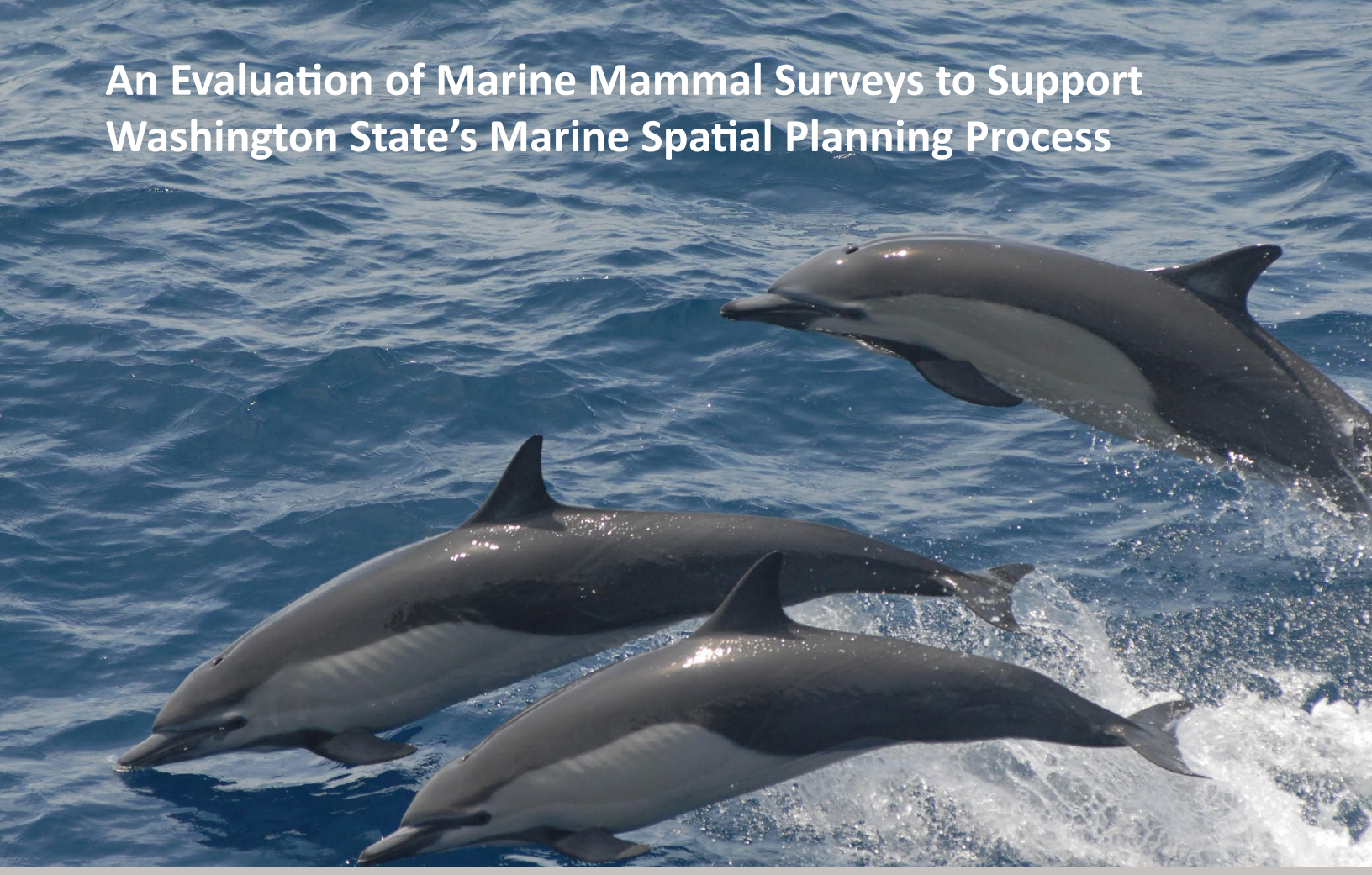
An Evaluation of Marine Mammal Surveys to Support Washington State's Marine Spatial Planning Process



NOAA National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment

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The covers for this document were designed and created by Gini Kennedy (NOAA); document design and layout completed by Sarah D. Hile. Front cover photos were provided by NOAA NMFS/SWFSC (short-beaked common dolphin), NOAA NMFS/SWFSC (killer whale), Vladimir Burkanov (NOAA NMFS/AFSC/NMML; Steller sea lion), and John Calambokidis (Cascadia Research Collective; gray whale). Back cover photos were provided by Amy Kennedy (NOAA NMFS/AFSC/NMML; humback whale), James Lamont (Northern elephant seals), Washington Department of Fish and Wildlife (gray whale), NOAA NMFS/SWFSC (striped dolphin), and NOAA NMFS/AFSC/NMML (California sea lion pup).

An Evaluation of Marine Mammal Surveys to Support Washington State's Marine Spatial Planning Process

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NOAA Technical Memorandum NOS NCCOS 195

About This Document

The objective of this report is to identify and evaluate existing datasets related to the distribution of marine mammals along the Northwest coast of the United States which can support Marine Spatial Planning (MSP) by the State of Washington. In this report, we consider the degree to which existing datasets are able to represent species distributions and provide information needed by Washington to mitigate potential conflicts among ocean users and ensure adequate biological conservation. A review of pelagic, nearshore and shore-based surveys, as well as data collected via passive acoustic sensors and animal borne sensors, is provided. This document is organized by the scale at which the surveys are conducted, starting with broad-scale offshore cetacean surveys observed primarily from ships. Next, moderate scale surveys (e.g., Olympic Coast National Marine Sanctuary and state waters) conducted from various platforms are described, followed by nearshore/onshore pinniped surveys. Lastly, brief reviews of passive acoustic surveys and animal borne sensor data available in the region are provided.

The focus of this report is on datasets collected in the last 10 years that contribute to our understanding of the current distribution of mammals commonly observed at sea. Information on research efforts and lead scientists, spatial and temporal aspects of the survey data, and the purpose of the data collection effort have been combined and evaluated. Intended outcomes of this report are to identify data gaps and general patterns of data availability that can support the development of maps to describe the relative distribution of marine mammal abundance needed by Washington. In a subsequent effort, we will use this report to develop statistical modeling techniques to determine the probabilities of relative occurrence and abundance for marine mammals in the region. Washington state is planning to use the new marine mammal models to identify important ecological areas and proactively plan for future uses of coastal and marine resources.

A methodology to guide the MSP process in the state of Washington is being crafted by the State Ocean Caucus (Hennessey, 2011), which includes multiple state agencies and is chaired by the Department of Ecology. The MSP process is intended to address increasing pressures on the resources, conflicts among uses, and proposed new uses by providing a non-regulatory framework for coordinating information and decisions (MSP Public Scoping Document: http://www.msp.wa.gov/wp-content/uploads/2013/07/MSP_scoping_document.pdf). A key component of the process is analysis and allocation of the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives. To this end, Washington state has called for maps that, at a minimum, summarize available data on key ecological aspects of the marine ecosystem, including physical and biological characteristics, as well as areas that are environmentally sensitive or contain unique or sensitive species or biological communities that warrant protective measures or conservation consideration.

In 2006, the Department of the Navy completed the Marine Resources Assessment for the Pacific Northwest Operating Area (U.S. Department of the Navy, 2006), which includes a list of marine mammal datasets and a list of data gaps. The authors of the Navy report recommended revision of the Assessment once every five years so that newly available data sets can be incorporated. While this report is not associated with the Navy's Assessment, it is the most recent review of marine mammal datasets since the state of Washington's initiated the MSP process.

In 2014, Menza et al. (2014) developed a spatial prioritization tool to identify seafloor mapping priorities and evaluate available datasets of ecological surveys of seabirds and deep sea corals. This document is a continuation of that work, focusing on marine mammal surveys that are relevant for MSP by Washington.

There is an extensive body of research documenting marine mammals along the coast of Washington state. Primary sources of ship-based and aerial survey information include data collected by: NOAA's National Marine Fisheries Service - Southwest Fisheries Science Center and Alaska Fisheries Science Center's National Marine

About This Document

Mammal Laboratory; NOAA's National Ocean Service - Office of National Marine Sanctuaries's Olympic Coast National Marine Sanctuary; Washington State Department of Fish and Wildlife; Cascadia Research Collective; and the Makah Tribe, among others. The majority of surveys examined in this report are systematic, which makes the data amenable to modeling techniques that can better resolve distributions of animals and contribute continuous maps of abundance to the MSP process. However, the reduced survey effort in winter months and in waters further than 100 kilometers from shore or deeper than 400 fathoms will present challenges in making robust predictions in the winter, and far out at sea. Opportunistic photo identification surveys, passive acoustics, and tracking studies provide complementary information, especially related to demographics and seasonal movement of animals. The need to continue monitoring these populations under the aegis of the Marine Mammal Protection Act and the Endangered Species Act and improve our understanding of species distributions as they change through time will require consistent, long-term observations to support management and conservation of these animals.

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For more information on this and similar projects visit the NCCOS web site, http://coastalscience.noaa.gov/, or send direct questions and comments to:

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List of Table and Figures

Chapter 1: Introduction

The geographic scope of this report extends from Cape Flattery in the north to Cape Disappointment in the south, and from shore westward to the 400 fathom (731.5 m) isobath (Figure 1). This area covers all of the continental shelf adjacent to Washington, as well as the upper portion of the continental slope, Willapa Bay and Grays Harbor. It excludes the Strait of Juan de Fuca, the Lower Columbia River Estuary and the Salish Sea. The 400 fathom isobath limit was originally proposed by the Washington Department of Fish and Wildlife (WDFW) for the MSP study area (Trosin, 2013), but was later revised to 700 fathoms to address public scoping commentary (WDOE, 2014). Since the revision occurred after this project was fully underway, our study area extends to the original 400 fathom limit which includes the majority of the marine spatial planning (MSP) study area, but not the area between 400 and 700 fathoms.

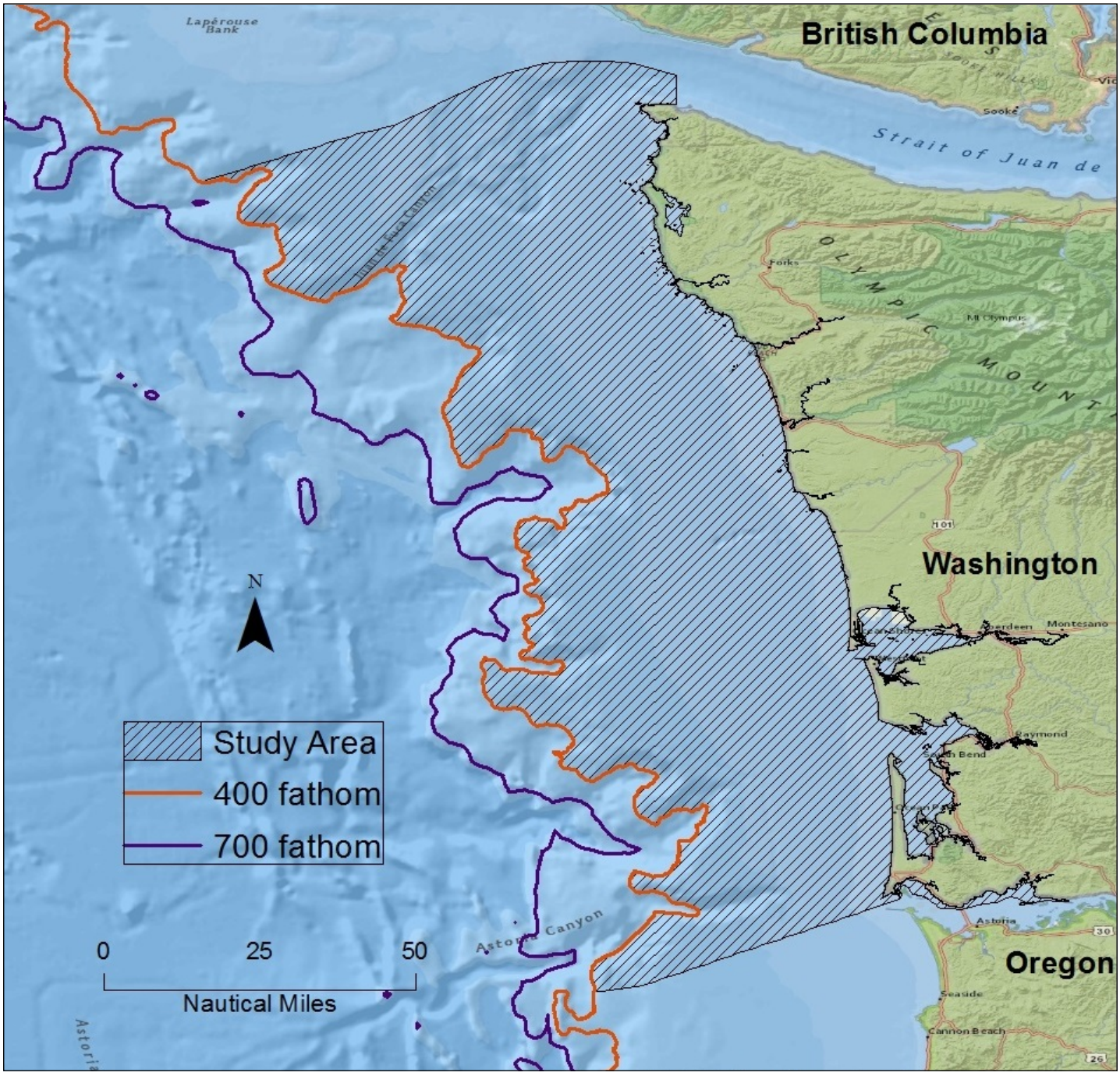


Figure 1. Study area of marine mammal surveys evaluated in this report.

Introduction

This report focuses on surveys that collect information on cetaceans (baleen and toothed whales) and pinnipeds (seals and sea lions) observed in the study area (Table 1). It does not include information on surveys of sea otters. Surveys collected after 2004 were prioritized for inclusion, since a report by the Marine Resources Assessment Program of the U.S. Department of the Navy (2006) provides a good inventory of data collected before then.

Marine mammals included in this report exhibit a diversity of life histories and physiologies, and are found across a range of coastal and pelagic habitats. Numerous at-sea surveys have been conducted to better understand their spatial and temporal distributions and how they are impacted by human activities. The Navy's Marine Resources Assessment (U.S. Department of the Navy, 2006) provided a thorough review of spatial data on marine resources to support environmental planning and compliance within the Pacific Northwest Operating Area and described the status, habitat preferences, distribution, behavior, life history, and acoustics and hearing characteristics of marine mammals of the Pacific Northwest.

All large whales and pinnipeds off the U.S. west coast are protected by the U.S. Marine Mammal Protection Act (MMPA). Eleven marine mammal species in the study area are listed as threatened or endangered or at some level of conservation concern by the state or federal government (WDFW, 2013). To protect marine mammals, ongoing monitoring, mapping and research is conducted by NOAA's National Marine Fisheries Service (NMFS) and NOAA's National Ocean Service's Office of National Marine Sanctuaries (ONMS), and other organizations such as the Cascadia Research Collective and Orca Network.

Top row (L-R): gray whale (John Calambokidis, Cascadia Research Collective), Pacific white-sided dolphins (Michael Richlen); California sea lions (Eric Boerner, NOAA NMFS/AFSC/NMML). Middle row (L-R): Sea otter (NOAA ONMS/OCNMS); Northern Pacific right whale (John Durban, NOAA NMFS/AFSC); Short-finned pilot whale (NOAA NMFS/SWFSC); NOAA NMFS/SWFSC). Bottom row (L-R): killer whales (NOAA NMFS/SWFSC); humback whales (Cornelia Odekoven); Northern elephant seals (James Lamont).

Table 1. Marine mammals reported in marine waters off Washington state. Conservation status is defined as State Endangered (SE), State Threatened (ST), State Sensitive (SS), State Candidate (SC), Federally Endangered (FE), Federally Threatened (FT), or Federal Species of Concern (FCo). The sources of the data are: Olympic Coast National Marine Sanctuary website (OCNMS Marine Mammals Species List 2013; OCNMS, 2013) and Washington State Threatened and Endangered Wildlife in Washington: 2012 Annual Report (WDFW, 2013).

Group	Common Name	Scientific Name	Relative Occurrence	Conservation Status
Carnivore	Sea Otter	*Enhydra lutris*	Regular	SE, FCo
Pinnipeds	California sea lion	*Zalophus californianus*	Regular	
	Northern (Steller) sea lion	*Eumetopias jubatus*	Regular	ST, FCo
	Northern fur seal	*Callorhinus ursinus*	Regular	
	Pacific harbor seal	*Phoca vitulina*	Regular	
	Northern elephant seal	*Mirounga angustirostris*	Regular	
Cetaceans	California gray whale	*Eschrichtius robustus*	Regular	SS
	Northern Pacific right whale	*Eubalaena glacialis*	Rare	SE, FE
	Minke whale	*Balaenoptera acutorostrata*	Regular	
	Fin whale	*Balaenoptera physalus*	Rare	SE, FE
	Sei Whale	*Balaenoptera borealis*	Rare	SE, FE
	Blue whale	*Balaenoptera musculus*	Rare	SE, FE
	Humpback whale	*Megaptera novaeangliae*	Regular	SE, FE
	Sperm whale	*Physeter macrocephalus*	Rare	SE, FE
	Pygmy sperm whale	*Kogia breviceps*	Rare	
	Stejneger's beaked whale	*Mesoplodon stejnegeri*	Rare	
	Hubb's beaked whale	*Mesoplodon carlhubbsi*	Rare	
	Cuvier's beaked whale	*Ziphius cavirostris*	Rare	
	Baird's beaked whale	*Beradius bairdii*	Rare	
	Short-finned pilot whale	*Globicephala macrorhynchus*	Rare	
	Risso's dolphin	*Grampus griseus*	Regular	
	Southern Resident Killer whale	*Orcinus orca*	Regular	SE, FE
	False killer whale	*Pseudorca crassidens*	Rare	
	Common dolphin	*Delphinus delphis*	Rare	
	Northern right whale dolphin	*Lissodelphis borealis*	Regular	
	Striped dolphin	*Stenella coeruleoalba*	Rare	
	Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Regular	
	Dall's porpoise	*Phocoenoides dalli*	Regular	
	Harbor porpoise	*Phocoena phocoena*	Regular	SC

MSP Planning Process

Chapter 2: Marine Spatial Planning Process in Washington

The coastal and marine waters off Washington state have finite resources (many of which are renewable) and many users. The area is home to a diversity of animal species, including invertebrates, fish, marine mammals and seabirds. To mitigate potential conflicts among users and ensure adequate conservation, the State of Washington recently enacted legislation to proactively plan for future uses of coastal and marine resources (2010 RCW §43.372). Some of the factors affecting the vulnerability and stability of marine mammal populations globally are ship strikes (Scordino and Mate, 2011); noise from vessel traffic, military activities and resource extraction; fishing activities, including competition for prey, bycatch and entanglement with fishing gear (Saez et al., 2013); marine debris; habitat persistence and alteration; and mass mortality due to harmful algal blooms (Marine Mammal Commission, 2014). Spatial data, visualized, provides a powerful tool for evaluating competition for resources stemming from industry, fishing interests, recreational uses and cultural activities.

Marine planning has important implications for marine mammal conservation because human activities can have large impacts on marine mammal populations and distributions. The marine spatial planning process is dependent on understanding where marine resources, including marine mammals, are found in relation to potentially conflicting human activities. This current effort identifies surveys of marine mammals that reside during some stage of their life history in the study area and considers the degree to which these datasets are able to address questions of seasonality, as well as long-term species abundance and distribution.

Chapter 3: Description of Marine Mammal Surveys

The following is a brief description of the most comprehensive marine mammal surveys (Figure 2) conducted between 2004 and 2014 (although some surveys prior to 2004 are included here for context). We provide a brief description of each survey and a map depicting the survey extent in relation to the study area (hatched area). A complete accounting of marine mammal surveys is provided in Appendix A.

> *The objective of this report is to identify and evaluate existing datasets related to the distribution of marine mammals along the Northwest coast of the United States in support of Marine Spatial Planning (MSP) efforts in the State of Washington.*

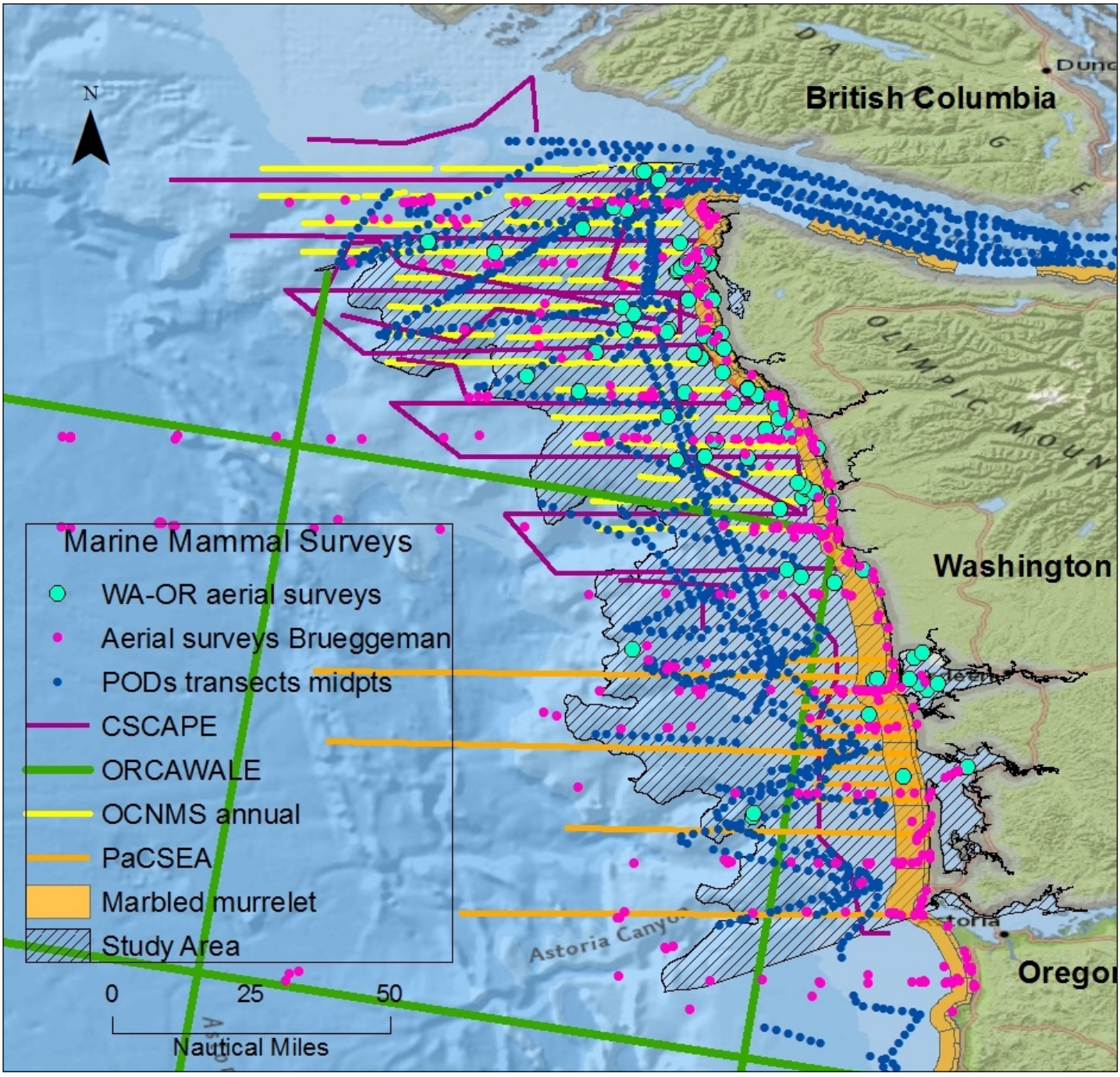


Figure 2. Marine mammal surveys conducted along the Washington coast reviewed in this report.

Marine Mammal Surveys

3.1. CETACEANS

Cetaceans are an integral component of the highly productive seascape of the northeast Pacific Ocean. Under the MMPA, NMFS is responsible for stock assessments to describe population trends and develop recovery plans to monitor the status of whales. To fulfill these mandates, NOAA's Fisheries Science Centers in the southwest and northwest, along with the NMFS Alaska Fisheries Science Center's (AFSC) National Marine Mammal Laboratory (NMML), collect and assimilate information from cetacean surveys along the U.S. West Coast to monitor and report on the status of strategic and non-strategic stocks (Carretta et al., 2014). Cetacean data are also used to support the California Current Integrated Ecosystem Assessment (Redfern et al., 2013).

In the study area, most at-sea cetacean observations have been collected from ship-based line transect surveys, which include observations of all cetaceans encountered, including both baleen whales (mysticetes) and toothed whales (odontocetes). These surveys commonly serve multiple objectives and include concurrent surveys of seabirds, and environmental parameters such as sea surface temperature, salinity, and surface chlorophyll, to support ecosystem-based management or aid in modeling habitat associations (Forney et al., 2012). In other cases, specific research efforts focus on a single species, such as California gray whale (*Eschrichtius robustus*) and Pacific harbor porpoise (*Phocoena phocoena*). Aerial surveys along the coast also add to our knowledge of the abundance and distribution of cetaceans and pinnipeds in the region.

3.1.1. Ship-based California Current Ecosystem Surveys (ORCAWALE, CSCAPE, CalCurCEAS)

A series of multi-disciplinary surveys of marine animals has been conducted over the past two decades by NMFS Southwest Fisheries Science Center (SWFSC; Chief Scientists: Jay Barlow, Karin Forney, Jason Appler) that provide information on the spatial and temporal distribution of marine mammals (https://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=259&id=1511) in the U.S. portion of the California Current Large Marine Ecosystem (CCLME).

The NMFS-led marine mammal surveys conducted within the study area include Oregon, California and Washington Line-Transect and Ecosystem (ORCAWALE) in 1996, 2001 and 2008 (Appler et al., 2004); Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE) in 2005 (Figure 3); and California Current and Ecosystem Survey (CalCurCEAS) in 2014. These surveys involve visual observations along systematic transects, photographic records, biopsy sampling, and acoustic sampling of cetacean calls via towed hydrophone arrays and opportunistic deployment of sonobouys. Systematic seabird surveys, opportunistic acoustic backscatter data collection from the water column, and oceanographic measurements are recorded as well. Line survey transect methods follow SWFSC established procedures (See Kinzey et al., 2000).

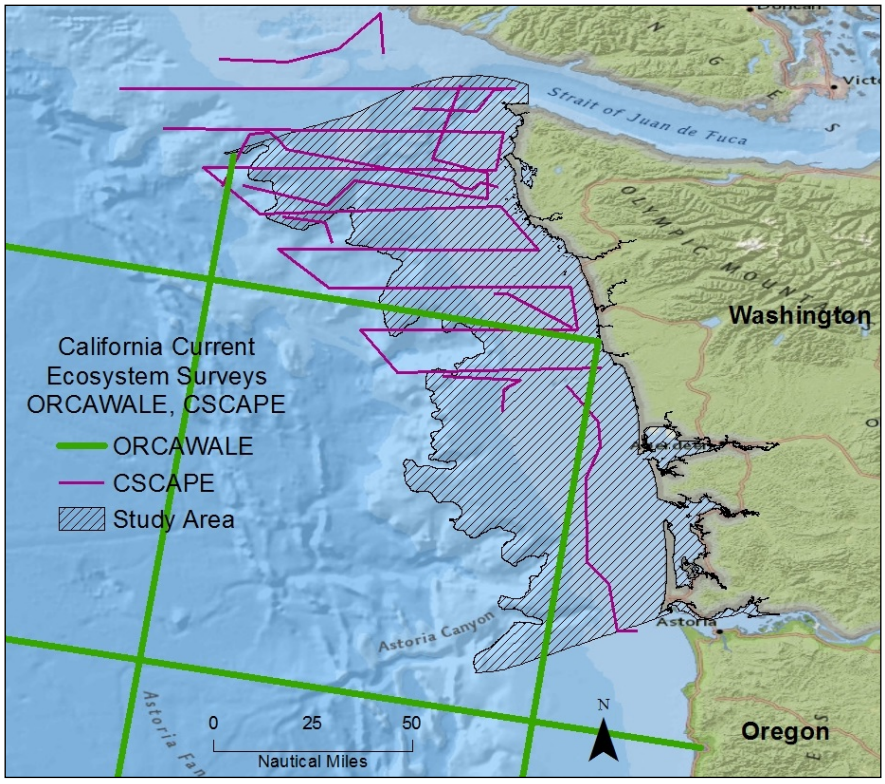


Figure 3. Transects from California Current Ecosystem (CCLME) surveys conducted by NOAA's Southwest Fisheries Science Center (SWFSC). Oregon, California and Washington Line-Transect and Ecosystem (ORCAWALE) transects shown are part of the broad scale CCLME surveys. Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE) included additional fine-scale transects across Olympic Coast National Marine Sanctuary (OCNMS).

Marine Mammal Surveys

These California Current surveys have been conducted at both broad and fine scales. Broad-scale surveys extend across the entire CCLME where long transects are widely spaced. Fine-scale surveys are focused in special areas of interest, such as the National Marine Sanctuaries of the West Coast or potential sites for ocean energy exploration.

The most recent CalCurCEAS cruise (Barlow, 2014) began in August 2014 in northern Washington state and ended in Southern California in December 2014 (Taylor, 2014). The first leg of this survey also included fine-scale survey lines in an area of interest to Bureau of Energy Management (BOEM, formally Minerals Management Service) as experimental sites for energy development off the coast of Oregon (Barlow, 2014). Only Leg 1 of CalCurCEAS encompassed the offshore waters of Washington state, out to 300 nmi (not shown).

Objectives of SWFSC California Current Ecosystem Studies

California Current Cetacean and Ecosystem Assessment Survey (CalCurCEAS 2014):
"… a multi-disciplinary expedition to estimate the abundance of cetacean species in the California Current and study their ecosystem." Barlow, 2014

Oregon, California and Washington Line-transect and Ecosystem (ORCAWALE 2008):
"The primary objectives of the 2008 Oregon, California and Washington Line-transect and Ecosystem (ORCAWALE) cruise were to collect data for estimating the abundance of cetacean (dolphin, porpoise and whale) populations along the U.S. West Coast and for better understanding their habitat and distribution." Barlow et al., 2010

Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE 2005):
"The survey objectives were to assess the abundance and distribution of marine mammals and seabirds, and to characterize the pelagic ecosystem within the National Marine Sanctuaries and in the ecological context of the broader California Current region." Forney, 2007

Oregon, California and Washington Line-transect and Ecosystem (ORCAWALE 2001):
"The primary goal of this expedition was to estimate the abundance and distribution of cetaceans by visual and acoustic methods. Concurrent with the abundance estimation, the expedition collected oceanographic data, as well as other forms of biological data, to contribute to a more thorough understanding of the environment in which these species are found." Appler et al., 2004

Broad-scale ORCAWALE surveys were conducted in 1996, 2001 and 2008 (Appler et al., 2004; Barlow et al., 2010). In 2005, CSCAPE included both broad-scale survey transects along the entire U.S. West Coast (Figure 4, top) and fine-scale line transects along the Washington coast (Figure 4, bottom) to assess the distribution of marine mammals and characterize the pelagic ecosystem of the U.S. West Coast, with an added emphasis on cetaceans within Olympic Coast and central California National Marine Sanctuaries (Forney, 2007).

Methods for analysis of line transect surveys have evolved (Buckland et al., 2001; Marques and Buckland, 2003), with newer methods accounting for sighting distance at various sea states (effective strip width) by incorporating multiple sighting covariates. Multiple covariate methods were applied to data collected from surveys occurring between 1991 and 2005 conducted by SWFSC to estimate the abundance and population density of cetaceans in the study area (Barlow and Forney, 2007) based on over 550,000 cetacean sightings across 21 species (note: surveys in 1991 and 1993 did not include the Washington/Oregon coast). More recently, generalized additive models to predict cetacean densities for the California Current Ecosystem, based on a suite of environmental predictors, have been developed from data collected from 1986-2006 and standardized for effort (Forney et al., 2012).

Marine Mammal Surveys

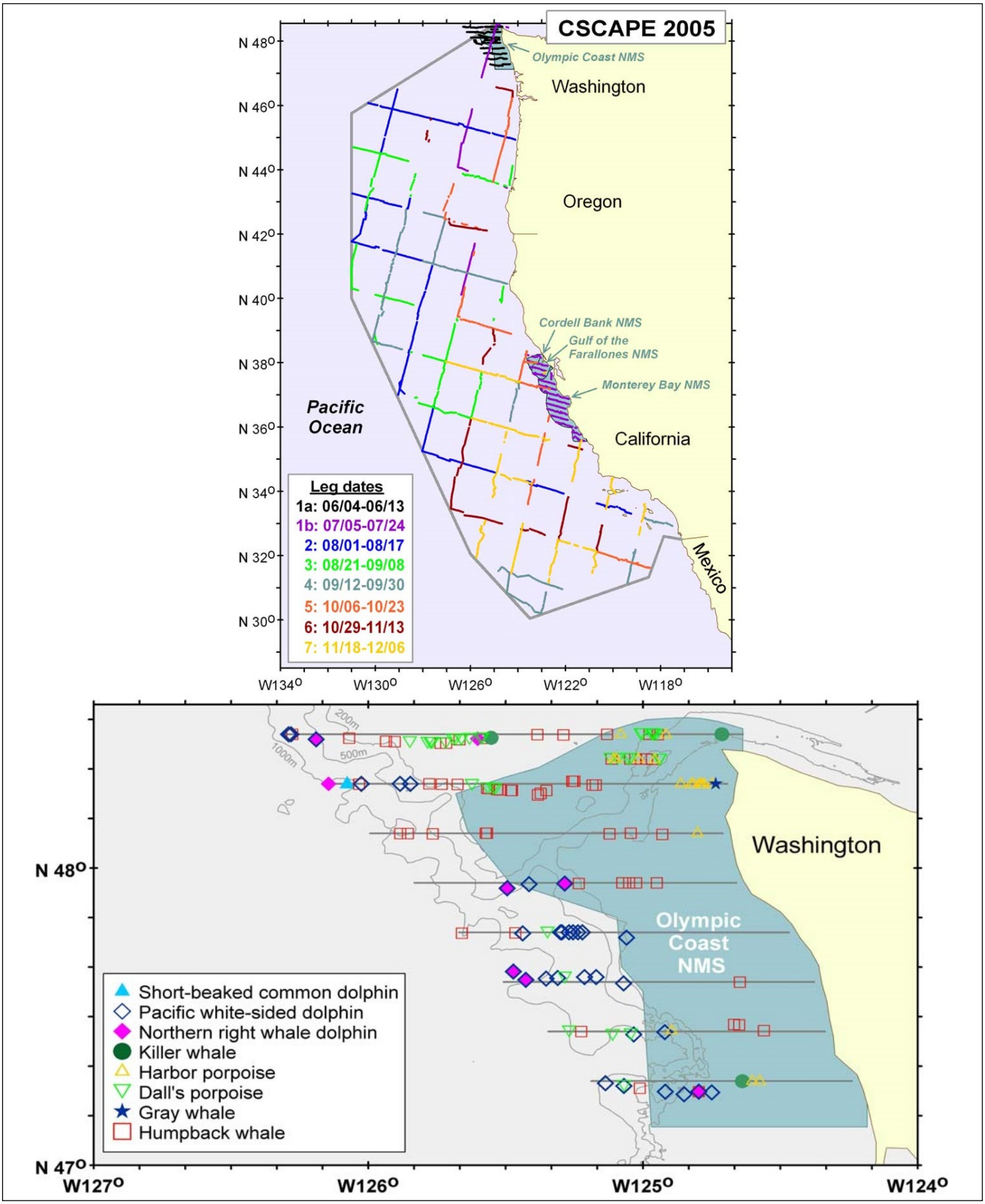


Figure 4. Broad-scale transects from CSCAPE 2005 survey (legs 2-7) on the NOAA Ship David Starr Jordan*, Aug. 1-Dec. 7, 2005 (top). Fine-scale transects from CSCAPE 2005 survey (leg 1a), June 4-13, 2005 in Olympic Coast National Marine Sanctuary on the NOAA Ship* McArthur II *(bottom). Reprinted from Cruise Report DS-05-07 and Cruise Report AR-05-04 / AR-05-06 with permission from author. Chief Scientist: Karin Forney (NOAA NMFS/SWFSC). Source: SWFSC, 2006a, b.*

3.1.2. Ship-based Pacific Ocean Killer Whale and Other Cetaceans Distribution Surveys (PODs)

Killer whales inhabiting the coastal waters of the northeast Pacific are divided into three ecotypes (residents, transients and offshore), with offshore killer whales rarely observed (Dalheim et al., 2008). Southern resident killer whales (*Orcinus orca*; SRKW) inhabit protected inland waterways of Washington, primarily in the summer, with fewer sightings along the outer coast of Washington (Carretta et al., 2014). With actions taken from the early to mid-2000s to petition and eventually list the SRKW population under the Endangered Species Act (ESA), the need to better understand this population's winter distribution was identified (Hanson et al., 2008a).

The Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*) (NMFS, 2008) identified prey availability, pollution and contaminants, and effects from vessels and sound as major threats to SRKW populations. Demographic data on killer whale individuals within populations has been analyzed to examine the relationship between fecundity and prey abundance; in particular, availability of Chinook salmon (*Oncorhynchus tshawytscha*) from Puget Sound, the Columbia River, and especially, the Fraser River throughout the summer (Ward et al., 2009). Inland waters (a Summer Core area in Haro Strait, waters around the San Juan Islands, Puget Sound, and the Strait of Juan de Fuca) are designated as critical habitat for SRKW (NMFS, 2008). Long-term surveys of inland waters are now complemented by offshore surveys targeting SRKW through the Pacific Ocean killer whale and other cetaceans Distribution surveys (PODs) along the Washington coast (Figure 5) using systematic, line-transect visual survey methods from the NOAA ship *McArthur II* (March 13-30, 2006; May 3-15, 2007; March 17-26, 2008; March 23 to April 9, 2009), with the goal of identifying the winter range of SRKW. Additionally, seabird surveys and acoustic monitoring were conducted on these expeditions, along with a suite of biological and oceanographic observations (Hanson et al., 2008a, 2008b, 2009, 2010).

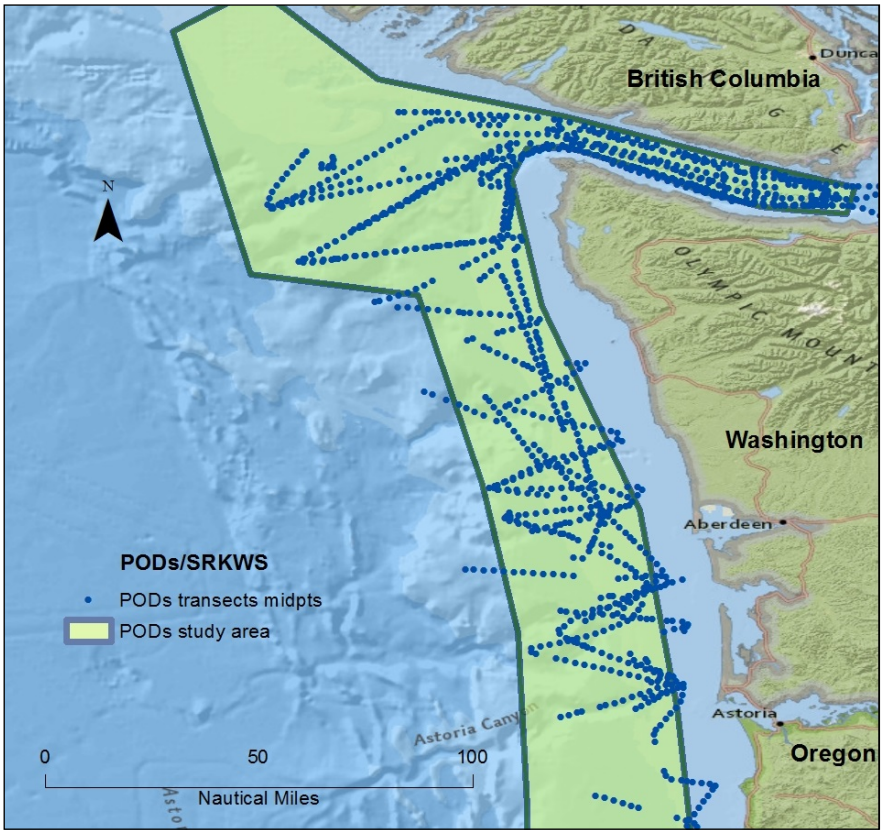


Figure 5. Southern resident killer whale PODs survey area 2006-2009.

Pacific Ocean killer whale and other cetaceans Distribution survey (PODs)

"The overall objective of this cruise was to locate southern resident killer whales (SRKWs) in order to better document their winter range as well as improve our understanding of their behavior and habitat use in these areas. In addition, other biological and oceanographic data were collected to better characterize their environment. Other objectives included photo-identification, behavioral observations, and acoustic study of sounds produced by other cetaceans in this area during the winter." Hanson et al., 2008a.

Marine Mammal Surveys

3.1.3. Large Whale Vessel-Based Surveys

Cascadia Research Collective has long been active in conducting research on marine mammals along the entire West Coast (http://www.cascadiaresearch.org/). An extensive long-term database of over 20,000 records of photographs identifying marine animals has shed light on the shifting numbers and distributions of many species, including humpback (*Megaptera novaeangliae*), blue (*Balenoptera musculus*) and California gray whales (Calambokidis et al., 1999, 2000; Calambokidis and Barlow 2004; Calambokidis et al., 2009, 2014). Additional research by Cascadia Research Collective has included aerial surveys of harbor porpoises in the 1990s (Calambokidis et al., 1997).

Large whale surveys (Figure 6) conducted in support of ESA-listed whales off the coast of Washington and Oregon (2011-2013; Jeffries and Calambokidis, 2014) included both systematic and opportunistic surveys. Opportunistic photo ID surveys were conducted from several vessels (*Corliss, Thomas G. Thompson, New Horizon, Oceanus*) and provide valuable insight into the long-term presence of identifiable animals. Systematic surveys were conducted on the WDFW enforcement vessel *Corliss* and were conducted in 2010 (spring, summer), 2011 (spring, summer, fall), and 2013 (winter, spring) off the coast of Washington (Jeffries and Calambokidis, 2014).

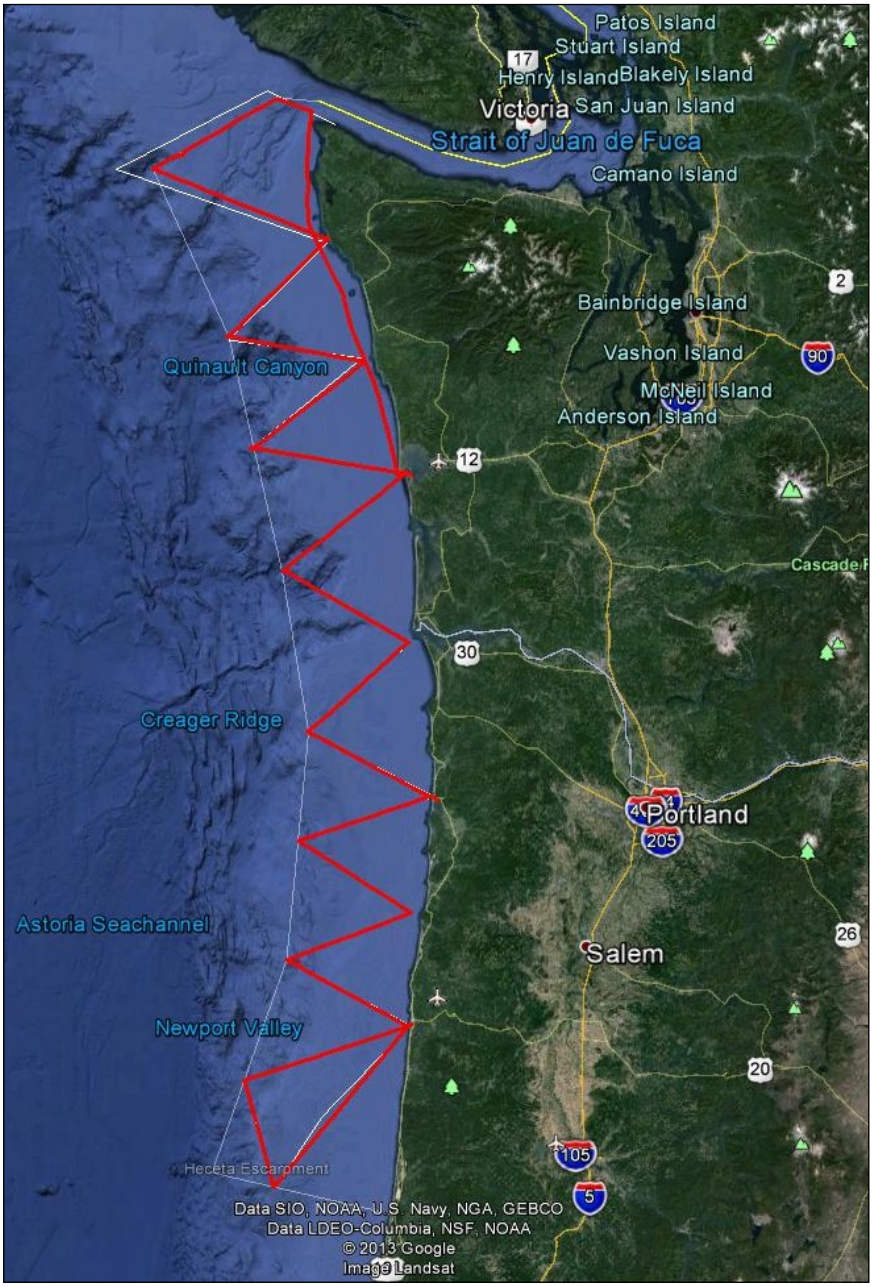


Figure 6. Example of systematic transect lines (summer 2011) surveyed on the WDFW boat Corliss *to support management of ESA listed large whales (Jeffries and Calambokidis, 2014).*

Large Whale Surveys

"The objectives of this research are to conduct surveys to understand cetacean (1) abundance, (2) distribution and habitat use, (3) information on stock structure, and (4) areas of human interaction including ship strikes, entanglements, and other fishery interactions." Jeffries and Calambokidis, 2014.

3.1.4. Olympic Coast National Marine Sanctuary (OCNMS)

Some of the marine mammal surveys included in this report have been conducted in conjunction with NOAA ONMS's Olympic Coast National Marine Sanctuary (OCNMS). For example, CSCAPE 2005 was a coordinated effort between NMFS and OCNMS to collect fine-scale marine mammal data within OCNMS using the same methods as ORCAWALE, the broad-scale systematic transect study conducted by SWFSC. Annual surveys conducted by the OCNMS (Chief Scientist: Ed Bowlby) followed a systematic design that was repeated each summer in 1995, 1996, 1997, 1998, 2000, 2002, 2004, 2005, 2007 and 2008 (Figure 7), to document the presence of marine mammals in the Sanctuary.

In another study (Oleson et al., 2009b), passive acoustic recorders were placed at two sites to record year round marine mammal vocalizations in response to the proposed expansion of the Navy's Quinault Underwater Tracking Range (see Section 3.3.2). Joint visual observations following a route from Grays Harbor out to Grays Canyon and back to shore (not shown on map) visually identified species associated with recorded vocalization of marine mammals (Oleson et al., 2009a). While not systematic in design, these surveys fill in some of the data gaps regarding presence of marine mammals in the vicinity of OCNMS throughout the entire year.

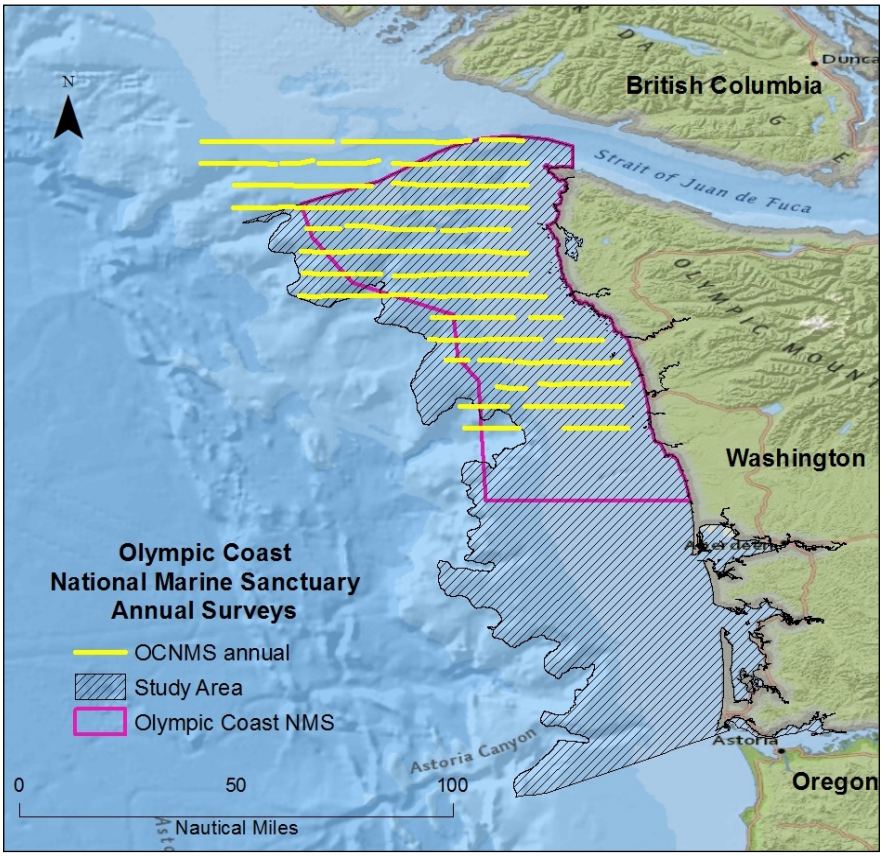


Figure 7. Marine mammal ship-based surveys conducted by Olympic Coast National Marine Sanctuary 1995, 1996, 1997, 1998, 2000, 2002, 2004, 2005, 2007 and 2008.

3.1.5. Pacific Continental Shelf Environmental Assessment (PaCSEA) Aerial Surveys

In 2011 and 2012, the Pacific Continental Shelf Environmental Assessment (PaCSEA) conducted aerial transect surveys of seabirds and marine mammals (methods follow Mason et al., 2007) from Fort Bragg, California to Grays Harbor in Washington state. Data collection was conducted by U.S. Geological Survey (USGS) Western Ecological Research Center in conjunction with BOEM and NOAA (Adams et al., 2014). The survey design included uniform broad-scale parallel east-west transects (spaced 25 km apart). Six focal areas were surveyed more intensively; with shorter transects placed closer together (6 km apart). One focal area was located in our study area off Grays Harbor (Figure 8, left). Broad-scale transects extended out to the 2000m isobath and were placed to follow earlier MMS Marine Mammals surveys by Brueggeman (1992) in 1989-1990 (Figure 8, right).

PaCSEA transects were flown in three seasons (June-July, September-October, January-February). Inter-seasonal trends in abundance and distribution of animals are reported by Adams et al. (2014). All sightings of marine animals, vessels and floating debris were recorded within a fixed-transect width. Hyperspectral radiometric data were collected concurrently to measure sea surface temperature.

Marine Mammal Surveys

Pacific Continental Shelf Environmental Assessment (PaCSEA)

"Our three primary objectives were to (1) conduct aerial at-sea surveys of seabirds and marine mammals in shelf and slope waters off northern California, Oregon, and Washington and summarize species and seasonal at-sea densities, (2) conduct a comparison with existing similar surveys in northern California, Oregon, and Washington, and (3) validate and enhance aerial survey data for numerically abundant indicator species and certain resident breeding and non-resident migratory seabird species. Data generated are intended to inform resource managers concerned with evaluation of proposed renewable energy sites and environmental review of specific project proposals received by BOEM." Adams et al., 2014.

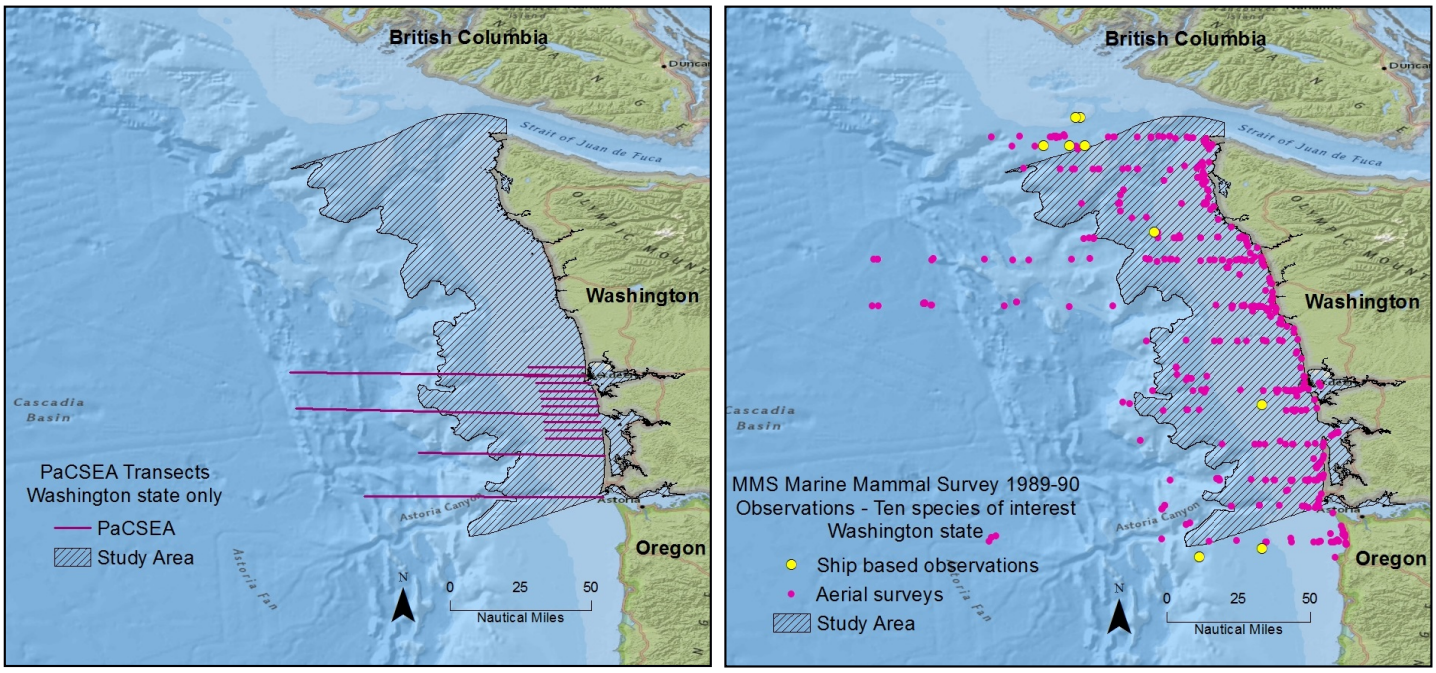


Figure 8. Pacific Continental Shelf Environmental Assessment (PaCSEA) transects in Washington state (left) and observations for select species from the Minerals Management Service (MMS) Marine Mammal Survey (right; Brueggeman, 1992). Brueggeman dataset was extracted from Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP; Halpin et al., 2009) noted as Oregon and Washington Marine Mammal and Seabird Surveys Studies (Green et al., 1993).

3.1.6. Washington - Oregon State Led Cetacean Aerial Surveys

Systematic aerial surveys of cetaceans were conducted along the coasts of Washington and Oregon in 2002 and 2003 by WDFW and Oregon Department of Fish and Wildlife (ODFW; J.L. Laake, pers. comm.; Figure 9). These data were collected along systematic transects, and observations can be standardized by effort for more accurate estimates of density. While the original driver behind these surveys was to document harbor porpoises, many other marine mammals, including pinnipeds, were observed (Figure 10).

Steller sea lions. Photo credit: Vladimir Burkanov (NOAA NMFS/ AFSC/NMML).

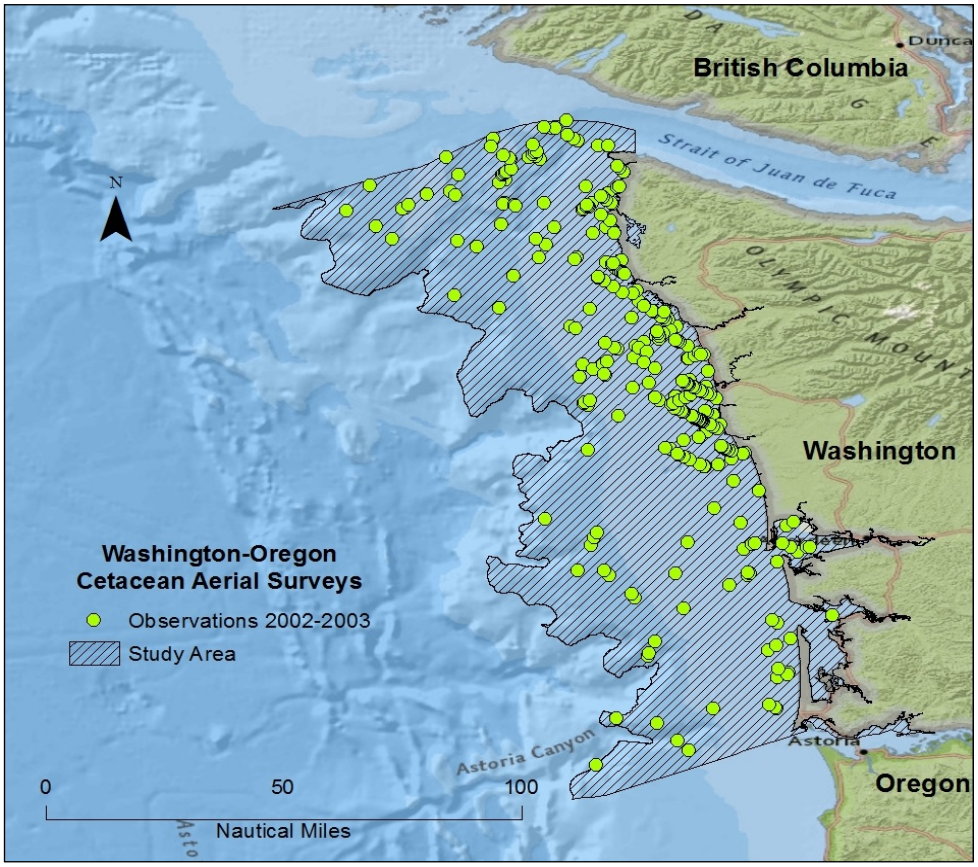


Figure 9. Cetacean, pinniped and sea otter observations from Washington-Oregon Cetacean Aerial Surveys conducted in 2002 and 2003.

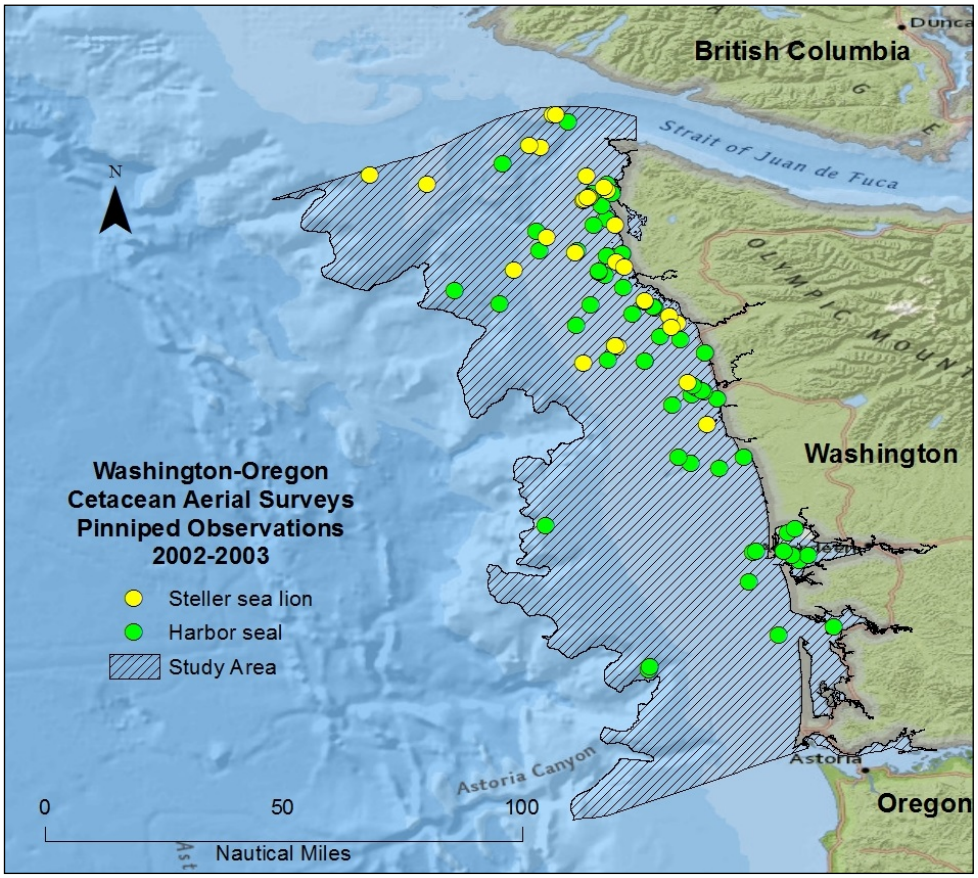


Figure 10. Steller sea lion and Pacific harbor seal observations extracted from Washington-Oregon Cetacean Aerial Surveys conducted in 2002 and 2003.

Marine Mammal Surveys

3.1.7. Leatherback Turtle Aerial Surveys

We found two systematic surveys targeting taxa other than marine mammals that provided large numbers of at-sea marine mammal observations in the study area. One such survey was the aerial survey of the distribution and abundance of western leatherback turtles (*Dermochelys coriacea*) in coastal waters of Oregon and Washington (Benson and Seminoff, 2010, 2011; Figure 11). Records of marine mammals sighted (excluding California sea lion [*Zalophus californianus*]) were shared with NMML. See also, Forney et al. (2014) for estimates of harbor porpoise.

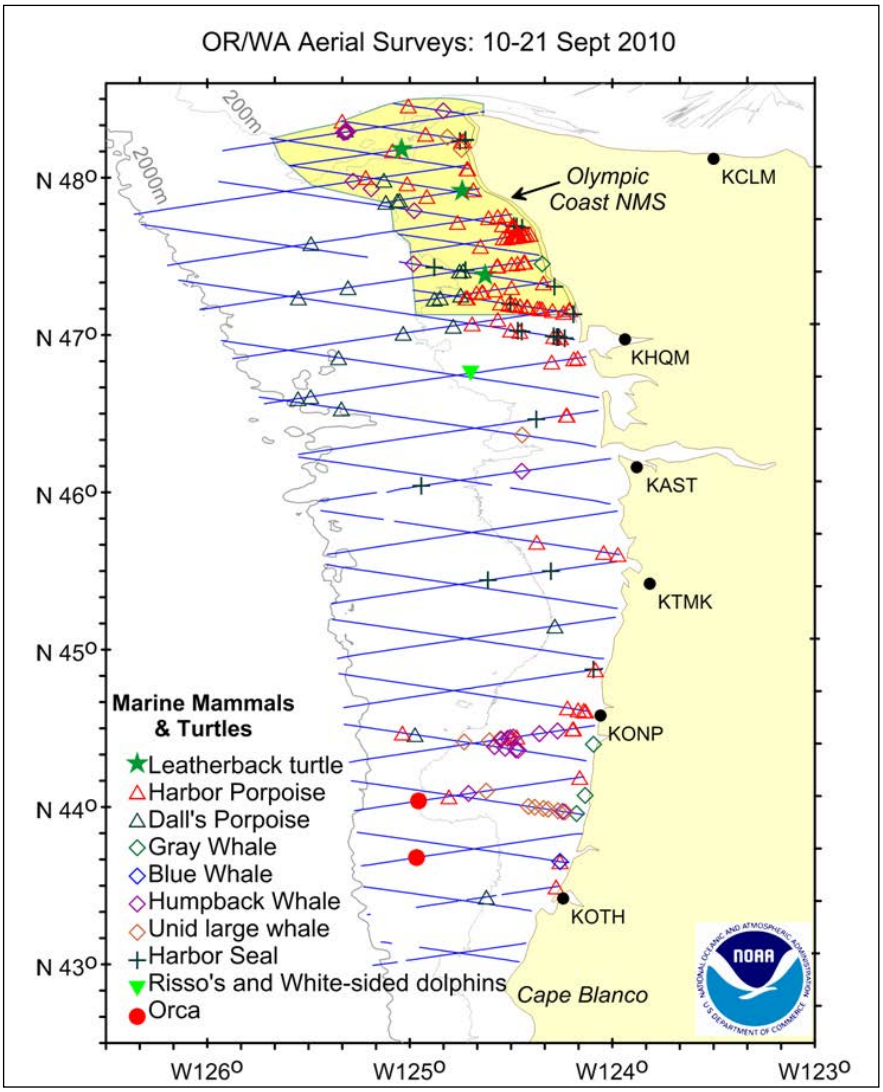


*Figure 11. Leatherback turtle (*Dermochelys coriacea*) survey conducted by SWFSC that also recorded sightings of marine mammals. Map and data source: Scott Benson (NOAA NMFS/SWFSC - Marine Mammal and Turtle Division).*

Leatherback turtle: hatchling (left) and adult (right). Photo credit: NOAA NMFS/SWFSC and NOAA NMFS.

3.1.8. Marbled Murrelet Nearshore Surveys

WDFW and U.S. Department of Agriculture Forest Service conduct at-sea surveys to monitor population trends of the threatened Marbled Murrelet (*Brachyramphus marmoratus*) along the west coast of the U.S. These surveys have occurred annually since 2000 during late spring- early summer (May 15 to July 31) to coincide with nesting (Pearson et al., 2011). The survey encompasses waters from shore out to 8 km from the coast (Figure 12) and is divided into rectangular strata every 20 km along the coast. This dataset also contains records of gray and humpback whales, harbor porpoise, killer whale, Pacific harbor seal (*Phoca vitulina*) and Steller sea lion (*Eumetopias jubatus*) sightings.

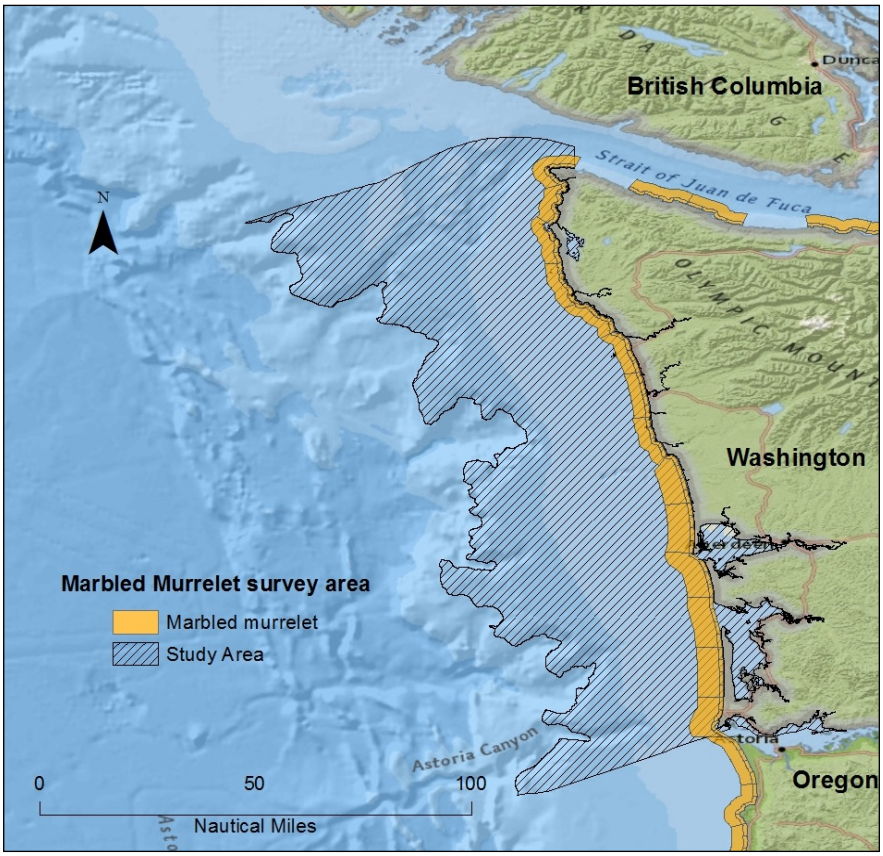


*Figure 12. Extent of Marbled Murrelet (*Brachyramphus marmoratus*) at-sea surveys which also contain information on marine mammals.*

Marbled Murrelets. Photo credit: David Pereksta (BOEM).

Marine Mammal Surveys

3.2. PINNIPEDS

Pinniped surveys documented in this report include seals and sea lions. In contrast to cetacean surveys, pinniped surveys target known haulout locations and rookeries. The surveys also target key times of year, such as the pupping season, which occurs mid-April to July along the outer coast of Washington. While pinnipeds are typically surveyed along the coast, observations of pinnipeds at sea are included in other surveys, such as PaCSEA, which documented five pinniped species (Section 3.1.5), and the Washington-Oregon aerial surveys conducted in 2002-2003 by WDFW, which include sightings of harbor seals and Steller sea lions (Section 3.1.6).

Five species of pinniped species (L-R): Pacific harbor seal (top; Dave Withrow, NOAA NMFS/AFSC/NMML), California sea lions (Tony Orr, NOAA NMFS/AFSC/NMML), Northern fur seals (Rolf Ream, NOAA NMFS/AFSC/NMML), Northern elephant seals (Eric Boerner, NOAA NMFS/AFSC/NMML), Steller sea lions (Vladimir Burkanov, NOAA NMFS/AFSC/NMML).

3.2.1. WDFW Pinniped Haulout Surveys

Washington state maintains the Atlas of Pinniped Haulouts based on systematic aerial surveys conducted by WDFW from 1978 to 1999 (Jeffries et al., 2000, 2003). Within the study area, pinniped haulout sites occur along coastal estuaries and along the coast of the Olympic Peninsula (Figure 13). A recent WDFW aerial survey of pinniped haulout sites conducted by WDFW surveyed only inland waters and did not include the outer coast (Jeffries, 2013).

A recent vessel-based survey of California and Steller sea lion use in 2010 to 2013 documented haulout locations (not shown) in northwest Washington only (Scordino and Akmajain, 2013). Counts of California and Steller sea lion were averaged monthly at eight sites in northwest Washington providing information on seasonal distributions.

Steller sea lions. Photo credit: Steven Jeffries (Washington Department of Fish and Wildlife).

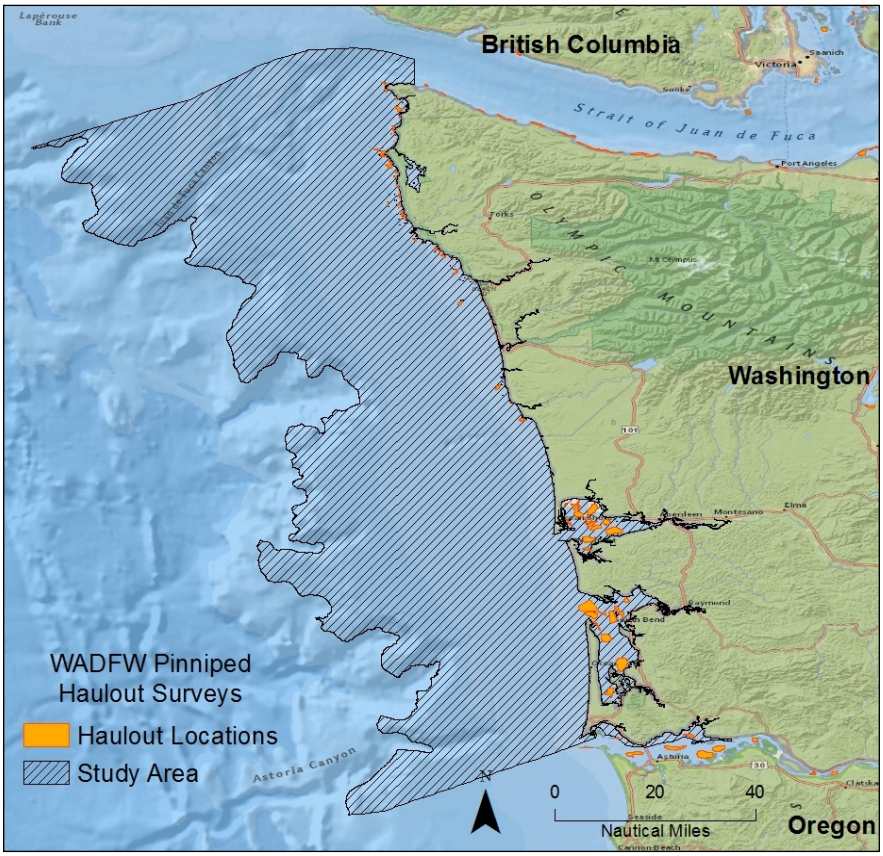


Figure 13. Pinniped haulout sites surveyed along the Washington coast.

Marine Mammal Surveys

3.3. PASSIVE ACOUSTICS

Passive acoustic recorders are used in several ways to detect the presence of marine mammals. Hydrophones can be deployed as towed arrays to associate marine mammal vocalizations with sightings and identify species. Alternatively, moored hydrophone stations are used to document occurrence by detecting calls of animals in the area, quantifying presence over time and providing context for seasonal movements of animals.

3.3.1. Killer Whale Passive Acoustics Surveys

A study conducted in conjunction with the PODs survey described earlier was designed to fill a data gap in the winter distribution of the SRKW. Seven autonomous passive acoustic recorders were deployed from Cape Flattery, WA to Pt. Reyes, CA, with four units deployed off the coast of Washington (Hanson et al., 2013). This study recorded 131 acoustic calls over a five year period (2006-2011) along the entire west coast of the US to document seasonal use by SRKW and their association with availability of Chinook salmon at the Columbia River as a factor driving seasonal distribution patterns. While this dataset was not intended to model the fine-scale spatial distribution of SRKW along the Washington coast (there are limitations, such as placement of sensors, detection range and intermittent vocalizations), this study contributed to a better understanding of how SRKW are distributed seasonally in the study area.

Killer whales. Photo credit: David Ellifrit (NOAA).

3.3.2. Passive Acoustic Monitoring and Small Boat Visual Surveys in Response to Proposed Navy Tracking Range Expansion

A series of surveys, using both passive acoustic monitoring and visual surveys of marine mammal distribution were conducted along the Northwest coast with support from the Navy to address a proposed extension of the Quinault Underwater Tracking Range (QUTR). Two locations, the inshore continental shelf (off Cape Elizabeth) and the offshore shelf slope (Quinault Canyon), were surveyed intermittently for ten years, using high-frequency acoustic recording packages (HARPs). HARPs provide information on the seasonal presence of marine mammals by detecting calls (Oleson et al., 2007, 2009a; Kerosky et al., 2013) and are capable of continual observations that are largely unimpeded by weather, visibility, seasons, or time of day (J. Hildebrand, pers. comm.). Algorithms have been developed to detect calls of baleen whales, odontocetes, and pinnipeds. While these data are not spatial in nature, they complement visual transect surveys by providing a temporal component. The visual survey component was completed by small boat and NOAA research vessels from 2004 to 2009 along a planned survey route (Oleson et al., 2009a; Oleson and Hildebrand, 2012). In June 2008, acoustic and visual surveys encompassed OCNMS. The full data description is summarized in several reports (Oleson et al., 2009a; Sirovic et al., 2011, 2012; Kerosky et al., 2013).

Marine Mammal Demographics off the Outer Washington Coast

"This effort was designed to allow for: 1) characterization of the vocalizations of species present in the area, 2) determination of the year-round seasonal presence of all marine mammal species, and 3) evaluation of the distribution of marine mammals near the Navy range." Oleson and Hildebrand, 2012

3.4. TRACKING/TELEMETRY

Our search effort was focused on at-sea visual surveys, but we found four tracking studies with information on the spatial distribution of marine mammals in or very near the study area. There are likely more studies. All studies were species specific and were generally focused on other areas, with tracked individuals moving into the study area.

Animal borne sensors can track the spatial positions and behaviors of marine mammals at sea. Tracking data provides distributional information at higher temporal and spatial resolutions than ship-based surveys or passive acoustic monitoring. However, since sensors are generally attached to a small number of individuals, tracks from multiple individuals are typically combined to ensure observed patterns are representative of a population and not a selection of individual behaviors. Mammal tracks integrated across a period of time have been used to identify migration routes (Bailey et al., 2010), specific feeding and breeding grounds (Irvine et al., 2014), subsurface behaviors, and relationships with prey distribution, or physical and biological oceanographic conditions. Animal borne sensors are especially useful to map migration corridors because of the ephemeral nature of these observations.

Blue whale. Photo credit: NOAA NMFS/SWFSC.

Irvine et al. (2014) identified home ranges and core areas of use from tagged blue whales in the California Current. Irvine found blue whale home ranges in 2004, 2005 and 2008, and a core area of use in 2008 offshore of Washington. Dr. Brad Hanson and colleagues tagged killer whales off Washington to determine winter distribution and found they traveled and foraged along the Oregon and Washington coasts (NWFSC, 2013). To the north of the study area, Drs. Marla Holt, Brad Hanson, and Candice Emmons of the NOAA NMFS Northwest Fisheries Science Center (NWFSC), along with collaborators from Cascadia Research Collective, University of Washington, and University of California, Davis, are using digital acoustic recording tags to examine sound exposure, sound use and behavior of SRKW (NWFSC, 2014). Lastly, a long-term study by the University of California, Santa Cruz and Tagging of Pacific Pelagics (TOPP) program (Block et al., 2003) has shown movement of elephant seals through the area and identified several spatial hotspots in the study area (Robinson et al., 2012).

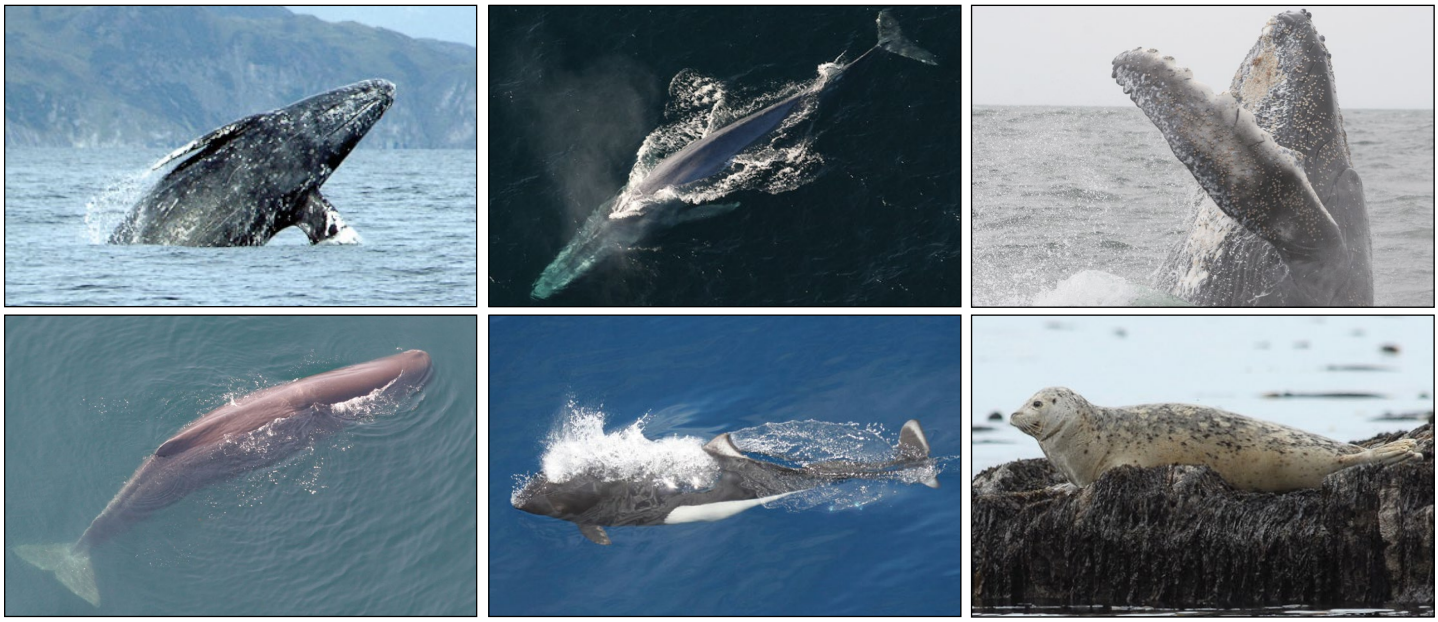
Predictive Modelling and Synthesis

Chapter 4: Predictive Modelling and Synthesis Products

Early stages of marine mammal studies in the Northwest consisted largely of sightings data focused on identifying broad-scale patterns of diversity, distribution and abundance (Brueggeman, 1992). These earliest studies documented the location of sightings and, for more abundant species, mapped summaries of occurrence and relative abundance into coarse resolution geographic bins (15 X 15 minute). In addition, long-term photo identification surveys were conducted to assess population dynamics and migrations, and in some cases, mark-recapture analyses were applied to these data (Calambokidis and Barlow, 2004). Many of these sources of data were used by NMFS for the process of determining the status of U.S. Pacific marine mammal stocks for protection and recovery (Carretta et al., 2014). As systematic line transect methods evolved, improved density estimates resulted when conditions at sea that affect sighting distance (effective strip width) were incorporated. More recently, various predictive modeling approaches have incorporated marine mammal data collected in the California Current Ecosystem.

Studies employing a predictive modeling approach attempt to use environmental covariates to estimate animal densities and discern patterns at a finer resolution than the original survey data (Forney et al., 2012; Redfern et al., 2013; Caldow et al., 2015). These predictive models use biophysical covariates, such as remotely sensed sea surface temperature and mixed-layer depth, to interpolate occurrence and relative abundance from sightings. Model results provide species distribution data at much finer spatial scales than previous studies (approximately 5 km versus 30 km). Given the discontinuous nature of at-sea surveys, predictive modeling serves as a useful tool to fill in spatial and/or temporal gaps and provide objective estimations of uncertainty. An alternative approach for predicting the spatial distribution of marine mammals involves combining diverse data sets to extend the spatial and temporal footprints and increase the resolution of discernible patterns.

NOAA's National Ocean Service (NOS) National Centers for Coastal Ocean Science (NCCOS) is pursuing a project, planned to be completed in 2015, which will combine many at-sea data sets and use the combined data to develop fine spatial scale predictive models of key marine mammal distributions in the study area. NCCOS's plan is to develop models for the California gray whale, fin whale (*Balaenoptera physalus*), blue whale, humpback whale, sperm whale (*Physeter macrocephalus*), killer whale, Dall's porpoise (*Phocoenoides dalli*), harbor porpoise, Steller sea lion and Pacific harbor seal.



From top left: gray whale (Merrill Gosho, NOAA NMFS/AFSC/NMML), blue whale (NOAA), humpback whale (Annie Douglas), sperm whale (Tim Cole, NOAA NMFS), Dall's porpoise (NOAA NMFS/SWFSC/PRD), Pacific harbor seal (Dave Withrow, NOAA NMFS/AFSC/NMML).

Predictive Modelling and Synthesis

We found four synthesis products beyond this report that provide inventories of marine mammal data in the study area and/or interpretations of such data. There is extensive overlap in data cited in the other synthesis products and this report, but each presents information in different ways and focuses on different data sets reflecting unique objectives. This report provides up-to-date information on marine mammal surveys conducted between 2004 and 2014 in the study area, and its focus was on data that could be used to support MSP. The other four synthesis products are:

1) The Navy's Marine Resources Assessment for the Pacific Northwest Operating Area (U.S. Department of the Navy, 2006) is a comprehensive review of sighting, stranding, and bycatch data collected before 2005.

2) Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) is a compilation of user-submitted geospatial data with many records of marine mammals in the study area (Halpinet al., 2009; Figure 14).

3) NMFS (Redfern et al., 2013) developed a comprehensive review of data collected by NMFS and others for inclusion in the California Current Integrated Ecosystem Assessment: Phase II Report with a focus on assessment surveys and monitoring to detect changes in the California Current IEA (Levin et al., 2013) .

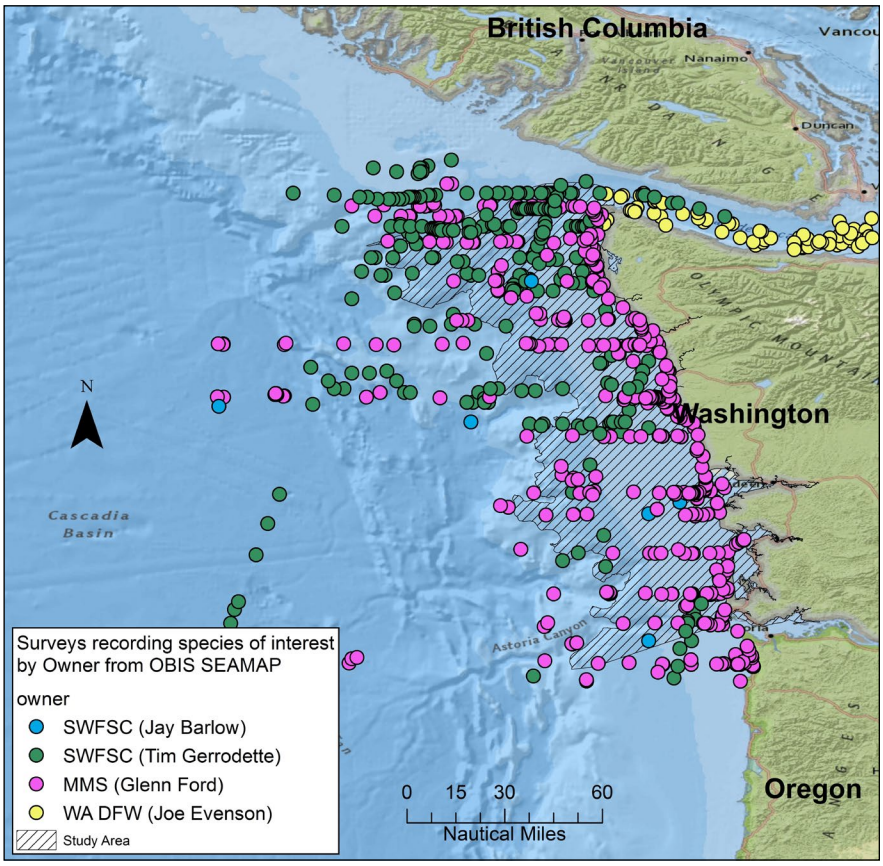


Figure 14. Records of select species queried from OBIS-SEAMAP by data owner for some surveys described in this report (Halpin et al., 2009).

4) CetMap (CetMAP, 2014) presents and distributes existing cetacean density and distribution maps, including habitat-based density models and observations from at-sea surveys and important areas (e.g., reproductive areas, feeding areas, migratory corridors) identified by experts.

Evaluation

Chapter 5: Evaluation of Surveys

5.1. SPATIAL

When the past ten years of at-sea effort across the entire survey area is mapped (Figure 15), there is a notable concentration of effort in the northern half of the state focused within OCNMS. The effort is concentrated given the overall spatial extent of surveys, the relatively short distance between transects, and the number of years in which annual surveys were conducted by the Sanctuary. The CSCAPE survey conducted in 2005, PODS surveys of SRKWs conducted from 2006-2009, and the systematic large whale surveys from 2010-2013 all provide information on species distributions within the Sanctuary. South of the Sanctuary, PaCSEA and PODs provide spatial data on the distribution of 15 cetacean species, including SRKW and five pinniped species. The Washington – Oregon state led aerial surveys provide a layer of observations of harbor porpoise and pinnipeds spread over a two year period along the entire Washington coast.

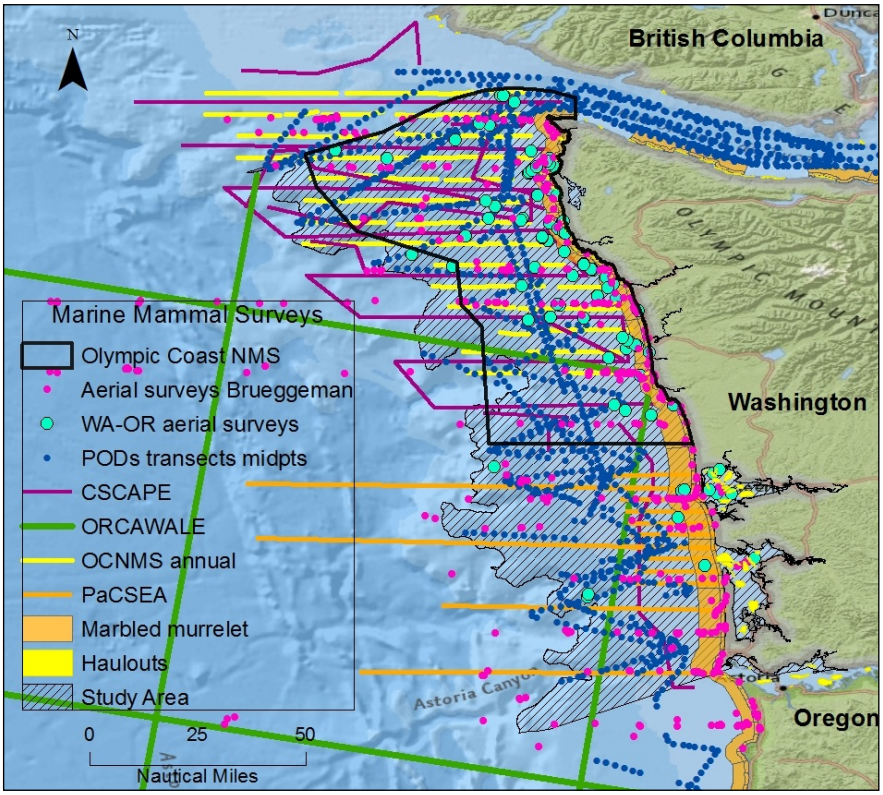


Figure 15. Distribution of marine mammal surveys in the study area.

The area close to shore has been intensively surveyed through the Marbled Murrelet survey in the spring and summer from 2000-2013. While this survey targets this ESA-listed bird, it also includes nearshore observations of California gray and humpback whales, harbor porpoise, killer whale, Pacific harbor seal, and Steller sea lion and provides more dense coverage than other surveys in the study area, both spatially and over a long time period.

Most surveys do not extend beyond the continental shelf and are generally within 60 km of shore. The furthest westward extent is covered by the ORCAWALE surveys which have continued on a regular basis, and the Brueggeman surveys from 1989-1990. Both of these survey programs used transects spaced 100 km apart. The PaCSEA surveys extend well offshore to the 2,000 m isobath in the southern half of the study area, have transects spaced 25 km apart, and cover nearshore, shelf, slope and offshore waters.

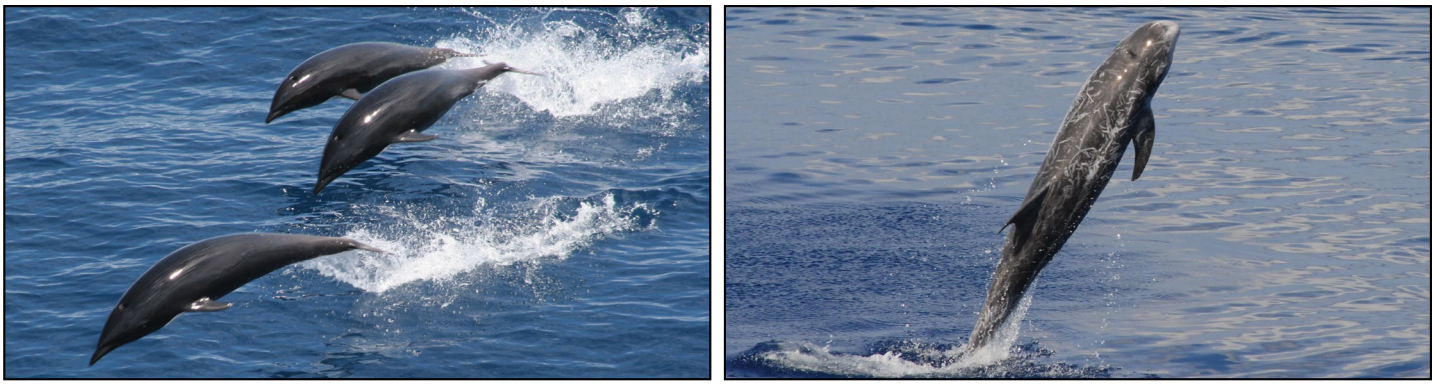
The amount of survey effort in an area and the distance between transects are important because they determine the resolution at which spatial and temporal patterns of species distribution can be discerned. Across the entire study area, large scale surveys, such as ORCAWALE, provide sufficient information to assess patterns of occupancy and abundance at coarse spatial (10-100 km) and long temporal scales (years to decades). While ORCAWALE covers much of the eastern North Pacific, the ability to capture fine-scale distributional patterns is sacrificed. Within OCNMS and in nearshore areas, the increased number of surveys and shorter distance between transects allows for more finely resolved spatial patterns to be mapped when survey data are merged or combined in a predictive modeling framework. Ultimately, there is a trade-off between covering large spatial extents and making observations at a finer scale.

5.2. TEMPORAL

In our study area, temporal data gaps are a larger issue than spatial data gaps. The lack of temporal information regarding the year round distribution and abundance of animals has long been recognized (Carretta et al., 2014). Implementing studies that can address species distributions across seasons is complicated in terms of timing and intensity of effort and limited by logistics, manpower, and availability of funds.

In the late 1980s, the Brueggeman aerial surveys documented many of the common species of cetaceans along the entire Washington coast following systematic transects over an entire year (Brueggeman, 1992), but that was one of the last systematic surveys to do so for many years. PaCSEA surveys recently conducted surveys throughout the year in 2011 and 2012, but their observations were limited to areas in the southern half of our study area, outside of OCNMS. Surveys of marine mammals in the CCLME have been conducted by SWFSC in the summer and fall since the mid-1990s.

As management plans for listed species were being developed, the lack of year round data was recognized as a limiting factor in assessing the status of marine mammal populations. For instance, surveys of SRKW had been conducted during the summer when they were known to reside in inland waters but the location and extent of their winter range was not well understood. As a result, PODs surveys were conducted offshore in 2006-2009 to address this information gap. Other systematic surveys which documented large whales (humpback, gray and minke whale [*Balaenoptera acutorostrata*]) as well as Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), Risso's dolphin (*Grampus griseus*), Northern right whale dolphin (*Lissodelphis borealis*), Dall's porpoise and harbor porpoise in 2010-2013 covered all seasons over a three year period, although not all areas were sampled in each season.



Northern right whale dolphin (left) and Risso's dolphin (right). Photo credit: Jim Cotton (NOAA NMFS/SWFSC; left) and NOAA NMFS/SWFSC (right).

Table 2 summarizes temporal nature of the surveys reviewed here (more detail is provided in the Appendix), first by totaling the number of systematic surveys within the study area by season. Next, the number of surveys in each season is multiplied by the number of years in which each survey was conducted, partitioned into nearshore and shelf/slope regions to come up with number of 'survey events.' The large number of survey events in the nearshore area, March-May and June-August, is dominated by the Marbled Murrelet survey conducted over a thirteen year period. The large number of survey events in shelf/slope waters is driven largely by the OCNMS annual surveys and five years of ORCAWALE surveys conducted in summer months. The least amount of data collection effort has occurred during September-February in nearshore waters.

Table 2. Temporal distribution of survey data/gaps. The number of systematic surveys by season described in this report and the number of 'survey events' (number of surveys X number of years conducted) listed by season and partitioned by water body.

	Mar-May	June-Aug	Sep-Nov	Dec-Feb
Number of systematic surveys by season	5	8	6	3
Nearshore: number of survey events	14	14	1	1
Shelf/slope: number of survey events	7	23	15	6

Evaluation

5.3. SYSTEMATIC VERSUS OPPORTUNISTIC AND STATIONARY STUDIES

Surveys can be broadly categorized into three types: systematic surveys, which attempt to collect information uniformly across an area of interest; opportunistic surveys, which collect data irregularly and at opportune times; and stationary surveys, which focus data acquisition at one or few sites. Each type has its advantages and limitations. Many synthesis reports focus attention on systematic surveys, to make use of unbiased effort. However, both opportunistic and stationary studies can be useful for addressing targeted objectives, such as understanding seasonal distributions and trends in population demographics. The extensive record of marine mammal presence in the photo ID database held by Cascadia Research Collective has been useful in understanding the abundance, seasonal distribution, demographics and status of various species, such as blue, humpback, and gray whales (Gosho et al., 2010; Laake et al., 2012; Carretta et al., 2014). Other non-systematic surveys capture seasonality, to some degree, by tracking the movement of individual animals or using passive acoustics to detect animals over long time frames. These data are limited spatially and will require novel approaches to apply this information within a predictive modeling framework. Despite these limitations, this information contributes to the understanding of temporal changes in species distributions. Therefore, future work should address how opportunistic and stationary data can be combined with systematic survey data and test methods for using these data as confirmatory data for predictive models of seasonal distributions.

Humpback whale (top) and blue whale (bottom). Photo credit: John Calambokidis (Cascadia Research Collective; top) and NOAA NMFS/SWFSC (bottom).

Chapter 6: Summary

There is an extensive research community and a long-standing body of work documenting marine mammals along the coast of Washington state. Over the broad areas of the West Coast of the U.S., a primary source for information on most cetaceans is the California Current / ORCAWALE surveys conducted by SWFSC (J. Barlow, pers. comm.). Off the coast of Washington, the OCNMS surveys provide many years of data within the Sanctuary and adjacent areas. Data on harbor porpoises and at-sea pinnipeds, surveyed by air, is held by Cascadia Research and NMML (J. Barlow, pers. comm.). Both WDFW and ODFW collaborate with these partners as well as collecting select data on pinnipeds and cetaceans in state waters, both nearshore and inland.

There are a variety of factors that complicate the design and implementation of marine mammal surveys ranging from the movement of animals in space and time to availability of resources and research dollars. Likewise, there is a diversity of study objectives and field methods that result in disparate datasets, often overlapping in terms of the species observed (e.g., Forney et al., 2014). As data from various sources are combined, a thorough understanding of data collection methods and limitations help define data quality of products for the marine spatial planning process.

Chapter 7: Future Directions

Existing marine mammal surveys provide robust observational data sets for much of the study area. However, additional data are needed to reveal fine-scale spatial patterns and to better describe marine mammal distribution in offshore waters and during the winter. Each individual survey is a snapshot of the targeted marine mammal community and is constrained by the spatial extent, methods and timing of observations. Assessments that combine data from multiple surveys or interpolate between discrete observations can effectively assess distributions across the entire study area. Recent studies (e.g., Forney et al., 2012; Redfern et al., 2013) that provide robust assessments of marine mammal assemblages and distribution patterns will be useful for marine planning, because they provide information at spatial and temporal scales that are better than individual surveys alone. Future research should consider integrating diverse datasets (e.g., at-sea censuses, shore-based censuses, tracking, expert knowledge) to identify key marine areas for management and conservation purposes, yielding complementary perspectives on habitat use and suitability.

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Appendix

Summary of surveys reviewed in this report.

Table A. Table of reviewed surveys in this report

SURVEY/DATASET NAME	Data Collector(s)	Years	Geographic Coverage	Marine Mammal Species	Survey Type
3.1 CETACEANS					
California Current Ecosystem Surveys for Whales, Dolphins and Porpoises (CalCurCEAS, 2014) (ORCAWALE, 1996; 2001; 2008) (CSCAPE, 2005)	NOAA SWFSC	1996 2001 2005 2008 2014	Entire west coast out to 300 nmi	Whales, dolphins, porpoises	Ship-based
Pacific Ocean killer whale and other cetaceans Distribution survey (PODs)	NOAA NWFSC	2006-2009	WA, OR coast	Southern Resident killer whale and other cetaceans	Ship-based systematic line-transect (McArthur II)
Large Whale Surveys in support of ESA Listed Species	WDFW, Cascadia Research Collective	2010-2013	WA, OR nearshore	Humpback, gray, minke whales; Pacific white-sided dolphin, Risso's dolphin, Northern right whale dolphin, Dall's porpoise, harbor porpoise.	Small boat, line transects, photographic ID
OCNMS Annual Surveys	NOAA OCNMS	1995-1998 2000 2002 2004 2005 2007 2008	OCNMS	Marine mammals	Ship-based
Joint acoustic and visual monitoring for cetaceans along the outer Washington coast	Cascadia Research Collective	2004-2008 Navy's N45 research program	WA, OR nearshore	Humpback, gray, minke, killer, beaked, sperm whales; Pacific white-sided dolphin, Risso's dolphin, Northern right whale dolphin, Dall's porpoise, harbor porpoise, pinnipeds	Small boat along select route photographic ID
Pacific Continental Shelf Environmental Assessment (PaCSEA) Aerial Seabird and Marine Mammal Surveys off Northern California, Oregon, and Washington, 2011-2012	USGS	2011 2012	N. California (39°N), OR, WA (47°N) from shore to 2000 m isobath	16 cetacean species 5 pinniped species	Aerial surveys
Oregon and Washington Marine Mammal and Seabird Surveys Studies (MMS Marine Mammal Survey)	ECI	April 1989 to October 1990	Pacific Ocean waters of OR and WA from coast to 60 nmi offshore	Cetaceans, pinnipeds	12 aerial surveys, 1 ship-based survey
Washington - Oregon State Led Cetacean Aerial Surveys	WDFW, ODFW, Cascadia Research	2002 2003	WA, OR	Harbor porpoise, Pacific harbor seal, Steller sea lion	Aerial surveys
Aerial survey of distribution and abundance of western Pacific leatherback turtles	NOAA SWFSC	2010 2011	WA, OR	Marine mammals excluding California sea lion	Aerial surveys
Marbled Murrelet	WDFW, USDA Forest Service	2000-2013	WA	Gray, humpback, killer whales; harbor porpoise, Pacific harbor seal, Steller sea lion	Small boat at-sea

Appendix

Design Type	Seasonal Coverage	Mar-May	June-Aug	Sep-Nov	Dec-Feb	Contact	Collaborators	Section	Notes
Systematic line transects	summer fall		x	x		Jay Barlow	Elizabeth Becker, Karin Forney, Lisa Ballance, US Navy, BOEM	3.1.1	CSCAPE (June 2005), Forney (2007)
Systematic	Spring to early summer	x				Brad Hanson	Jen Zamon	3.1.2	
Systematic	Depends on year	x	x	x	x	Steven Jeffries, John Calambokidis	WDFW, NOAA	3.1.3	Systematic surveys conducted on WDFW patrol vessel Corliss. Includes satellite tagging.
Systematic transects	June July		x			Ed Bowlby, Liam Antrim, Nancy Wright	John Calambokidis	3.1.4	
Opportunistic visual observation along repeated route	Year round	x	x	x	x	Erin Oleson	John Calambokidis, Erin Falcone, Greg Schorr, John Hildebrand	3.1.4	Visual and acoustic monitoring
Standardized low-elevation, Broad and fine scale transects	summer fall winter		x	x	x	Josh Adams	BOEM, NOAA	3.1.5	2011 - Jan, June, Oct 2012 - Feb, July, Sept
Systematic transects	Most months of the year	x	x	x	x	Glenn Ford	Brueggeman (1992)	3.1.5	
Systematic transects	Late summer		x	x		Jeff Laake, John Calambokidis	NOAA AFSC/NMML	3.1.6	
Systematic transects, Broad and fine-scale adaptive	fall			x		Scott Benson	NOAA OCNMS	3.1.7	Records of marine mammals sent to NMML
Stratified	spring summer	x	x			Scott Pearson	WDFW	3.1.8	Nearshore

Appendix

Table A Continuted... Table of reviewed surveys in this report

SURVEY/DATASET NAME	Data Collector(s)	Years	Geographic Coverage	Marine Mammal Species	Survey Type
3.2 PINNIPEDS					
WDFW Pinniped Haulout Surveys	WDFW	1978-1999 [2010-2013]	WA waters	Harbor seals, Steller sea lions, California sea lions, Northern elephant seals	Aerial, ground, boat haulout sites
3.3 PASSIVE ACOUSTICS					
Killer Whale Passive Acoustics Surveys (Conducted in conjunction with PODs)	NOAA NWFSC	2006-2011	Cape Flattery, WA to Pt. Reyes, CA	Southern Resident killer whale	Moored passive acoustic recorders at seven locations (four along WA coast)
Passive acoustics and visual monitoring for cetaceans (Navy Training Range)	Scripps, Cascadia Research Collective	Intermittent over 10 yrs	Navy NW Training Range (two monitoring sites -inshore shelf, offshore shelf slope)	Calls of baleen whales, toothed whales, and pinnipeds	Small boat visual observations with passive High-frequency Acoustic Recording Packages (HARPs)
3.4 TRACKING/TELEMETRY					
Large Whale Tagging	OSU Marine Mammal Institute	1993-2008	Entire west coast out to 300 nmi	Blue whales	Satellite monitored radio tags
Killer Whale Acoustic Recording	NOAA NWFSC	2010-2014	Northern U.S. and southern Canada, West Coast	Killer whale	Digital acoustic recording tags
Killer Whale Satellite Tagging	NOAA NWFSC, Cascadia Research Collective	2010-2014	U.S. and Canada, West Coast	Killer whale	Satellite linked tags
Elephant Seals	UC Santa Cruz, Tagging of Pacific Pelagics	2004-2010	Eastern North Pacific	Elephant seal	Satellite linked tags

Appendix

Design Type	Seasonal Coverage	Mar-May	June-Aug	Sep-Nov	Dec-Feb	Contact	Collaborators	Section	Notes
Point	Mid-April to July	x	x			Steve Jeffries, Scott Pearson, [Jonathan Scordino]	NMFS AFSC/NMML, WDFW	3.2.1	
Moored			x		x	Brad Hanson	Eric Ward, Mike Ford	3.3.1	
Stationary HARPs (two), Visual boat surveys (OCNMS)			x		x	Erin Oleson	John Hildebrand	3.3.2	June 2008 surveys included OCNMS
Animal borne sensor	summer/ early fall		x	x		Ladd Irvine	Bruce Mate, Martha Winsor, Daniel Palacios, Steven Bograd, Daniel Costa, Helen Bailey	3.4	171 blue whales off California
Animal borne sensor							Cascadia Research Collective, University of WA, UC Davis	3.4	
Animal borne sensor	All year	x	x	x	x	Brad Hanson	Center for Whale Research, University of Alaska Fairbanks, Canada Fisheries and Oceans	3.4	15 killer whales in Washington state
Animal borne sensor	All year	x	x	x	x	Brad Hanson	Sonoma State, Centro de Investigación en Alimentación y Desarrollo, UC San Diego, Nagoya University	3.4	15 killer whales in Washington state

U.S. Department of Commerce
Penny Pritzker, *Secretary*

National Oceanic and Atmospheric Administration
Kathryn Sullivan, *Under Secretary for Oceans and Atmosphere*

National Ocean Service
Russell Callender, *Acting Assistant Administrator for National Ocean Service*




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