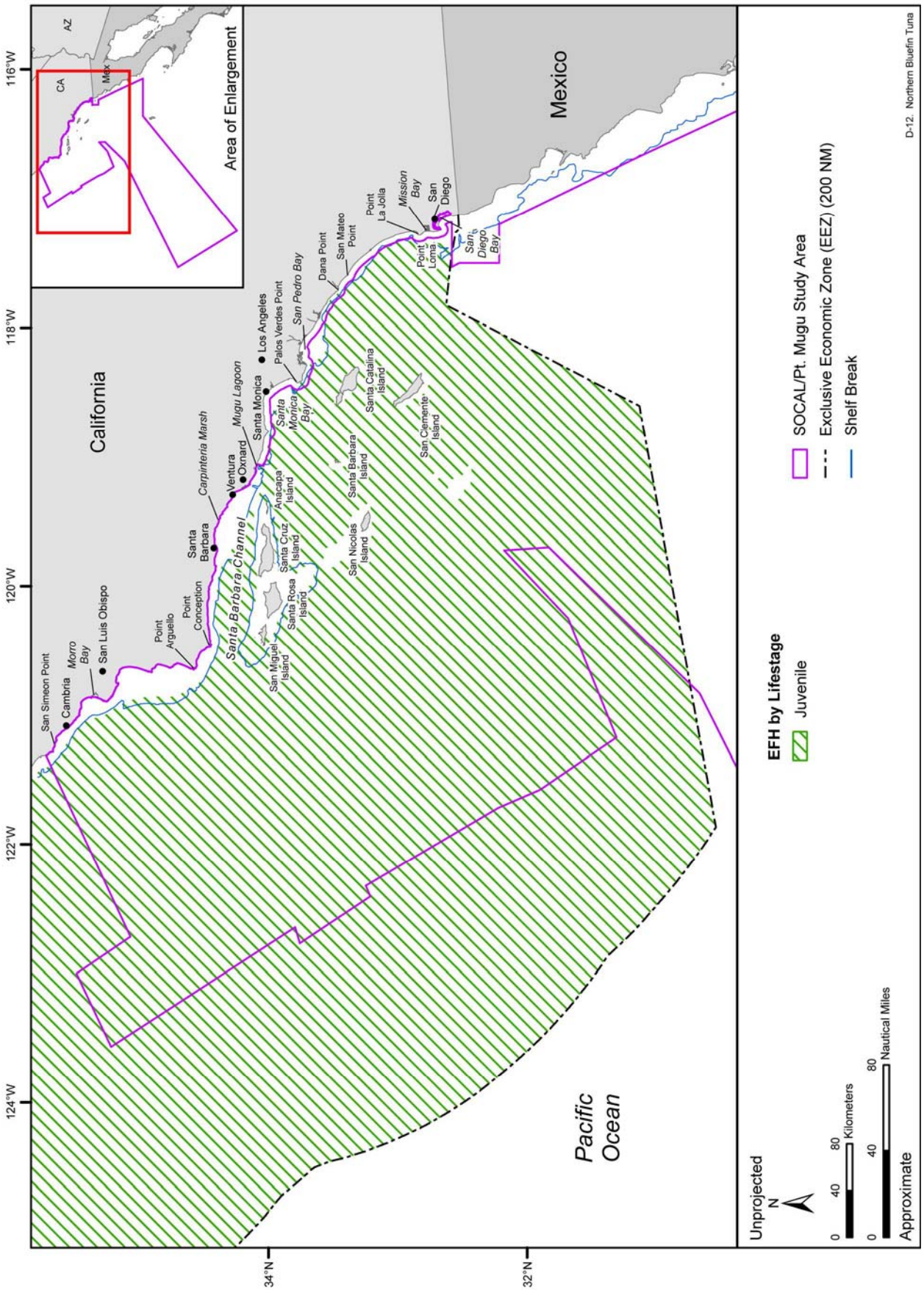

Figure D-12. EFH for the juvenile (183 m to EEZ) lifestage of northern bluefin tuna designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

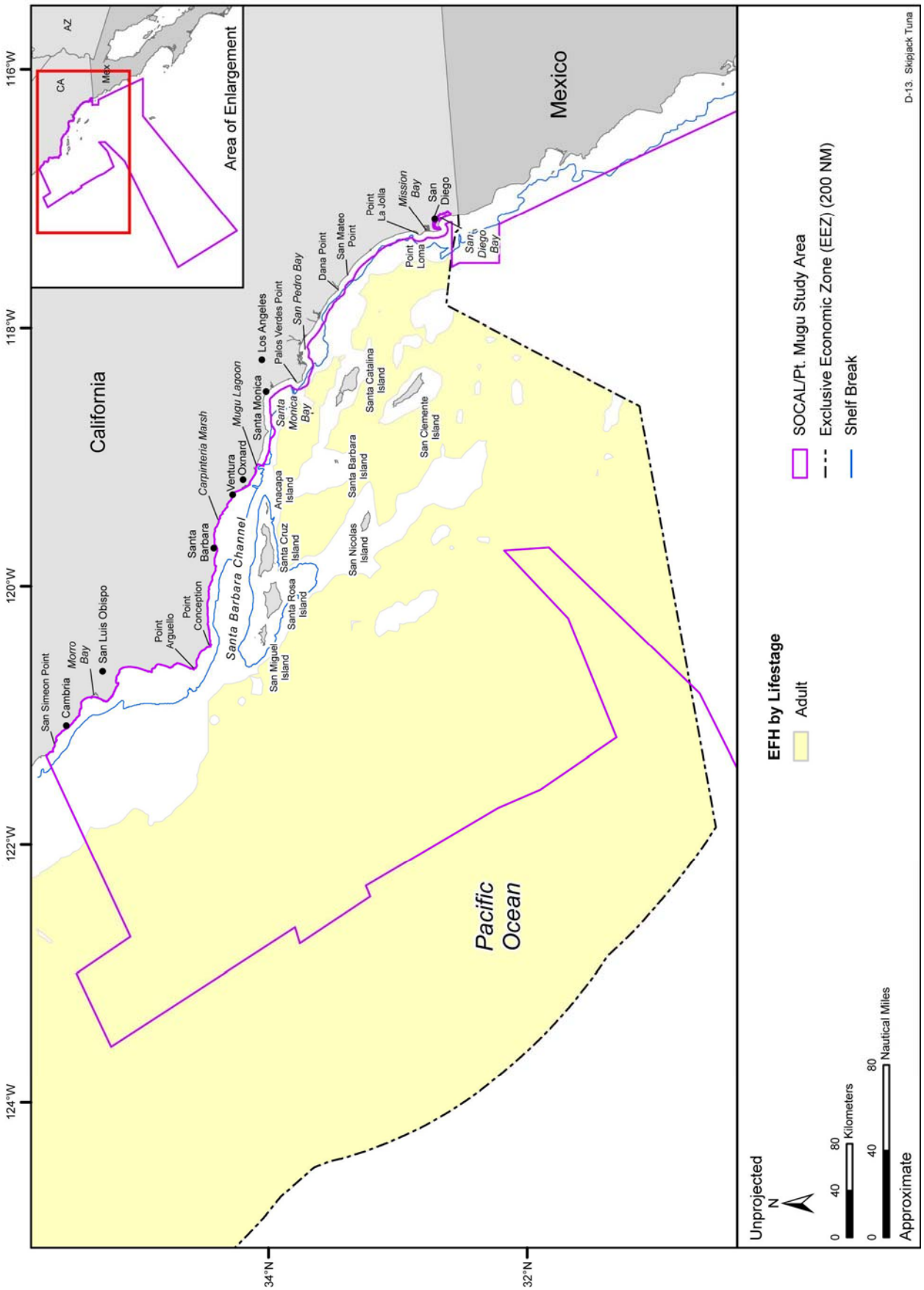

Figure D-13. EFH for the adult (732 m to EEZ) lifestage of skipjack tuna designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

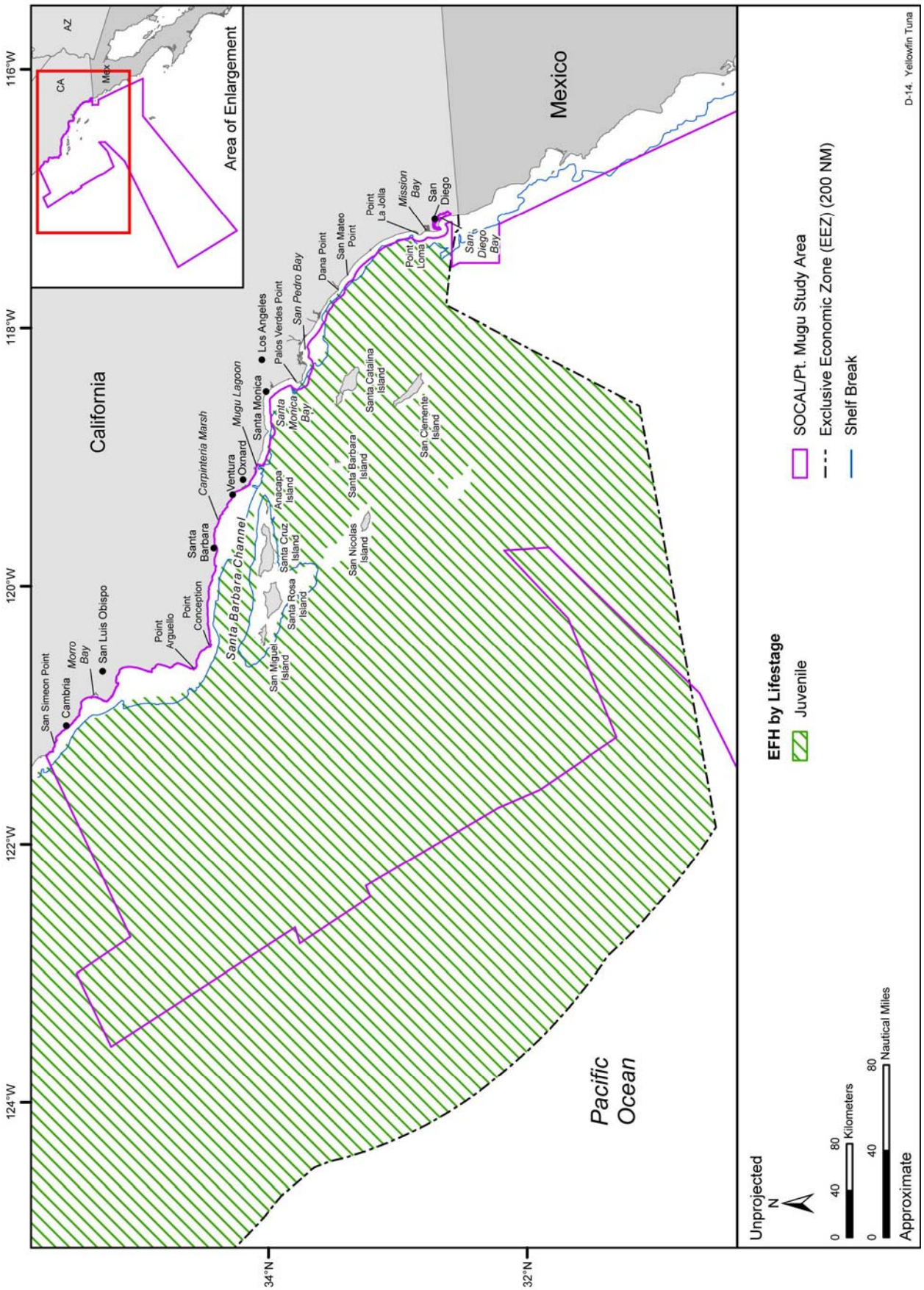

Figure D-14. EFH for the juvenile (183 m to EEZ) lifestage of yellowfin tuna designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

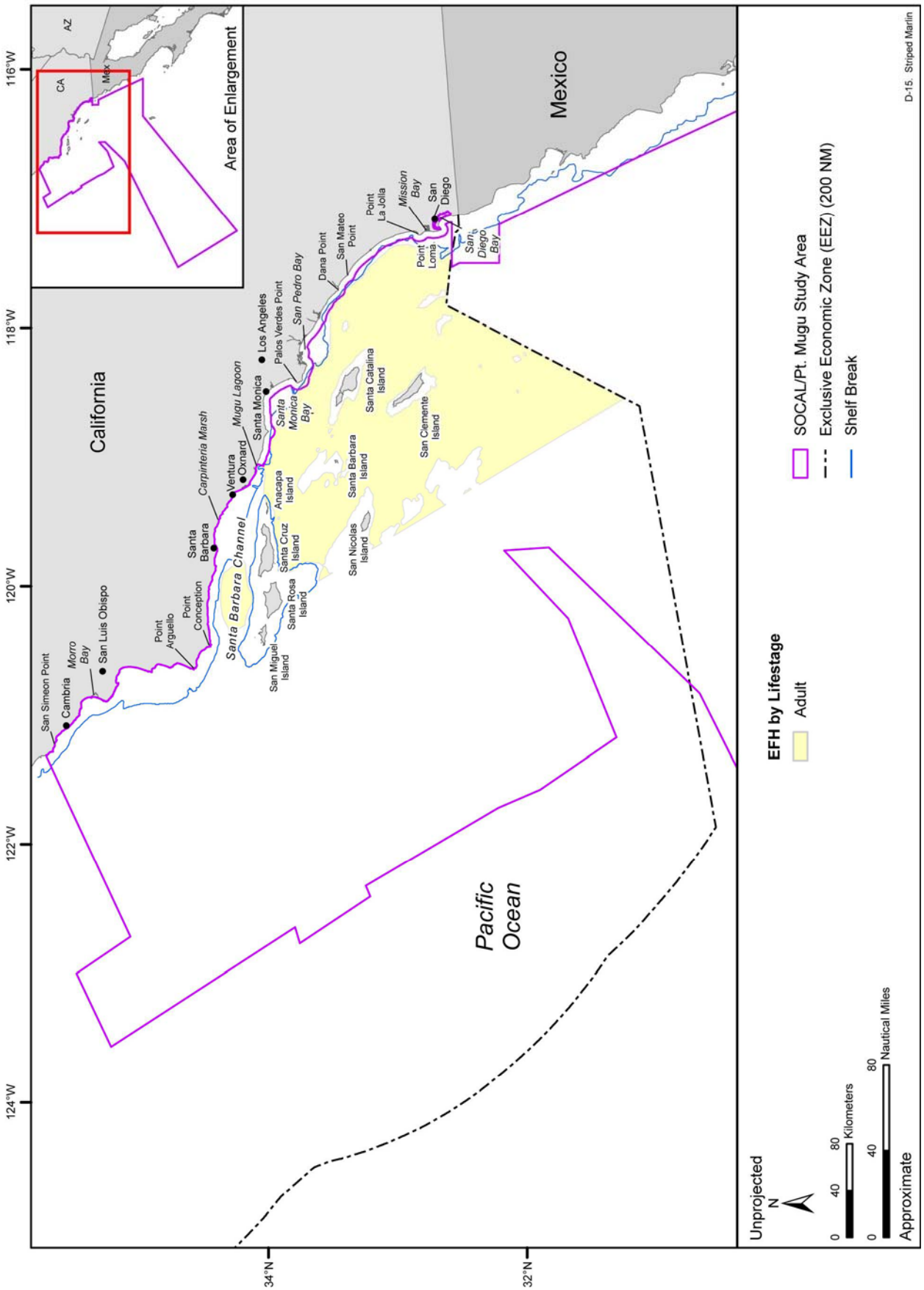

Figure D-15. EFH for the adult (366 m to east of Santa Rosa-Cortes Ridge) lifestage of striped marlin designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

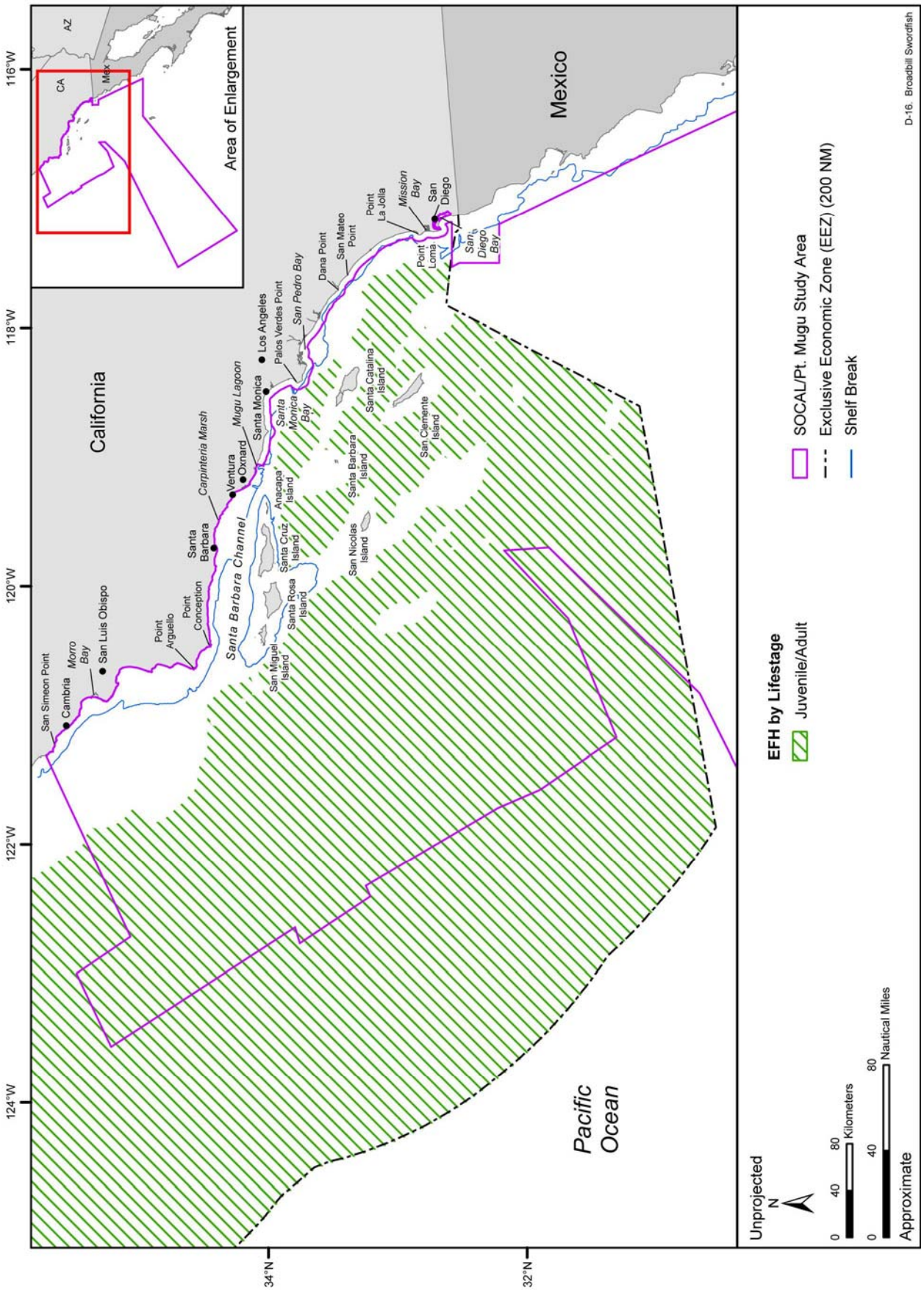

Figure D-16. EFH for juvenile/adult (732 m to EEZ) lifestages of broadbill swordfish designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

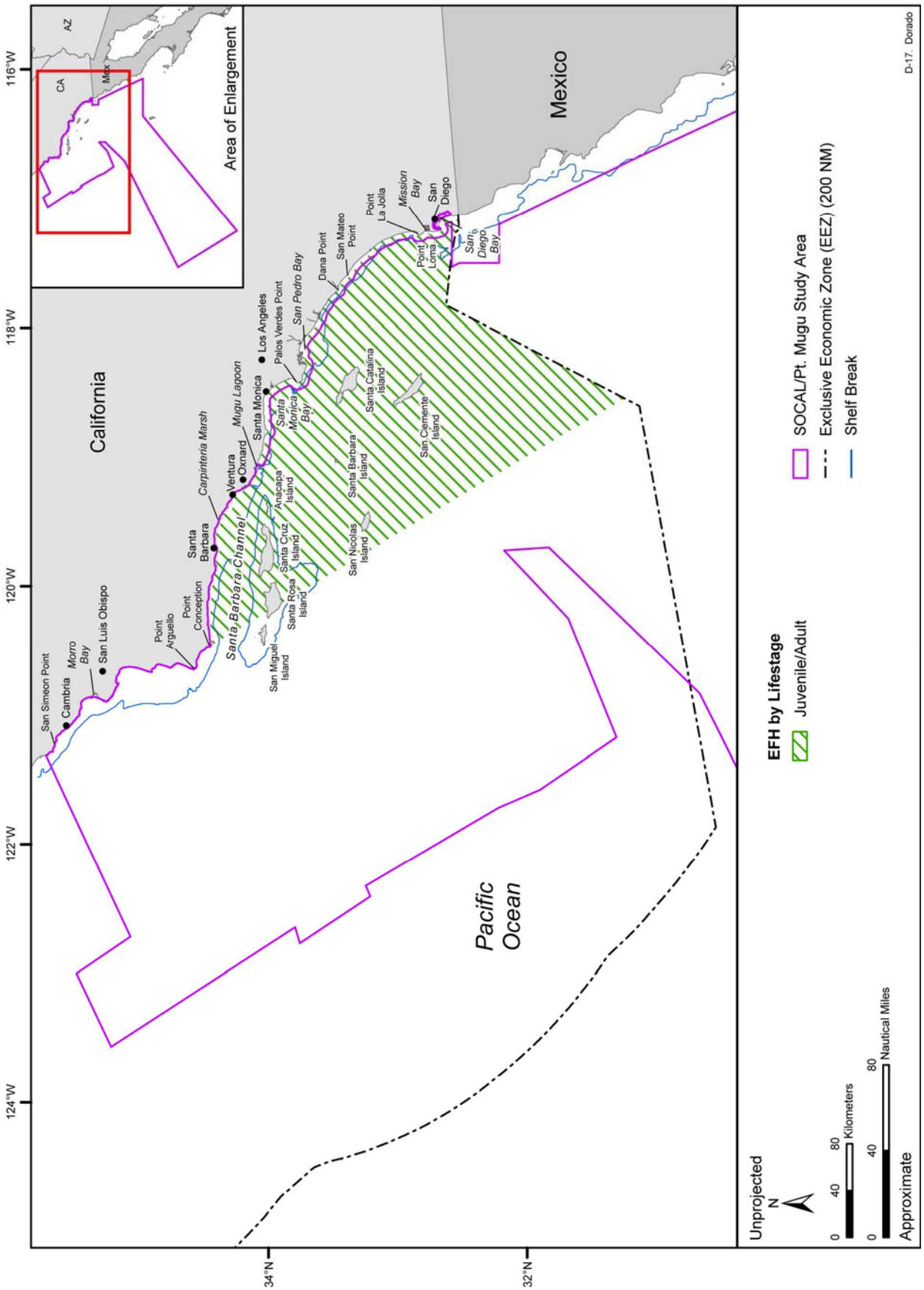

Figure D-17. EFH for juvenile/adult (11 m to east of Santa Rosa-Cortes Ridge) lifestages of dorado designated in the SOCAL/Pt. Mugu Study Area and vicinity. Map adapted from: PFMC (2003b).

Appendix D-1. Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

Pacific Coast Groundfish Species	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
	Rooted macrophytes, algae, or seagrass	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Flatfish									
Arrowtooth flounder		A[1], J[1]	A[2], J[2]	A[1], J[1]	A[2], J[2]				A = 1-19 and J/L/E = 1-59 Morro Bay north
Butter sole			A, J		A[3]				A = 1-59; south of Santa Barbara north
Curfin sole			A, J		A[3], J[3]				A = 1->80; U.S./Mexico Border north
Dover sole			A[4], J, L		A, J, L				A = 1->80 and J = 1-59; U.S./Mexico Border north
English sole	A, J		A, J		A[3]		A, J	A, J, L, E	A = 1->80 and J/L = <1; U.S./Mexico Border north
Petrale sole			A, J		A, J[3]				A = 1-79 and J = 1-39; U.S./Mexico Border north
Rex sole			A, J		A, J				A/J = 1-79; U.S./Mexico Border north
Rock sole		A[1], J[1]	A[2], J[2], E	A[1], J[1]	A[2], J[2], E		A, J		A = 1-39; U.S./Mexico Border north
Sand sole		A, J		A[1], J[1]	A[3]				A = 1-79, J = 1-59, and L = 20-59; Los Angeles north
Starry flounder			A					A, J, L, E	A/J = 20-59 and E = 40-79; Los Angeles north
Pacific sanddab	A	A[1], J[1]	A[2], J[2]	A[1]	A[2]				A = 1-59; U.S./Mexico Border north

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

Pacific Coast Groundfish Species	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
	Rooted macrophytes, algae, or seagrass	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish									
Aurora rockfish		A	A, J	A	A, J				A= 1->80, J = 20->80, and L = 1-79; U.S/Mexico Border north
Bank rockfish		A[5] , J	A[1], J	A[5]	A[1]	A, J			A = 1-39; U.S./Mexico Border north; J = 60->80; Oceanside north
Black rockfish	A, J	A, J[5]	J[1]				J		A/J = 40-59; Los Angeles north
Black-and-yellow rockfish	A, J	A, J[5]	J[1]				A, J		A = 60-79; Long Beach to Pt. Sal; J = 60-79; Los Angeles to south of Pt. Sal; L = 20-59; U.S./Mexico Border north
Blackgill rockfish		A[6]	J	A	J	A			A = 1->80 and J/L = <1; U.S./Mexico Border north
Blue rockfish		A, J[5]		A[6]					A = 40-79; San Diego Bay north ; J = 1-59; San Clemente Island to Pt. Sal; L = 20-79; U.S./Mexico Border north
Bocaccio	A, J, L	A[5], J[5]	A[5], J[5]	A[6]		A[1], J[1]			A/J = 1-39, and L = 40-79; U.S./Mexico Border north

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
Pacific Coast Groundfish Species	*Rooted macrophytes, algae, or seagrass*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish (continued)									
Bronzespotted rockfish		A		A, J					A = 20-79 and J = 1-59; Tanner/Cortez Banks to north of Morro Bay
Brown rockfish	A, J	A[5], J				J	A		NA
Calico rockfish		A[5], J[5]	A[1], J[5]	A[6]		A	J		A = 40-79; Long Beach to Pt. Sal; J = >80; U.S./Mexico Border north
Canary rockfish	J	A[5], J[5]	A[1], J[1]				J		A = 1-39 and J = 20-59; U.S./Mexico Border north
Chilipepper	J, L	A, J	A, J	A	A	J	J		A = 1->80 and J = 60-79; U.S./Mexico Border north
China rockfish	A	A, J							A = 40-59 Long Beach north; J = <1; U.S./Mexico Border north
Copper rockfish	A, J, L	A[5], J[5]	A[1], J[1]				J		A = 40-59; San Diego north
Cowcod		A, J[5]	J[5]	A		A[1]			A = 1->80 and J = 60.80; U.S./Mexico Border north
Darkblotched rockfish		A[1], J[1]	A[5], J[5]	A[1]	A[5]	A[1]			A = 1-39; U.S./Mexico Border north; J = 20-59 and L = 1-59; Oceanside north

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
Pacific Coast Groundfish Species	*Rooted macrophytes, algae, or seagrass*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish (continued)									
Flag rockfish		A, J				A			A = 1-59; San Clemente to Pt. Sal; J = 1-19; Tanner/Cortez Banks to Pt. Sal
Gopher rockfish	A, J	A, J[5]	J[1]				A[7], J[7]		A/J = 1-79; Tanner/Cortez Banks to Pt. Sal; L = 1-79; U.S./Mexico Border north
Grass rockfish	A, J	A, J[5]	J[1]				A, J, L		A = 20-79 and J = 40-79; U.S./Mexico Border north
Greenblotched rockfish		A[5], J[5]	A[1], J[1]	A[5]	A[1]	A			A = 20->80; Tanner/Cortez Banks to north of Morro Bay
Greenspotted rockfish		A[5], J	A[5], J			A[1]			A = 1-79 and J = >80; U.S./Mexico Border north
Greenstriped rockfish		A[5], J[1]	A[5], J[5]	A[5]	A[5]				A = 1-39 and J = 20-39; U.S./Mexico Border north
Honeycomb rockfish		A, J	J			J			A = 20->80 and J = 60->80; U.S./Mexico Border north
Kelp rockfish	A, J, L	A, J							A = 60->80; U.S./Mexico Border north

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
Pacific Coast Groundfish Species	*Rooted macrophytes, algae, or seagrass*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish (continued)									
Mexican rockfish		A		A[1]	A[1]				A = 1-59, J = 1-79; Tanner/Cortez Banks to Los Angeles; L = 40->80; U.S./Mexico Border north
Olive rockfish	A, J	A, J				A	A, J, L		A = 1-79; Tanner/Cortez Banks to Pt. Sal
Pacific ocean perch		A, J	A	A, J	A, J	A			A = <1 and J/L = 1-59; U.S./Mexico Border north
Pink rockfish		A[5]	A[1], J	A[5]	A[1], J	A			A = 20->80; Tanner/Cortez Banks to Los Angeles
Quillback rockfish	A, J	A[5], J[5]	A[1], J[5]				A, J		J = 40-59; Los Angeles to Pt. Sal
Redbanded rockfish		A[1]	A[5], J	A[1]	A[5], J				A = 1-39; U.S./Mexico Border north
Redstripe rockfish		A[5], J[5]	A[1], J[1]	A[5], J[5]	A[1], J[1]			A[8], J[8]	A = 1->80; Tanner/Cortez Banks to north of Morro Bay
Rosethorn rockfish		A[5], J[5]	A[1], J	A[1]	A[1], J	A			A = 1-19: U.S./Mexico Border north
Rosy rockfish		A[5], J[5]	A[1], J[1]						A = 1-59; Tanner/Cortez Banks to north of Morro Bay; J = 1->80; Tanner/Cortez Banks to Pt. Sal

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

Pacific Coast Groundfish Species	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
	Rooted macrophytes, algae, or seagrass	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish (continued)									
Rougheye rockfish		A[5]	A[5], J	A[5]	A[5], J				A = 1-19; Oceanside north; J = 1-59; U.S./Mexico Border north
Sharpchin rockfish		A[5], J[1]	A[1], J[5]	A[1], J[1]	A[2,5], J[5]				A = 1-19; U.S./Mexico Border north; J = 1-39; La Jolla north; L = 1-39; Oceanside north
Shortbelly rockfish	J	A, J[5]	A, J[2]		A	A	J		A = 1->80; U.S./Mexico Border north
Shortraker rockfish		A[5]	A[5]	A[1]	A[5]				A = 1-59; Santa Barbara north
Silvergray rockfish	J	A, J		A, J					A = <1; U.S./Mexico Border north
Speckled rockfish	J	A, J		A[6]		A			A = 1-79; Tanner/Cortez Banks to north of Morro Bay; J = 20-79; San Clemente to Pt. Sal
Splitnose rockfish	J	A[1], J[1]	A[5], J[5]	A[1], J[1]	A[5], J[5]	A			A = 1-39 and J/L = 1-79, U.S./Mexico Border north
Squarespot rockfish		A, J							A = 1-79; Tanner/Cortez Banks to Pt. Sal; J = >80; Long Beach to Pt. Sal

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

Pacific Coast Groundfish Species	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
	Rooted macrophytes, algae, or seagrass	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish (continued)									
Starry rockfish		A, J		A[6]					A = 1-79; Tanner/Cortez Banks to Pt. Sal; J = 40->80; San Clemente Island to Pt. Sal
Stripetail rockfish	J	A[1], J	A[5], J	A[1]	A[5]				A = 1->80 and J = 1-79; U.S./Mexico Border north
Tiger rockfish		A, J		A, J					A = 1-19: Tanner/Cortez Banks to Pt. Conception
Treefish		A, J							A = 20->80 and J = >80; U.S./Mexico Border north
Vermilion rockfish	A, J, L	A, J[1]	J[5]	A		A	J		A = 1-79; Tanner/Cortez Banks to north of Morro Bay
Widow rockfish	J	A[5], J[5]	A[1], J[5]	A[5]	A[1]	A[1], J			A = 20->80; Tanner/Cortez Banks to Pt. Sal; J = 1-79; U.S./Mexico Border north
Yelloweye rockfish		A[5], J	A[1]	A		A			A = 1-59; Tanner/Cortez Banks to Los Angeles; J = 1-59; San Clemente Island to Pt. Sal

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
Pacific Coast Groundfish Species	*Rooted macrophytes, algae, or seagrass*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Rockfish (continued)									
Yellowtail rockfish	A, J	A[5], J	A[5]	A[5]	A[5]				A = 1-79 and J = 40-79; Santa Catalina Island to north of Morro Bay
Scorpionfish									
California scorpionfish	A, J	A, J	A				A, J		A = 1-79; Tanner/Cortez Banks to Pt. Sal
Thornyheads									
Longspine thornyhead				A[1]	A[5], J				A = 1->80 and J = 20->80; U.S./Mexico Border north
Shortspine thornyhead		A[1], J [1]	A[5], J[5]	A[1], J [1]	A[5], J[5]				A = 1->80 and J = 1-79; U.S./Mexico Border north
Roundfish									
Cabezon	A, J, E	A, J, E					A, J, L, E		A = 40-79; Santa Clemente Island to north of Morro bay
Kelp greenling	A, J, E	A, J, E					A, J, L		A = 1-59 and J = >80; Oceanside north
Lingcod	A	A	J				A, J, L, E	J, L, E	A = 60->80; San Clemente Island north of Morro Bay; J = 1-19 and L = 1-39; U.S./Mexico Border north; E = 60-79; San Diego Bay to Port Hueneme

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

Pacific Coast Groundfish Species	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
	Rooted macrophytes, algae, or seagrass	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Roundfish (continued)									
Pacific cod		J, E	A, J, E		A				A = <1; U.S./Mexico Border north; J = 1-19; Channel Islands to Pt. Conception; L = 60->80 and E = 20-79; Los Angeles north
Pacific hake (Whiting)						J	J		A/E = 1->80; U.S. Mexico Border north: J = 40-59; Newport Beach to Channel Islands
Sablefish			J		A, J, L	A			A = 1->80 and J/LE = 1-79; U.S./Mexico Border north
Skates and Sharks									
Big skate			A, J		A		A		A/J/E = 1-59; U.S./Mexico Border north
California skate			A, J, E		A[3]		A, E	A, J	A/J/E = 1->80; U.S./Mexico Border north
Longnose skate			A[5], J[5]		A[5]		A, E	A, J	A = 1->80, J = >80, and E = 20-79; U.S./Mexico Border north
Leopard shark	A, J	A[1]	A[1, 4]				A, J	A, J	A/J = 20-79; U.S./Mexico Border north

Appendix D-1 (*continued*). Pacific coast groundfish species, lifestages, habitats, and HSP in SOCAL-Pt. Mugu Study Area (NMFS-NWR 2005).

	Habitats								
	Estuarine, Intertidal, and Continental Shelf Zones	**Continental Shelf**		**Continental Slope and Rise**		**Canyons**	**Intertidal Zone**	**Estuaries**	**HSP Percent (%)**
Pacific Coast Groundfish Species	*Rooted macrophytes, algae, or seagrass*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*	*Hard and mixed hard/soft bottoms*	*Soft and mixed hard/soft bottoms*				
Skates and Sharks (continued)									
Soupfin shark			A, J		A	A	A, J	A, J	A = 1-39 and J = 1->80; U.S./Mexico Border north
Spiny dogfish			A, J		A, J		A, J	A. J	A = 1->80 and J = 1-39; U.S./Mexico Border north
Other Species									
Finescale codling (Pacific flatnose)	NA	NA	NA	NA	NA	NA	NA	NA	A = 1->80; U.S./Mexico Border north
Pacific rattail grenadier					A, J				A = 1-79 J = <1, and L/E = 1->80; U.S./Mexico Border north
Spotted ratfish		A, J, E	A, J, E						A/J/E = 1-79; U.S./Mexico Border north

[1] Indicates association with mixed hard and soft habitat
[2] Indicates association with both soft and mixed hard and soft habitat
[3] Indicates a weak association with soft-bottom habitats or mixed hard and soft habitat
[4] Indicates a weak association with soft-bottom habitats
[5] Indicates association with both hard and mixed hard and soft habitat
[6] Indicates a weak association with hard-bottom habitats
[7] Indicates a weak association with intertidal habitats
[8] Indicates a weak association with estuaries

A = Adults; J = Juveniles; L = Larvae; E = Eggs; NA = Not Available

Note: Maps of life history stages are not available for all Pacific coast groundfishes

Habitat Suitability Probability Maps: The shaded areas on the maps represent habitats within the Study Area that are likely to be suitable for individual species and life history stages based on the best available science. The darker areas have a higher probability of suitability than the lighter areas