CHAPTER 4: BIOGEOGRAPHY OF MARINE MAMMALS

4.1 INTRODUCTION

A preliminary characterization of marine mammals was included in the Phase I Biogeographic Assessment off North/Central California, completed in 2003 (NOAA NCCOS, 2003). The overall goal of this assessment was to identify, collect and analyze the best available data and information to identify the spatial and temporal patterns of marine mammals in the study area, and provide a report and related products for use in understanding and managing the marine protected areas of NOAA's National Marine Sanctuaries Program off central California. In Phase II, new analyses and revisions were done to complete the mammal chapter (e.g., updating correction methods and maps for at-sea densities, updating the pinniped colony maps, developing summary mammal maps and summary tables on spatial patterns and population estimates). This chapter includes products and results from the Phase II update.

Background

The objectives of the assessment were to: 1) identify spatial and temporal patterns for marine mammals that occur in ocean waters off north/central California, between Point Arena (38.91ºN) and Point Sal (34.90ºN); and 2) identify important areas and time periods associated with higher concentrations of these species in the study area (within or adjacent to the three national marine sanctuaries). The study area (see Figure 1.0) for this assessment encompasses three national marine sanctuaries off north/central California – Cordell Bank, Gulf of the Farallones and Monterey Bay, and was conducted to support NOAA's National Marine Sanctuary Program. In this analysis, 'important' time periods or areas refer to those having relatively higher concentrations or important functions (e.g., breeding, feeding, migration pathway) for a species. It is important for managers and users of coastal ocean resources to understand the spatial and temporal patterns of marine mammals and how they use the study area, so that mammals and their habitats can be protected. All marine mammals in the study area are protected under the Marine Mammal Protection Act. However, human-related sources of mortality of marine mammals in the study area still occurs, and include: incidental catch by fisheries; entanglement in fishing gear; entanglement in, and ingestion of marine debris; ship strikes; pollution-related events (e.g., oil spills); impacts from human-generated sonar and competition for food with fisheries.

The study area off north/central California is located within the California Current System (CCS). The California Current System extends up to 1,000 km offshore from British Columbia south to Baja California, Mexico. This system includes a southward, meandering surface current (the California Current), a poleward California Undercurrent, and surface countercurrents (the Davidson Current), which, along with areas of strong coastal upwelling, upwelling jets (that run perpendicular to the coast), steep topography, and shallow- and deep-water habitats, makes this area one of the most productive ocean systems in the world (Glantz and Thompson, 1981). Because of this productive environment, the study area contains a rich fauna of marine mammals, as evidenced in marine mammal (and seabird) abundance and richness.

In addition to the numerous marine mammal species that live here year-round and use the region's coasts and islands for breeding and hauling out, the community of seasonal marine mammal residents and migrants is even more robust. The coastal ocean off north/central California is the foraging destination for many marine mammal and bird spe-

cies seeking productive feeding areas and acceptable habitat in which to spend their nonbreeding periods, providing evidence of the region's trophic richness. Over 30 species of marine mammals occur in the study area, including approximately 25 cetaceans (whales, dolphins, and porpoises), six pinnipeds (seals and sea lions), and one fissiped species (the sea otter); in this assessment we provide information for 24 species.

Many mammal species included in this analysis have a wide distribution and range, well beyond the study area. Point Conception, just south of the study area, is a significant biogeographic boundary for some marine mammals, and the approximate southern range point for several species in this analysis (northern right whale dolphin, Dall's porpoise, harbor porpoise, Hubb's beaked whale, and Stejneger's beaked whale; NOAA NCCOS 2005). See the Channel Island Biogeographic Assessment for additional information on this range analysis (NOAA NCCOS, 2005, http://ccma.nos.noaa.gov/products/biogeography/cinms/)

4.2 DATA AND ANALYSES

Overview of Data Analysis and Map Development Process

Several methods have been used in the collection and compilation of the at-sea survey data sets used in this analysis. Because of this, careful consideration and correction was required to merge the data sets in a meaningful and scientifically acceptable way. The major steps of the compilation, analysis and mapping of the data are as follows: 1) species and study area selection; 2) data set identification and collection; 3) data correction so that different data sets are compatible; 4) data conversion of data sets into comparable units; 5) organization and merging of data, as appropriate (e.g., by species, into 10'x10' cells or, as sightings and effort point data); 6) map development; and 7) map review by experts and revisions. For species present in sufficient numbers, seasonal at-sea density maps were developed, and for infrequently sighted species, sighting and effort maps were developed. Maps were also developed for pinniped haulouts and rookeries using similar methods. The maps in Phase I were reviewed at an expert workshop in October 2002; there it was determined that additional data, corrections and analyses were required to improve the mammal maps. Since the release of the Phase I Assessment in April 2003, additional data, corrections, analyses and updates have been made for the Phase II products.

Species Selected for Analysis

Selection criteria for marine mammal species included in this assessment were: 1) species that occurred with some regularity in the study area; and 2) adequate survey data for the species were available in a usable format. Table 4.1 is a list of marine mammal species that were addressed in this analysis. The table provides information on the types of data and maps that were used for the at-sea maps.

Literature Used in this Assessment

The at-sea distribution and abundance of marine mammals within the study area has been described in many publications, some of which include the following: Bonnell *et al.,* (1983); Dohl *et al.,* (1983); Calambokidis *et al.,* (1988, 1990a, 1990b, 1996); and Allen (1994). Numerous marine mammal stock assessment studies have been conducted by NOAA's Southwest Fisheries Science Center, La Jolla, CA (NMFS/SWFSC, ship and aerial surveys): information from these surveys are contained in related NMFS publications – Carretta *et al.,* (2004, 2006); Barlow (1988, 1995); Barlow and Forney (1994); Barlow and Gerrodette (1996); and Forney and Barlow (1998). A few ecosystem studies of marine mammals in this region have also been conducted by Schoenherr (1991); Black (1994); Kieckhefer (1992); Croll *et al.,* (1998); Forney and Barlow (1998); Forney *et al.,* (2000); Benson *et al.,* (2002); and Keiper *et al.,* (2005). Most of these studies investigated relatively short time periods (less than ten years); exceptions include Keiper *et al.,* (2005), Carretta *et al.,* (2004), and Allen (1994). Whereas this assessment encompasses two decades of data, a unique opportunity in the study of marine mammals. Two marine biogeographic assessments were conducted for NOAA's National Marine Sanctuary Program that are relevant to this study: 1) Phase I of this assessment off North/Central California (NOAA NCCOS, 2003), and 2) an assessment for the Channel Islands National Marine Sanctuary (NOAA NCCOS, 2005).

See the following website for these and other biogeographic assessments being done in support of NOAA's National Marine Sanctuaries. Program: http://ccma.nos.noaa.gov/about/biogeography/projects.html.

Table 4.1. Marine mammal species and related map information in the Phase II assessment.

Species Common Name (and stock name) or Map Name	Scientific Name(s)	Order/Suborder	Family	Maps with CDAS Data	Maps with Data from NOAA/ SWFSC	Maps with Data from Other Sources[1]	Total No. of Maps per Species or Species' Stock
Fissiped							
Southern sea otter	*Enhydra lutris nereis*	Carnivora/(none)	Mustelidae			1	1
Pinnipeds							
California sea lion	*Zalophus californianus*	Carnivora/Pinnipedia	Otariidae	4	1		5
Steller sea lion	*Eumetopias jubatus*	Carnivora/Pinnipedia	Otariidae	1	1		1
Northern fur seal	*Callorhinus ursinus*	Carnivora/Pinnipedia	Otariidae	4		1	4
Pacific harbor seal	*Phoca vitulina richardsi*	Carnivora/Pinnipedia	Phocidae	1	1	1	2
Northern elephant seal	*Mirounga angustirostris*	Carnivora/Pinnipedia	Phocidae	1	1	1	1
Cetaceans							
Dall's porpoise	*Phocoenoides dalli*	Cetacea/Odontoceti	Phocoenidae	4	1		5
Harbor porpoise (stocks: Northern CA, San Francisco/ Russian River, Monterey Bay)	*Phocoena phocoena*	Cetacea/Odontoceti	Phocoenidae	1	1		2
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	Cetacea/Odontoceti	Delphinidae	4	1		5
Risso's dolphin	*Grampus griseus*	Cetacea/Odontoceti	Delphinidae	4	1		5
Bottlenose dolphin (CA coastal stock and CA/OR/WA stock)	*Tursiops truncatus*	Cetacea/Odontoceti	Delphinidae		2		2
Short-beaked common dolphin	*Delphinus delphis*	Cetacea/Odontoceti	Delphinidae		1		1
Northern right whale dolphin	*Lissodelphis borealis*	Cetacea/Odontoceti	Delphinidae	4	1		5
Killer whale	*Orcinus orca*	Cetacea/Odontoceti	Delphinidae	1	1		2
Baird's beaked whale	*Berardius bairdii*	Cetacea/Odontoceti	Ziphiidae	1	1		2
Cuvier's beaked whale	*Ziphius cavirostris*	Cetacea/Odontoceti	Ziphiidae	1	1		2
Mesoplodont beaked whales	*Mesoplodon spp.*	Cetacea/Odontoceti	Ziphiidae	1	1		2
Sperm whale	*Physeter macrocephalus*	Cetacea/Odontoceti	Physeteridae	1	1		2
Gray whale	*Eschrichtius robustus*	Cetacea/Mysticeti	Eschrichtiidae	4	1		5
Minke whale	*Balaenoptera acutorostrata*	Cetacea/Mysticeti	Balaenopteridae	1	1		2
Fin whale	*Balaenoptera physalus*	Cetacea/Mysticeti	Balaenopteridae	1	1		2
Blue whale	*Balaenoptera musculus*	Cetacea/Mysticeti	Balaenopteridae	1	1		2
Humpback whale	*Megaptera novaeangliae*	Cetacea/Mysticeti	Balaenopteridae	4	1		5
Summary Mammal Maps							
Summary of pinniped rookeries & haulouts		Carnivora/Pinnipedia			1	1	1
Summary at-sea richness for pinnipeds		Carnivora/Pinnipedia		1			1
Summary at-sea richness for cetaceans		Cetacea		1			1
CDAS pinniped effort map		Carnivora/Pinnipedia		1			1
CDAS cetacean effort map		Cetacea		1			1
SWFSC ship tracks of survey effort					1		1
TOTALS				**48**	**24**	**5**	**71**

Notes
1. Data sources other than SWFSC and CDAS are described in map sources and descriptions.
2. New data were available for Phase 2 CDAS mammal maps. At-sea data for SWFSC at-sea maps was the same as in Phase 1. All pinniped and haulout data were updated from Phase 1, and also the map for southern sea otter.Summary maps for richness and pinniped rookery/haulouts are new In Phase 2.

Data Used In the Assessment

The maps in the marine mammal assessment are based on different types of surveys: the efforts of individual researchers to study marine mammal spatial and temporal patterns, Federal and state government efforts to assess stock sizes and the potential biological impacts of oil development, and state government efforts to respond to oil spills.

Most of the at-sea data sets used in this assessment were compiled into the "CDAS central California data set (1980-2003)", developed by the R.G. Ford Consulting Company, in Portland Oregon. Another data set, the marine mammal stock assessment surveys (1991-2001), was from NOAA's Southwest Fisheries Science Center; this data set was used to develop separate sighting and effort maps along the California, Oregon and Washington coast for selected mammal species.

Estuaries and the coastline were initially not part of this GIS study area or analysis, but exceptions were made for sea otters, pinniped haulouts and rookeries, when data were available, to provide a more complete view of important areas for these species. Data for southern sea otter, pinniped haulouts and rookeries, and map descriptions came from a variety of sources - see individual map descriptions for sources.

Table 4.2. Summary of at-sea data sets in the CDAS central California data set (1980-2003) used in the marine mammal assessment.

Data Set	Principal Investigator	Vessel Name & Platform Height	Habitat Covered[2]	Years	Ocean Seasons Covered	Total Transect Width: Pinnipeds	Total Transect Width: Cetaceans
MMS High-Altitude Aerial Surveys	Dohl	Pembroke, 270m	Surface survey of the shelf, slope & deep ocean beyond	1980-1983	All three seasons	N/A	harbor porpoise, 254m; great whales, 1130m; all others, 885m
MMS Low-Altitude Aerial Surveys	Bonnell	Pembroke, 62m	Surface survey of the shelf, slope & deep ocean beyond	1980-1983	All three seasons	109m	109m
EPOCS Shipboard Surveys	Ainley	Surveyor, 12m, Discoverer, Oceano-grapher, 15m	Surface survey of the deep ocean	1984-1994	All three seasons	300-600m	800m
CA Seabird Ecology Low-Altitude Aerial Surveys	Briggs	Partenavia, 62m	Surface survey of shelf and slope	1985	Mainly Upwelling	50m	50m
NMFS Midwater Trawls for Juv. Rockfish: Ship Surveys	Ainley	David Starr Jordan,10m	Surface survey of shelf and slope to 3000 m	1985-2001	Mainly Upwelling	300m	800m
OSPR Low Altitude Aerial Surveys	Bonnell, Tyler	Partenavia, 62m	Surface survey of shelf and slope	1994-1998, 2001-2003	All three seasons	50m	50m
MMS Santa Barbara Channel Low Altitude Aerial Surveys	Bonnell	Partenavia, 62m	Surface survey of shelf and slope	1995-1997	All three seasons	50m	50m
SF-DODS Shipboard Surveys	Ainley	Point Sur, 8m	Surface survey of shelf and slope to 3000 m	1996-2000	All three seasons	300m	800m

Note: See additional descriptions of these data sets in the chapter.

The CDAS Central California Data Set (1980-2003)

This data set was developed using software called the 'Marine Mammal and Seabird Computer Data Analysis System' (CDAS), by the R.G. Ford Consulting Company, in Portland Oregon. The data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003, and extends from Pt. Arena to Pt. Sal. Four of the data sets were from high and low altitude aerial surveys from the Minerals Management Service, and the fifth aerial data set was from the California Department of Fish and Game, Office of Spill Prevention and Response (CDFG-OSPR, unpublished data). The source of data for the three ship-based survey data sets is David Ainley of H. T. Harvey and Associates and collaborators (unpublished data; Keiper *et al.,* 2005 for details on methods). See Table 4.2 for a summary of the eight at-sea data sets, and the Data and Analyses section of the bird chapter for detailed descriptions of the at-sea surveys. Figures 3.1 and 3.2 in the bird chapter contain maps of the survey extent of each at-sea data set in CDAS, and Figures 4.1 and 4.2 are summary maps of CDAS survey effort for pinnipeds and cetaceans.

Summarizing Survey Data into Grid Cells for CDAS Maps

The distributions of effort and species sightings from the data sets in Table 4.2 were mapped into 10' latitude by 10' longitude cells using CDAS, a custom geographic information system for analyzing marine bird and mammal surveys, developed by R.G. Ford Consulting Co.

The data sets were processed to compensate and correct for differences in survey methodology, including platform type (ship or aerial) and strip width, among the various studies, as well as differential sightability among species. Because wind speed affects detection of marine mammals, data collected when wind speed exceeded 25 knots were excluded. Mammal observation data and survey trackline data from these studies were converted to a common format of observations and trackline surveyed. All aerial data were continuous; ship-based data were converted separately into a continuous transect to the extent possible. The continuous aerial data were binned into the appropriate cell.

For the SF-DODS and EPOCS studies, and the Rockfish Assessment cruises prior to 1997, the beginning position, ship heading, and ship speed were used to compute the end position of each 2-4 km continuous transect. From this, a midpoint of the transect was determined. Times of observations were not available, therefore the position of midpoint was used to select the cell to which the survey effort was assigned. If this midpoint fell on a cell boundary, it was assigned to the cell to the north or west. To maintain the correspondence between effort and mammal observations, observations were also assigned to the transect midpoints. For the Rockfish Assessment Cruises from 1997 onward, effort was assigned to the cells through which the vessel passed based on the proportion of trackline that fell within each cell, and observations were interpolated along the cruise track according to the time of each observation.

The length and width of the survey trackline in a given cell were used to estimate the area sampled on a particular survey. An additional species-specific adjustment was made to the area surveyed to correct for detectability and availability bias. The number of mammals of each species seen in a cell was then divided by the area sampled in the cell to estimate density per cell. If a cell was surveyed more than once, densities were averaged, with an adjustment made for effort.

Analysis of CDAS Data

Effort Summary. For all at-sea surveys in the CDAS central California data set (1980-2003), 164,479 kilometers of trackline (pinnipeds and cetaceans) and 78,487 kilometers of additional trackline (cetaceans only) were analyzed; see Table 4.3. A total of

3,979 observations of 8,286 pinnipeds and 4,257 observations of 103,701 cetaceans were included in analyzed data. Survey effort used in this assessment for pinnipeds and cetaceans are summarized as maps in Figures 4.1 and 4.2, below. As evident in Table 4.3, the Upwelling Season had the greatest amount of survey effort, followed by the Davidson Current Season; the Oceanic Season had the lowest amount of effort. Unlike the other seasons, the Oceanic Season had no data from the 1980s. Because of the variation in effort coverage across space and time (and methods, as well as many other factors), interpretation of the data requires careful consideration. The mapped occurrence patterns only confirm that species have been sighted in certain areas and time periods; rather than a real absence from an area, the absence of sightings may reflect insufficient survey effort.

Organizing CDAS Data by Ocean Season**.** When adequate data existed for a species, the at-sea CDAS data were organized by ocean season to provide maps of the seasonal patterns of species. Survey effort and species sighting data were organized and mapped into three distinct ocean seasons (Bolin and Abott, 1963): Upwelling (~spring/summer), Oceanic (~fall), and Davidson Current (~winter). The ocean seasons were used because ocean conditions differ distinctly among these seasons and are known to have a strong influence on the biota and biogeography of the California Current system (Ainley, 1976; Briggs *et al.,* 1987). Although there is significant interannual variation in the actual duration, start, and end of these seasons, the following dates were chosen for each season for purposes of analysis: Upwelling Season is 15 March-14 August; Oceanic Season is 15 August-14 November; and Davidson Current Season is 15 November-14 March.

Although the at-sea data span the years from 1980 to 2003, data are not available for all seasons and all cells in all years. For the Upwelling Season, data are from 1980-1982 and 1985-2002; for the Oceanic Season, data are from 1980-1982, 1991, and 1994-2002; and for the Davidson Current Season, data are from 1980-1986 and 1991-2003.

Calculating Density and Developing Seasonal and Overall Density CDAS Maps**.** From the digitized survey data, the distribution of effort and of species observations was mapped into a grid of 10' by 10' cells, using the MMS-CDAS mapping system (MMS, 2001). The larger cell size (marine bird analysis used 5'x5' cells) was determined to be more meaningful for marine mammals by experts at a prelimi-

Table 4.3. A summary of combined at-sea effort in the CDAS central California data set for marine mammals (1980-2003).

Ocean Season	Dates Used for Each Ocean Season	Number of Months	Years Included	Taxa	Kilometers of Trackline Surveyed	Number of Visits	Number of 10' Cells Sampled
Upwelling	15 Mar-14 Aug	5	1980-1982, 1985-2002	*Pinnipeds*	78,534	16,374	283
				Cetaceans	112,251	20,752	317
Oceanic	15 Aug-14 Nov	3	1980-1982, 1991, 1994-2002	*Pinnipeds*	36,337	6,710	263
				Cetaceans	55,875	9,261	322
Davidson Current	15 Nov-14 Mar	4	1980-1986, 1991-2003	*Pinnipeds*	49,608	9,542	364
				Cetaceans	74,840	12,845	387
TOTAL	1 Jan-31 Dec	12	1980-2003	*Pinnipeds*	164,479	32,626	396
				Cetaceans	242,966	42,858	417

nary map/data review session. Linear effort data (kilometers of trackline) was transformed into area surveyed on the basis of strip widths (which varied by ship or aerial platform, depending on speed and height above water; see Table 4.2). Individual body size, group size, and species-specific behaviors, such as proportion of time spent submerged, are all factors known to affect detection and hence, observed distribution and density estimates as well. Because of the very different attributes of aerial and shipboard platforms, these factors, and the associated adjustments for observations, vary among the studies. Platform-, study-, and species-specific correction factors for detectability were applied in order to calculate the effective area surveyed in each cell for each species in each study. The number of individuals of each species seen was then divided by the effective area surveyed for that species to estimate density in each cell for that data set. For construction of density plots, if a cell was censused in other years or the same year by another survey, densities in cells were averaged and weighted according to area surveyed. Seasonal and overall density maps were then constructed for each species, showing the estimated density in each 10 by 10' cell.

Details of Density Calculations for Marine Mammals at Sea. Densities of marine mammals (animals per square kilometer) were calculated by dividing the number of animals seen by the amount of area effectively surveyed.

The area surveyed was calculated by multiplying the length of the trackline of the vessel or aircraft by the width of the survey strip. Survey widths for marine mammals varied from 50 meters for most low altitude aerial surveys to 800 meters for cetaceans on most ship-based surveys. Some high altitude aerial surveys for marine mammals used line transect methodology. For the line transect surveys, f(0) was calculated for each species and effective strip width and effective strip width (ESW) was determined from f(0). F(0) is the decrease in sighting probability as the perpendicular distance from the transect increases; the value of f (0) is the inverse of the ESW.

Density estimates were calculated using the formulas described below, for each species observed during each study and for each season in each geographic cell. Multiple density estimates in a given cell were averaged, using the effective survey area as a weighting factor.

Density (animals per km^2) was estimated using the standard formula:

1) $D = n / (l \bullet w)$

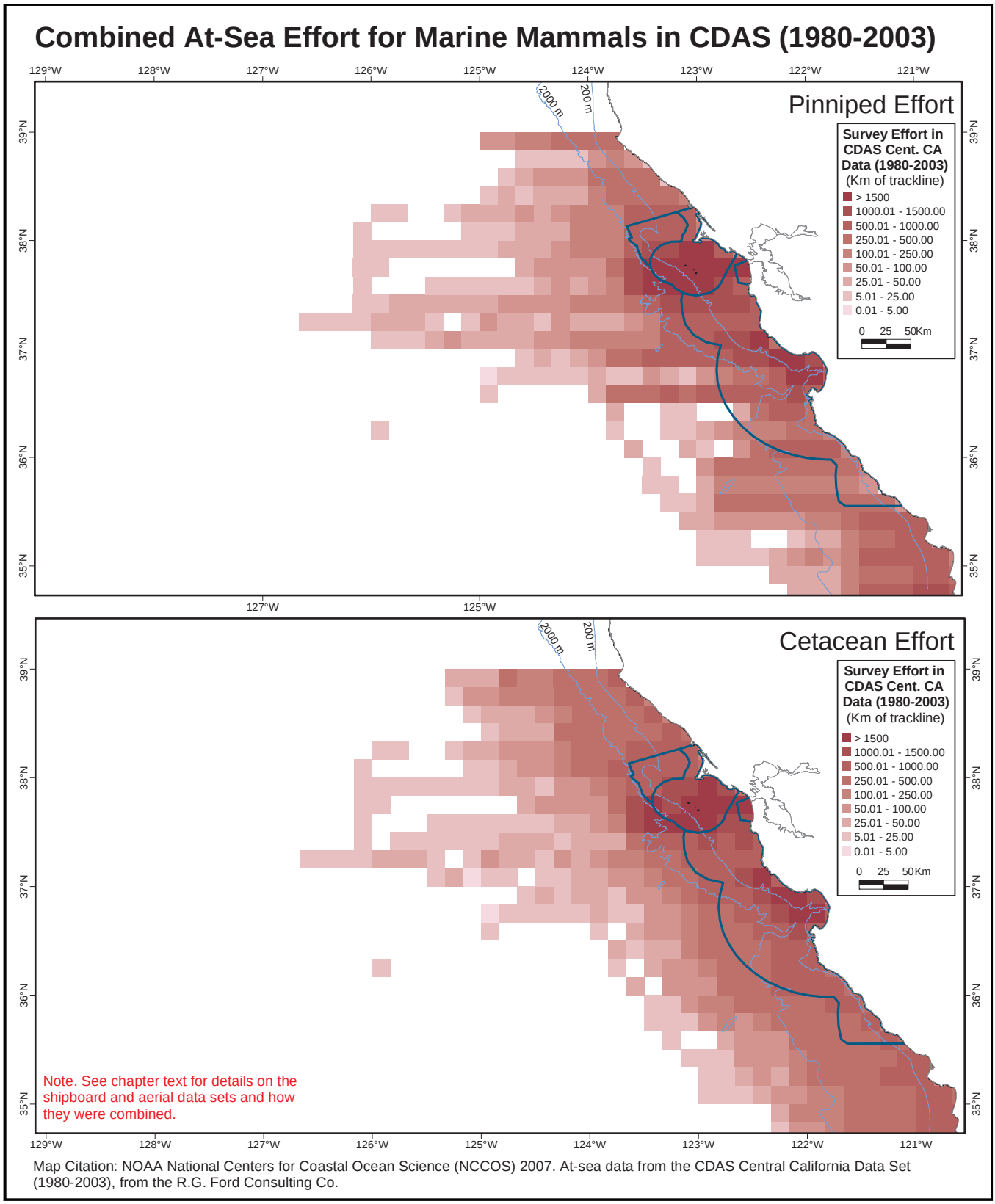
where D is density, n is the number of animals observed, l is the length of the trackline sampled (aircraft or ship), and w is the width of the sampled area. For strip transects, w was the specified strip width. For line transects, the Effective Strip Width (ESW) was calculated from f(0) using methods described in Thomas *et al.,* (2003) and Buckland *et al.,* (1993). All estimates of ESW were provided by the original investigators.

For all surveys, an additional adjustment, g(0), or the detection probability on the transect line, was made to the area surveyed to correct for perception and availability bias. This correction is the probability that an animal will be on the surface and available to be observed during the time period that the observer is passing, and includes the effects of surfacing and dive behavior of the species in question as well as the rate of movement of the survey platform. The maximum value of this parameter is 1.0; if the value is less than 1.0, the area effectively surveyed is less than the area that was estimated by multiplying trackline length by strip width. We corrected for limited time on the surface and perceptibility using the following equation (Burnham *et al.,* 1980):

2) $D = n / (g (0) \bullet l \bullet w)$

where g (0) is an estimate of the probability of detection, which combines the proportion of time spent at the surface (availability) with the probability that an animal available to be seen will be perceived by the observer (perceptibility). Estimates of g(0) for each species were based on Koski *et al.,* (1998).

Estimates of density were calculated using 10' by 10' cells for marine mammals. Block size was chosen as a compromise between larger size cells which minimize random variation between blocks and the number of unsampled blocks, and smaller size cells which provide greater spatial resolution. A larger block size was chosen for marine mammals than for birds because their densities are rela-



Figures 4.1 and 4.2. Summary maps of survey effort for pinnipeds (4.1) and cetaceans (4.2) from the CDAS central California data set (1980-2003).

tively low and therefore more subject to stochastic variation.

If blocks included results from multiple investigators or years, data were combined by using the area weighted average from all sources. The basic density within a block was calculated as:

$$3) \quad \sum_{i=1}^{k} n_i / (g(0) \bullet l_i \bullet w_i)$$

where k different studies are combined to calculate the density within a block.

Developing Sighting and Effort Maps for Infrequently Sighted Species. Where CDAS sightings were too few to warrant seasonal or overall density maps, observations were mapped as point locations. For context, overall survey effort is also presented. This display method was chosen in response to comments by expert reviewers at the October 2002 workshop and in view of the low numbers of sightings of certain species.

Additional Data Sources and Maps

Additional data on the at-sea distribution of cetaceans was provided by NOAA's Southwest Fisheries Science Center (SWFSC). These data are from ship surveys conducted July-December in 1991-2001. The SWFSC data are presented as separate species (or species group) maps after the CDAS maps in this chapter, and include a range that covers waters off the coasts of California, Oregon and Washington.

Data on the coastal distribution of sea otters were provided by Brian Hatfield, USGS, Western Ecological Research Center, Santa Cruz, along with Tim Tinker and Mike Kenner, University of California at Santa Cruz.

Pinniped rookeries and haulouts are monitored and surveyed by a variety of institutions and individuals; data sources are too many to list here but are included on the maps and in the map descriptions. Data mostly from 1998 to 2006 were used to represent locations of rookeries and haulout sites for all five pinniped species.

4.3 ANALYTICAL MAP PRODUCTS

A series of over 65 marine mammal maps and descriptions are presented for 24 marine mammal species. The section contains maps and descriptions for individual species, species groups (e.g., Mesoplodont beaked whales) and community metric maps (e.g., cetacean richness).

Maps of sea otters in coastal ocean waters and individual pinniped species' haulouts and rookeries are presented with their respective species descriptions. The at-sea mammal maps are grouped by data set, with maps based on the CDAS data set presented first, and a description of the map and species accompanies each CDAS map. Summary community metric maps developed using CDAS include: separate richness maps for cetaceans and pinnipeds, along with a summary map of pinniped haulouts and rookeries.

A brief introduction is provided for the maps based on data from NOAA's Southwest Fisheries Science Center (SWFSC), and two abbreviated species descriptions follow the SWFSC maps, because maps for two species (bottlenose dolphin and short-beaked common dolphin) were presented only using SWFSC data.

Map treatment varied, usually based on the amount of data available; species with relatively few sightings have sightings and effort shown and are sometimes presented on smaller maps; species with more data are presented with seasonal and/or overall densities (selected CDAS maps). The map for the California coastal stock of bottlenose dolphin had limited SWFSC sighting data, and so an approximate at-sea range in the study area was included.

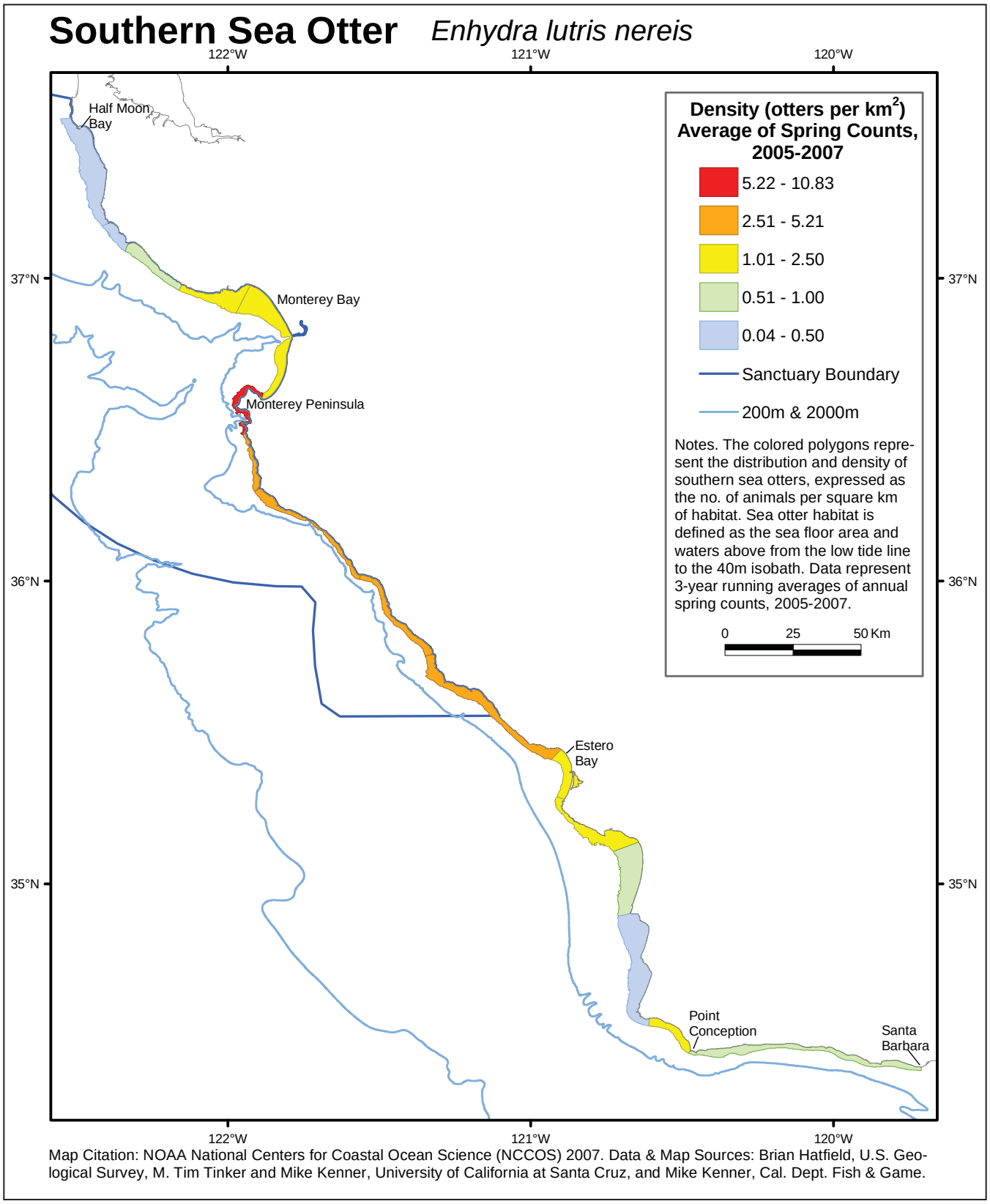


Figure 4.3. Map for southern sea otter: linear density in spring, 2005-2007, from the U.S. Geological Survey.

ABOUT THIS MAP

Figure 4.3 displays the current distribution and density of southern sea otters (*Enhydra lutris nereis*) along the California coast, based on the running -year average (2005-2007) of annual range-wide counts. Data are summarized for 17 contiguous coastal habitat sections, representing sea otter habitat (defined as the area of sea floor stretching from the low tide line to the 40 m isobath) divided at boundaries between different benthic substrate types (sandy, rocky or mixed). The current range of the sea otter in California extends from Half Moon Bay in the north to Santa Barbara in the south.

DATA SOURCES AND METHODS

Data were collected by wildlife biologists from the U.S. Department of the Interior (currently the U.S. Geological Survey, Biological Resources Division, Western Ecological Research Center), the California Department of Fish and Game (CDFG), University of California Santa Cruz, the Monterey Bay Aquarium, and trained volunteers during range-wide censuses, 2005-2007. Each census is conducted over a two week period, with the entire range surveyed using one of two methodologies: shore-based counts are made by pairs of experienced observers using binoculars and telescopes, and account for most of the range (~70% of the population), while those areas that are difficult to access or view from shore are counted by plane. Aerial counts are made by 3 experienced observers from a Partenavia PN68 Observer provided by the Department of Air Services, CDFG, flown at an altitude of 200' (60 m) above sea level and at a typical air speed of 90 kts. In the case of both shore-based and aerial-based counts, all sea otter sightings are recorded and entered into a GIS database: a single observation consists of a geo-location, number of animals, behavior, and presence/absence of a kelp canopy, as well as ambient weather and viewing conditions. Although otters cannot be reliably identified as male or female during the census, they are classified as either "independents" (i.e. > six months of age) or "dependent pups" (<6 months of age). Supplementary information suggest that regions without dependent pups present are predominantly male areas, although some juvenile and sub-adult females also utilize these areas.

Range-wide censuses are conducted twice annually, in late spring (May) and early autumn (October), but the late spring counts are considered to be the more reliable of the two data sets and are thus used as the primary indicator of change in population distribution and abundance. Because these data represent minimum population counts, with no associated correction factor or variance estimate, they include significant (but unquantifiable) observation error, probably caused mostly by year-to-year variance in survey conditions. Accordingly, in order to reduce potential influences from the vagaries of any single census, data are presented as 3-year running averages. The data set is provided by the USGS–Western Ecological Research Center, Santa Cruz Field Station: contact Brian Hatfield, Tim Tinker or Mike Kenner (831-459-2357) for more information.

RESULTS AND DISCUSSION

The southern sea otter (*Enhydra lutris nereis*) is one of three subspecies: southern (*E. l. nereis*), northern (*E. l. kenyoni*), and Russian (*E. l. lutris*) and is listed as "threatened" under the Federal Endangered Species Act, "depleted" under the Marine Mammal Protection Act (MMPA), and "fully protected" under California Fish and Game Code. The southern sea otter inhabits the nearshore waters of the central California coast; at present the range extends from about Half Moon Bay in the north to Santa Barbara in the south. A small, satellite population of approximately 20-40 animals also occurs at San Nicolas Island, the result of a translocation effort in the late 1980's (Rathbun *et al.,* 2000). Although sea otters are occasionally sighted outside of this range (as far North as Pt. Reyes Headlands and Bodega Bay, and as far south as Ventura and the Channel Islands), these sightings generally represent the transient movements of individual animals, almost always males, and are not considered part of the permanent range (defined as habitat occupied by three or more sea otters for at least three consecutive years). Range expansion continues to occur both to the north and south, with more rapid range expansion occurring to the south (Tinker *et al.,* 2006a). Since the mid 1990s, when otters moved south of Point Conception, the distribution at the southern end of the range has been particularly variable from year to year (Harris, pers. comm.).

Sea otters generally inhabit rocky shorelines with kelp beds, but also utilize open water habitats, sandy/soft bottom areas, and tidal estuaries. When resting, otters tend to aggregate in "rafts" in kelp beds, but may occasionally haul out on exposed

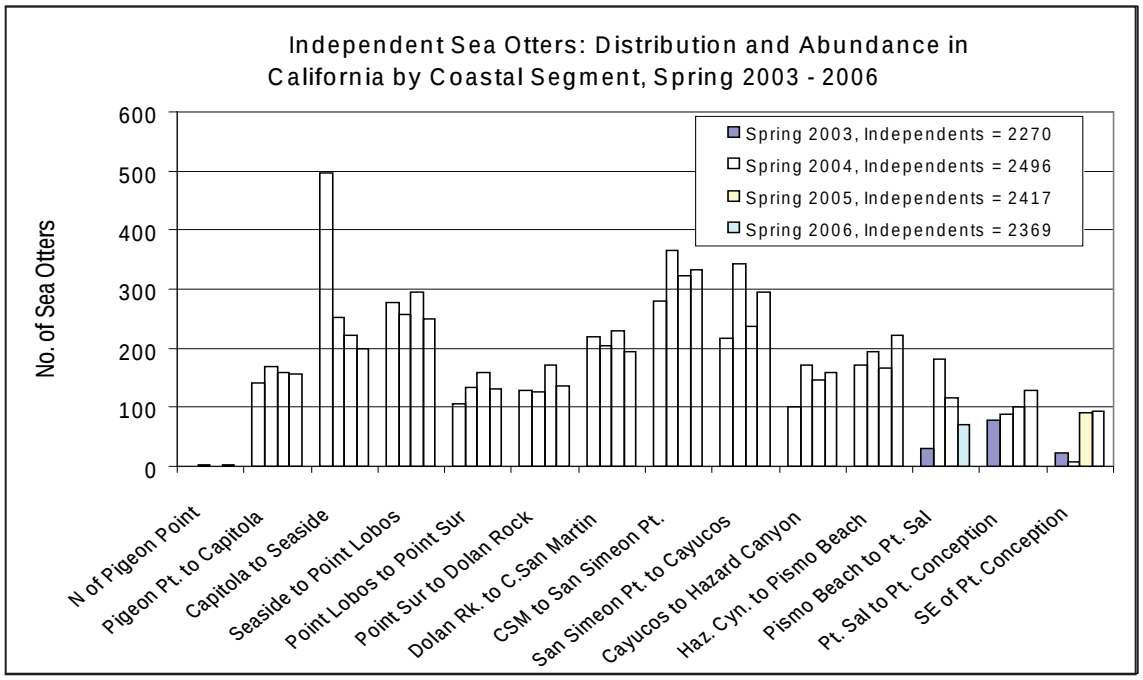


Figure 4.4. Independent southern sea otters: distribution and abundance in California by coastal segment, spring 2003-2006. http://www.werc.usgs.gov/otters/ca-surveyspr2006.htm

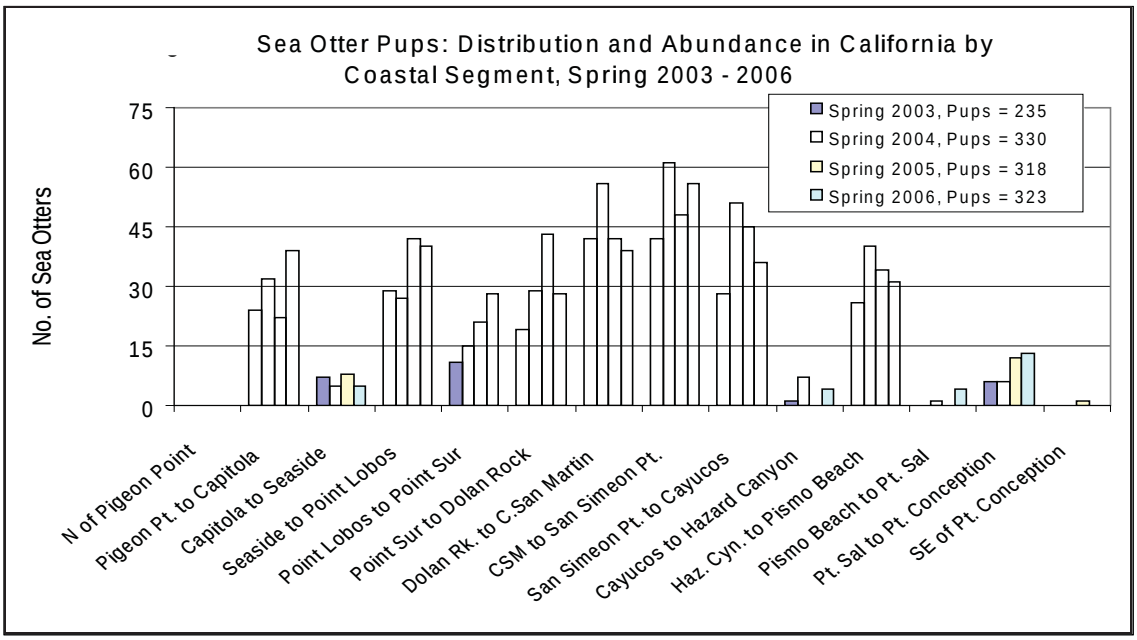


Figure 4.5. Southern sea otter pups: distribution and abundance of in California by coastal segment, spring 2003-2006. http://www.werc.usgs.gov/otters/ca-surveyspr2006.htm

rocky reefs, offshore rocks, and other areas protected from disturbance (Tinker, pers. comm.). Sea otters prey upon a wide variety of benthic marine invertebrates, including crabs, urchins, clams, mussels, abalone, marine snails, marine worms, sea stars, sand dollars, squid and octopus, although individual animals tend to specialize on a sub-set of the population diet (Estes *et al.,* 2003b; Tinker *et al.,* 2006a; Tinker *et al.,* 2007). Although sea otters occasionally make dives of up to 100 m, the vast majority of feeding dives (~99%) occur in waters less than 40 m in depth (Tinker *et al.,* 2006a): accordingly, sea otter habitat is typically defined out to the 40 m isobath (Laidre *et al.,* 2000). Dive

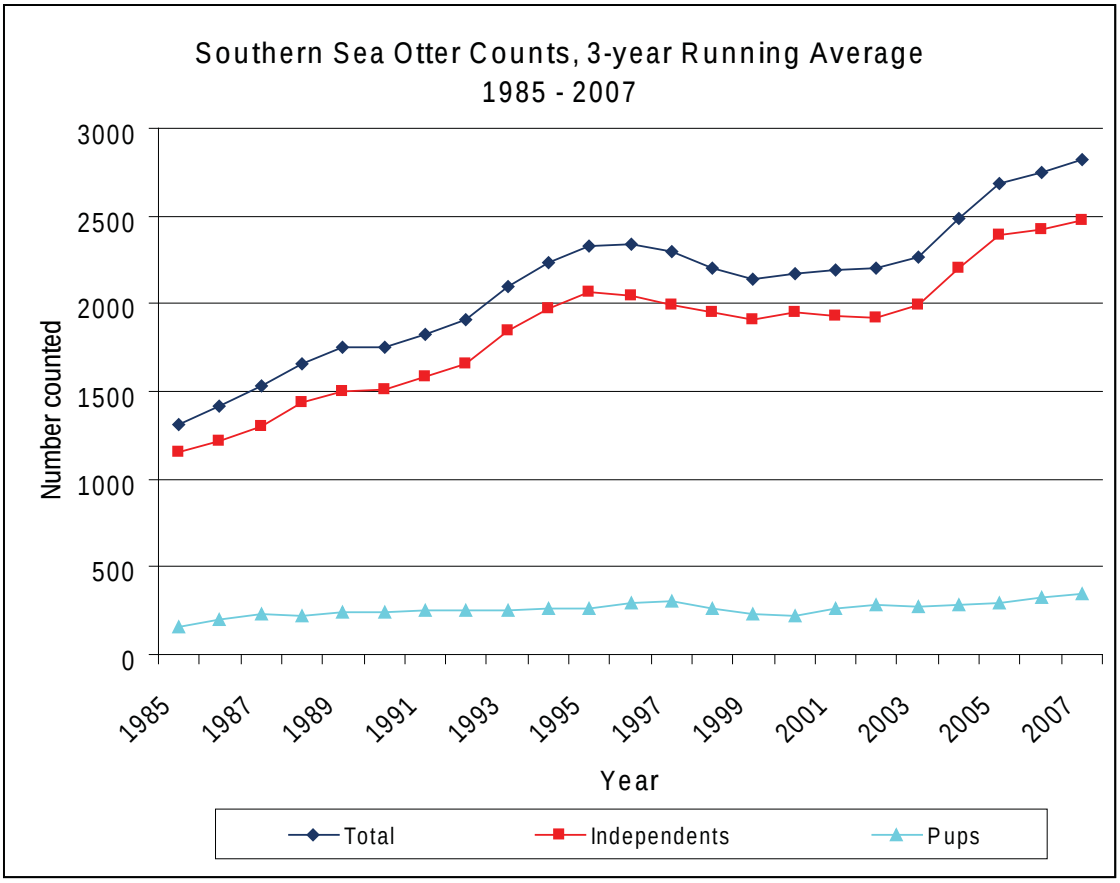


Figure 4.6. Number of southern sea otters counted during spring surveys, plotted as 3-year running averages from 1985-2007. Reprinted with permission from the USGS Western Ecological Research Center. http://www.werc.usgs.gov/otters/ca-survey3yr.html

depth and dive pattern vary by sex (males tend to make dives >25 m more frequently than females), geographic location and diet specialization (see Tinker *et al.,* 2006a; Tinker *et al.,* 2007).

Sea otter abundance varies considerably across the range, with higher densities mostly occurring in the center part of the range (Monterey peninsula - Estero Bay), where sea otters have been present for the longest (Figure 4.4). Sea otter densities tend to be most stable from year-to-year in rocky, kelp-dominated areas that are primarily occupied by females, dependent pups and territorial males. In contrast, sandy and soft-bottom habitats (in particular Monterey Bay, Estero Bay, and Pismo Beach – Pt. Sal) tend to be occupied by males and sub-adult animals of both sexes (but rarely by adult females and pups; see Figure 4.5), and these areas are more variable in abundance from year to year (Figure 4.4). This variation is apparently driven in part by the long-distance movements and seasonal redistribution of males (Tinker *et al.,* 2006b). The variability of counts at the south end of the range is also related to seasonal movements: many males migrate to the range peripheries during the winter and early spring, apparently to take advantage of more abundant prey resources, but then return to the range center during the period when most breeding occurs (June - November) in search of estrous females (Bonnell *et al.,* 1983; Jameson, 1989; Tinker *et al.,* 2006a, b).

Because the sea otter survey data consist of uncorrected counts, they do not represent population abundance estimates, but rather are used to assess trends. From 1983 until 2007 the spring population count increased from 1,277 animals to 3,026 animals (http://www.werc.usgs.gov/otters/ca-surveydata.html). However, the pattern of change was highly inconsistent, with periods of growth, stability and decline. The 3-year running average, the index used by management agencies to reduce the influence of variable survey conditions and assess long-term population trends,

indicates that after a period of decline (1995-2000), the population has now resumed recovery, with an average growth rate of approximately 5% per year over the 2001-2007 period (see Figure 4.6). It is important to note that most of this increase has occurred at the south end of the range (south of Estero Bay), with a more sluggish rate of growth in the north and center of the range where densities are highest, suggesting that sea otters may be approaching local carrying capacity in some areas (Tinker *et al.,* 2006b).

Estes *et al.,* (2003a) reported that elevated mortality appeared to be the main reason for both sluggish growth and periods of decline in southern sea otters. A period of decline from 1976 to 1984 was likely due to incidental mortality in set-net fisheries (Estes *et al.,* 2003a). An analysis by Tinker *et al.,* (2006b) indicated that increased mortality of sub-adult and prime-age females, particularly in the northern and center part of the range, was responsible for the period of decline from 1995-2000. Based on analysis of beach-cast carcasses, it appears that the two causes of death most important for limiting population growth are white shark attacks and infectious disease (Gerber *et al.,* 2004), with the prevalence of disease appearing to be unusually high (Thomas and Cole, 1996; Estes *et al.,* 2003a; Kreuder *et al.,* 2003; Hanni *et al.,* 2003). One such disease is toxoplasmosis, caused by the protozoan *Toxoplasma gondii*, a parasite that is shed in the feces of both wild and domestic cats (Miller *et al.,* 2002). Other sources of disease in sea otters include *Sarcocystus neurona* (another protozoan parasite), acanthocephalan worms (*Profilicollis* spp.) (Mayer *et al.,* 2003), bacterial and viral infections, domoic acid toxicity and cardiac lesions (Krueder *et al.,* 2005). Food limitation and nutritional deficiencies may also play a role in driving patterns of disease mortality (Tinker, pers. comm.), as well as the degree of exposure to chemical contaminants such as PCBs (Kannan *et al.,* 2006).

Due to its small population size and coastal distribution, the southern sea otter population is especially vulnerable to human disturbance, competition with fisheries, point-source and non-point source pollution (including both chemical contaminants and “pathogen pollution”), and the threat of a major oil spill. Other sources of human related causes of mortality include illegal shooting, boat strikes, capture and relocation efforts. In April 2003, the U.S. Fish and Wildlife Service released its recovery plan for the southern sea otter. The recovery plan identifies two main threats to the southern sea otter: (1) habitat degradation, which includes oil spills and the impacts from other environmental contaminants; and (2) human impacts, which includes shooting, entanglement in fishing gear, and harassment. As a result of their susceptibility to disease and contaminants, and their status as keystone predators in kelp forest ecosystems (Estes *et al.,* 2004), southern sea otters represent an ideal sentinel of marine ecosystem health in coastal California (Jessup *et al.,* 2004; Conrad *et al.,* 2005).

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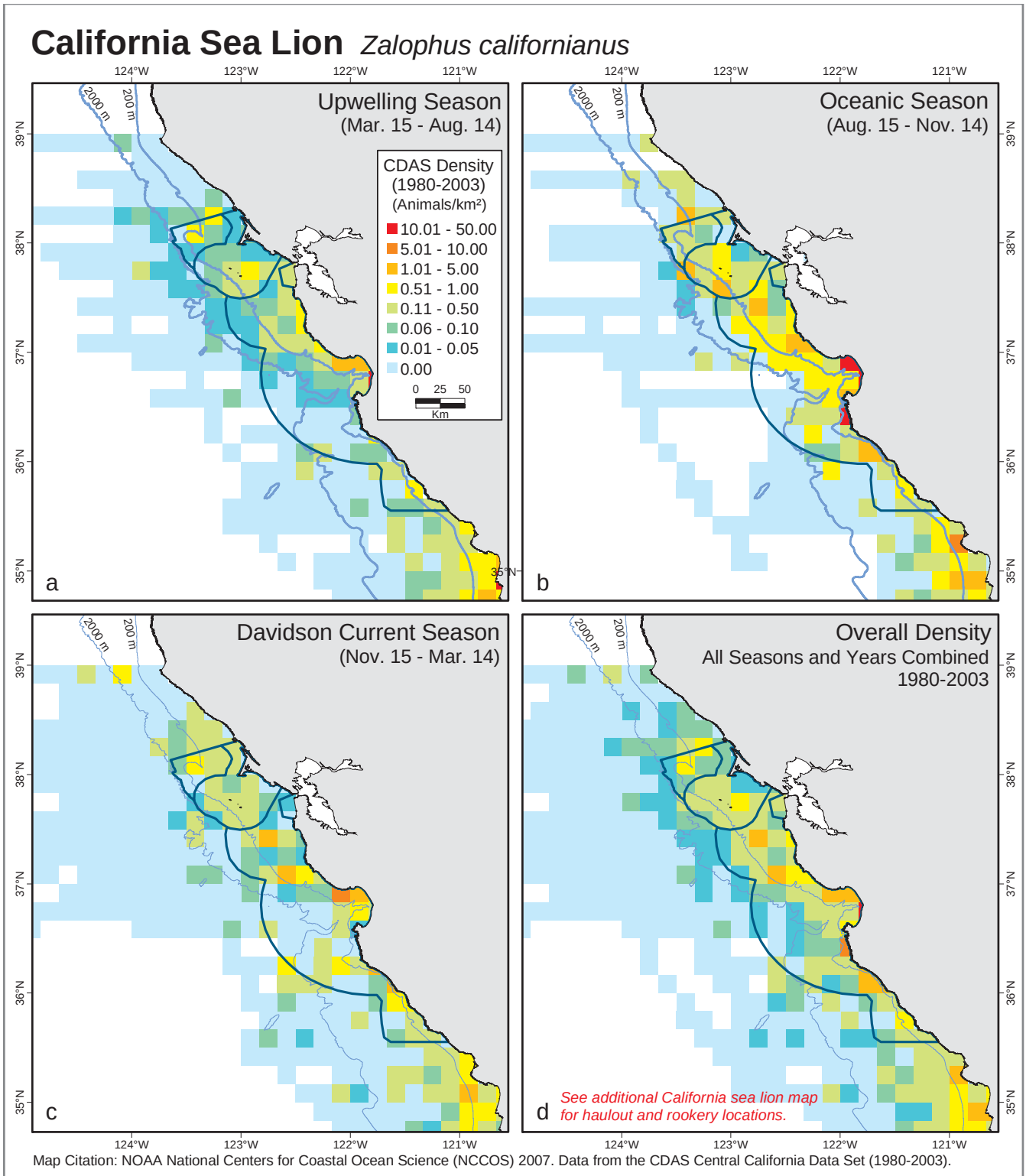

Figure 4.7. Maps for California sea lion: seasonal and overall at-sea densities from the CDAS central California data set **(1980-2003).**

ABOUT THESE MAPS

Figures 4.7a, b and c show the density (animals/km^2) of California sea lions (*Zalophus californianus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 10' latitude by 10' longitude. Figure 4.7d shows the corrected overall density combining all three seasons. Densities are based on the combined data sets of several studies conducted from 1980-2003; see "Data and Analyses" section of this chapter for more information. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no California sea lions were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

See also the additional map and description for haulouts and rookeries of the California sea lion.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set, (1980-2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

The California sea lion (*Zalophus californianus californianus*) is subdivided into three subspecies: *Z. c. californianus* (occurs from southwestern Canada to southern Mexico); *Z. c. wollebaeki* (occurs on the Galapagos Islands); and *Z. c. japonicus* (found in Japan but now thought to be extinct) (Carretta *et al.,* 2004; Carretta *et al.,* 2006). The breeding areas of the California subspecies are primarily in three locations: on islands along the coasts of southern California, western Baja California, and the Gulf of California. These geographic regions are used to separate *Z. c. californianus* into three stocks: 1) the United States stock (from Canada south to the U.S./Mexico border); 2) the Western Baja California stock (from the southern tip of the Baja California peninsula northward to the U.S./Mexico border; and 3) the Gulf of California stock (includes the Gulf of California from the southern tip of the Baja California peninsula and across to the mainland, extending to southern Mexico (Carretta *et al.,* 2006).

The breeding time period and rookery occupancy is mid-May to late July (Reidman, 1990); most births occur from mid-May to mid-June, with peaks in mid-June (Reidman, 1990). Lactation can last from six months to a year. In central California, a small number of pups are born on Año Nuevo Island, Southeast Farallon Island and occasionally at a few other locations (see additional haulout/rookery map for California sea lion); otherwise the central California population is composed of non-breeders. Adult females and immatures remain near the rookeries year-round, whereas adult males (along with most immatures) migrate northward to feeding areas ranging from central California to British Columbia.

Because all age and sex classes are never ashore at the same time, censuses are conducted by counting pups after all pups are born (July). In 2001, the minimum population size of the U.S. stock was estimated to be 138,881 (Carretta *et al.,* 2006).

Periods of unusually warm ocean waters associated with El Niño oceanographic conditions affect the number of California sea lions and pup production; off central and northern California the warm-water events have been associated with increases in the numbers of individuals at sea, as well as pup production. Conversely, during non-El Niño periods (e.g., La Niña), the number of individuals at sea and pups born have decreased in the study area (Lowry and Forney, 2005). Impacts of El Niño can also affect

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numbers of adult females available in the population to produce pups; this can subsequently affect future recruitment in the adult population. The frequency, length, timing and severity of future El Niño events will have significant effects on the sea lion population growth rate (Carretta *et al.,* 2006)

These at-sea data were not analyzed for effects of cold/warm water events on differences in abundance, therefore, no interpretation can be made relative to these events. However, although not apparent in the maps, distinct differences in at-sea abundance and distribution of California sea lions does occur off central/northern California during warm (El Niño) and cold water (La Niña) periods (Lowry and Forney, 2005). El Niño events have been known to alter at-sea distribution patterns and may result in greater numbers of sea lions off central California (Bonnell and Ford, 1987; Trillmich and Ono, 1991; Allen, 1994; Keiper, 2001; Keiper *et al.,* 2005; Lowry and Forney, 2005). During highly anomalous warm-water conditions in early 2005, male California sea lions altered their foraging effort by spending more time at sea and ventured up to 450 km off shore (Weise *et al.,* 2006).

In the study area, the California sea lion was the most abundant of the pinnipeds observed in the CDAS central California data set: 1,906 sightings and 5,509 individuals, with maximum group size sighted of 250. The species was widely distributed throughout the shelf and upper slope regions of the three national marine sanctuaries, and in the study area species forage mostly within 20 nmi of shore (Lowry and Forney, 2005). In general, the seasonal abundance of California sea lions off central California is linked to spring and fall pre- and post-breeding migrations, with greater numbers of sea lions present during the Oceanic season, just after breeding (August - November). The at-sea distribution map during the Oceanic season (post-breeding migration) reflects this pattern: greatest densities (0.58 animals/km^2) occurred in the Oceanic Season, whereas densities were somewhat less in the Upwelling Season (0.20 animals/km^2) and Davidson Current Season (0.26 animals/km^2). The temporal pattern observed in the mapping results may be due to migrating subadult and adult male sea lions on their way to (fall) and from (spring) British Columbia, Washington, and Oregon (Mate, 1975; Bigg, 1988 in: Lowry and Forney, 2005). Overall (all seasons and years combined), the density of California sea lions was relatively greater south of Monterey Bay, off Carmel. During the Oceanic Season, relatively greater densities occurred within the northeastern region of Monterey Bay and off Carmel, and during the Davidson Current Season, greatest densities occurred south of Pt. Año Nuevo, off Santa Cruz. The within-season spatial patterns observed in the maps likely reflect prey availability.

Since 1998, harmful algal blooms (HABs) have impacted the health of California sea lions. HABs associated with the diatom *Pseudonitzschia australis* (having domoic acid, a naturally-occurring neurotoxin) has been responsible for the deaths of sea lions in southern California (Scholin, 2000; Silvagni *et al.,* 2005; Gulland *et al.,* 2002) and reproductive failure (Brodie *et al.,* 2006). In 2006 there was a collaborative project to study the long-term effects of domoic acid exposure in California sea lions being conducted by, among others, The Marine Mammal Center (TMMC), California Department of Health Services, University of California, Santa Cruz. At TMMC, research is being conducted to study the sublethal and long term effects of domoic acid toxicity on health, survival, and reproduction in California sea lions. Results of this study suggest previous sub-lethal exposure to domoic acid can cause epilepsy and reproductive failure in California sea lions. Domoic acid can cross the placenta, and may expose the fetus to sublethal doses while the female is alive (Goldstein, pers. comm., June 2007).

Live strandings of California sea lions have been monitored and studied for over a decade (Greig *et al.,* 2005) and have provided a unique method of detecting diseases that may reflect environmental changes such as ocean pollution, prey shifts, and changes in ocean climate. Greig *et al.,* (2005) found malnutrition to be the most common reason for stranding (32%), followed by leptospirosis (27%), trauma (18%), domoic acid intoxication (9%) and cancer (3%).

Human-related sources of mortality include entanglement in set and drift gillnet fisheries, with an average annual mortality estimate of 1,476 California sea lions (Carretta *et al.,* 2006). Mortality also occurs in salmon troll fisheries, non-salmon troll fisheries, California herring purse seine fishery, California anchovy, mackerel, and tuna purse seine fishery, salmon net pen fishery, groundfish trawl fishery, and commercial passenger fishing vessel fishery (Carretta *et al.,* 2006; Perez, pers. comm.; Olesiuk, pers. comm.). Other sources of human-related mortality include illegal shooting, entanglements in gillnet fishing gear observed at rookeries and haulouts, hook and line entanglements, boat collisions, and entrainment in power plants. The serious injury and

total fishery mortality rate for the California sea lion stock is more than 10% of the calculated potential for biological removal (PBR) and cannot be considered to be insignificant (Carretta *et al.,* 2006). The PBR is the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. However, the population, as of 15 December 2003, is increasing at a rate of 5.4% to 6.1% per year (Carretta *et al.,* 2006).

California sea lions feed on a diversity of seasonally abundant fish (e.g., Pacific hake, northern anchovy, Pacific sardine, Pacific whiting, Pacific mackerel, herring, rockfish, salmon and steelhead) and invertebrates (e.g., market squid and octopus) (Weise, 2000; Reidman, 1990; Lowry and Forney, 2005).

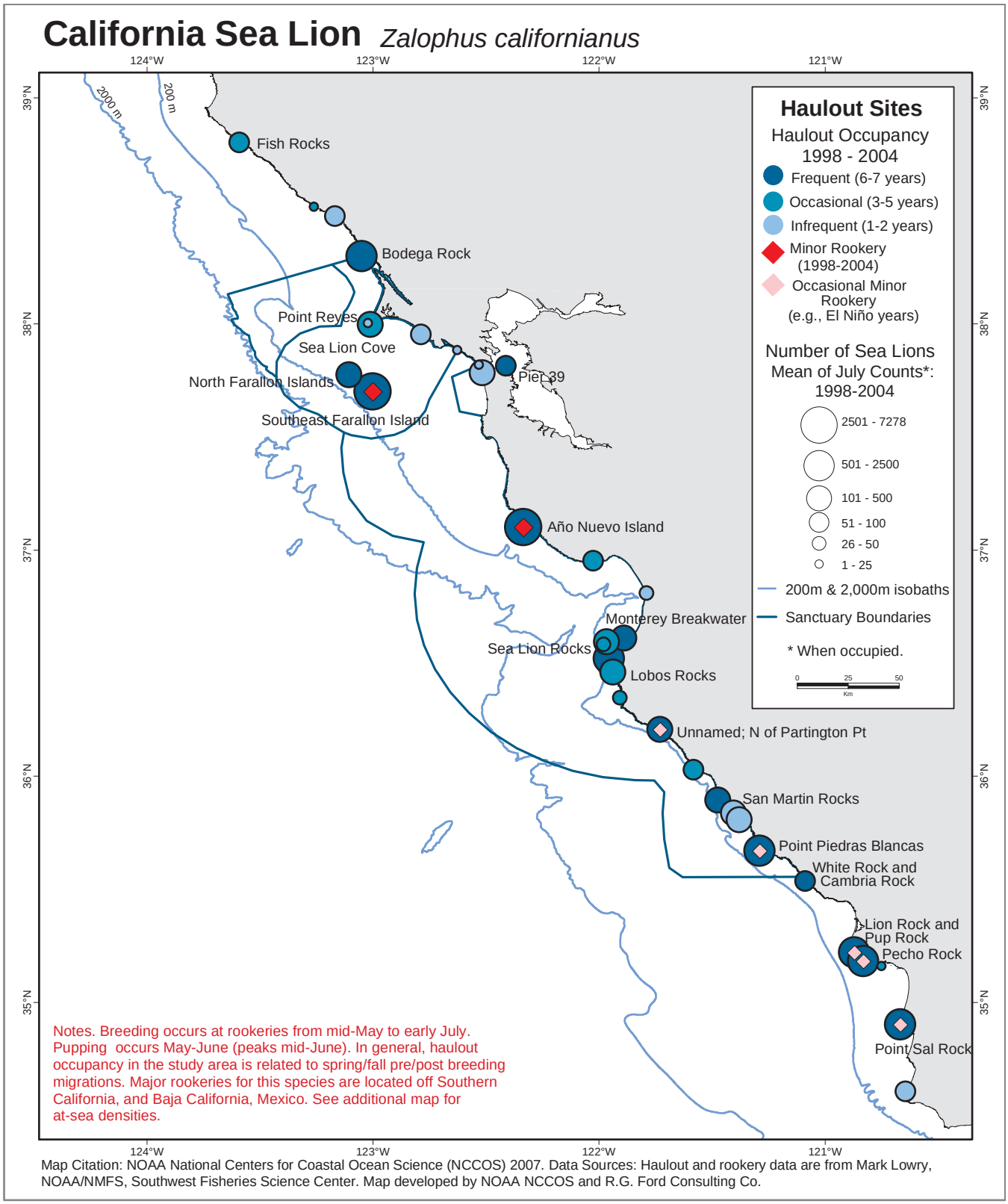


Figure 4.8. Map of California sea lion's haulouts and rookeries, 1998-2004, from NOAA's Southwest Fisheries Science Center.

ABOUT THIS MAP

This map summarizes information on haulout sites and minor rookeries for the California sea lion (*Zalophus californianus*) in the study area, based on number of animals, frequency of use, and rookery status. See also the map and description on the at-sea densities of California sea lion.

DATA AND METHODS

Haulout data and rookery information are from aerial photo counts (July 1998 - 2004) provided by Mark Lowry of the Southwest Fisheries Science Center, NOAA's National Marine Fisheries Service, La Jolla, CA.

Counts from aerial photographs (July 1998 -2004) were used to calculate frequency of use for each haulout location and the mean number of animals using each location when that location was occupied. Rookery status was determined by the inclusion of pups in the counts.

RESULTS AND DISCUSSION

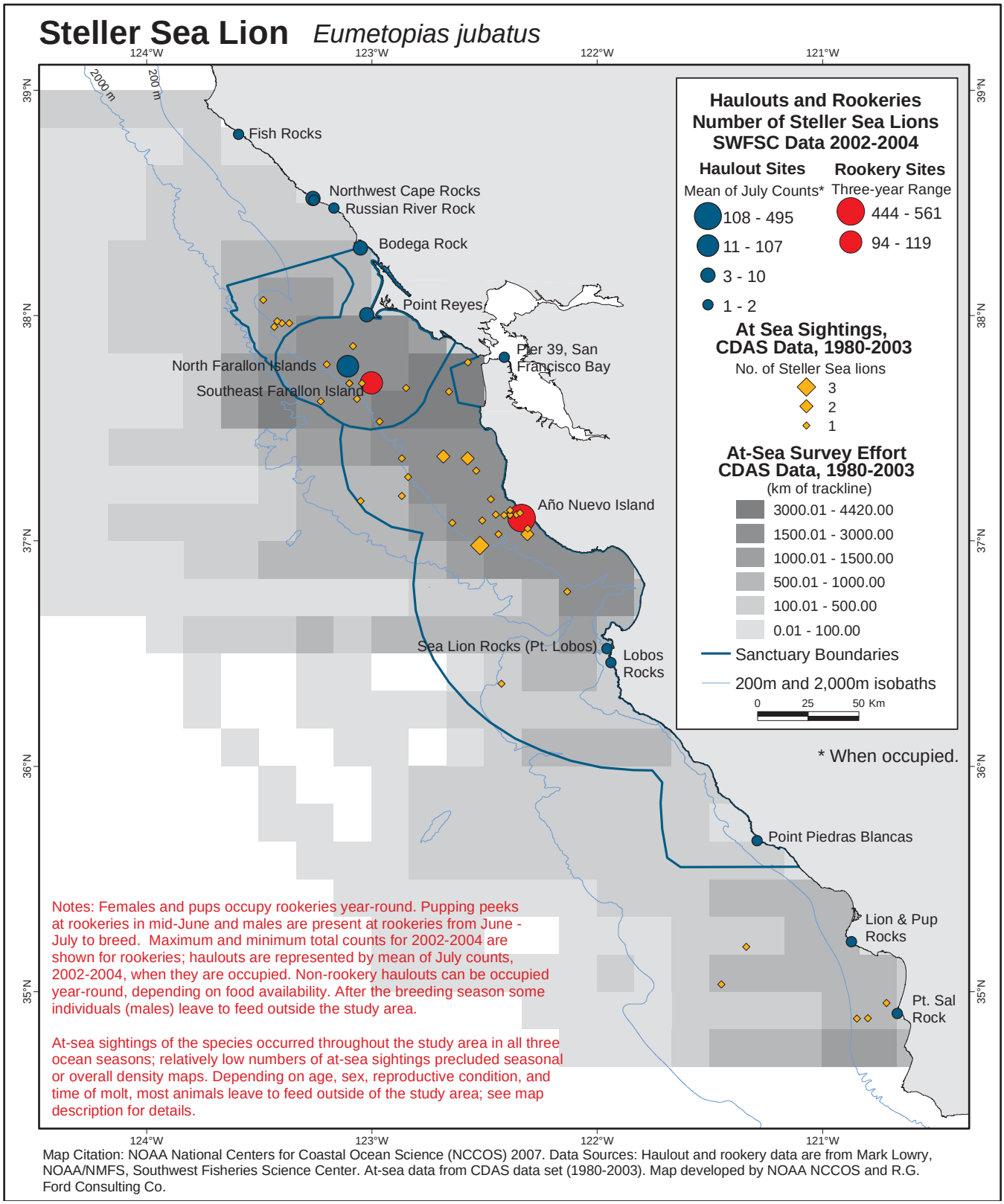
Haulout sites for the California sea lions in the study area are located along the coast from Fish Rocks (just south of Point Arena) to the south at Point Sal Rock, and inside San Francisco Bay (Pier 39). Minor rookeries are located on the Southeast Farallon Island and Año Nuevo Island (shown in red) and, similar to at-sea occurrence patterns, presence/absence at these minor rookeries may be related to the ocean climate variability in the California Current System.

During warm-water periods, some California sea lions move up from south of the study area and temporarily increase production (number of pups born). For example, over the seven-year period from 1998-2004, the number of pups born annually at Año Nuevo Island was often less than 12, except in 1998 and 2003; during the 1998 season, 99 pups were observed, and during the 2003 pupping season, 48 pups were observed.

Occasional minor rookeries (shown on the map in pink) occurred near Partington Pt., Pt. Piedras Blancas, and south of the Monterey National Marine Sanctuary at Lion Rock, Pup Rock, Pecho Rock and Pt. Sal Rock. Numbers of pups born at the occasional minor rookeries varied from zero to five with a peak of 12 during the strong 1998 El Niño event. Haulout patterns at the Farallon Islands and Point Reyes National Seashore also changed during El Niño events, indicated by an influx of immatures (Sydeman and Allen, 1999; Allen, pers. comm.).

Within the Gulf of the Farallones and Monterey Bay National Marine Sanctuaries, haulout sites with the highest mean counts during 1998 – 2004 occurred at Bodega Rock, the Farallon Islands, Año Nuevo Island, Sea Lion Rocks, Pt. Lobos, and Pt. Piedras Blancas; to the south of the MBNMS boundary, haulout sites with the highest mean counts occurred at Lion Rock, Pecho Rock, and Pt. Sal Rock.

For information on the diet and threats to California sea lion, see the previous map description of the at-sea map for this species.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Sources: Haulout and rookery data are from Mark Lowry, NOAA/NMFS, Southwest Fisheries Science Center. At-sea data from CDAS data set (1980-2003). Map developed by NOAA NCCOS and R.G. Ford Consulting Co.

Figure 4.9. Map for Steller sea lion: at-sea sightings and survey effort, rookeries and haulouts. At sea data from the CDAS central California data set (1980-2003); haulout and rookery info from NOAA's Southwest Fisheries Science Center.

ABOUT THIS MAP

Figure 4.9 shows a map of individual sightings of Steller sea lions (*Eumetopias jubatus*) at sea, along with the locations of haulout sites, rookeries, and at-sea effort in the study area. At-sea observations are based on combined data of several studies in the CDAS central California 1980-2003 data set. For context, the amount of combined survey effort (km of trackline) is shown, summarized in 10'x10' cells. Haulout and rookery locations are based on counts conducted by SWFSC in July 2002-2004.

DATA SOURCES AND METHODS

At-sea sightings and effort for the Steller sea lion are based on the CDAS central California data set (1980-2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and mapping methods used.

Rookery and haulout data are provided by Mark Lowry of the Southwest Fisheries Science Center, NOAA's National Marine Fisheries Service, La Jolla, CA.. The rookery numbers represent a general range based on counts of all animals (pups and adults) in three years, 2002-2004. Haulout data are from three July counts (2002-2004), and are displayed as mean counts when occupied.

RESULTS AND DISCUSSION

The Steller sea lion ranges along the North Pacific rim, from northern Japan, the Aleutian Islands, Gulf of Alaska, and south to Año Nuevo Island, California (the southernmost rookery). Two separate stocks of Steller sea lions are now recognized within U.S. waters: the Federally Threatened Eastern U.S. stock (animals east of Cape Suckling, Alaska, 144°W), and the Federally Endangered Western U.S. stock, which includes animals at, and west of Cape Suckling (Loughlin, 1997; Angliss and Outlaw, 2005). Rookeries for the Eastern U.S. stock are located in Southeast Alaska, British Columbia, Oregon, and California, with none in Washington.

Steller sea lion females have a protracted lactation period (12-36+ months; Reidman, 1990) and females and pups are found at the rookeries year-round, but adult bulls are only at the rookeries during the breeding season (mid-May to mid-July for the Eastern U.S. stock; June-July at the Farallon Islands and Año Nuevo Island (Hastings and Sydeman, 2002; Morris, pers. comm.). Timing of pupping depends on maternal condition, thus any changes may reflect changes in environmental conditions (Reidman, 1990). In the study area, two of the most southerly haulout and breeding areas are located on the Farallon Islands, where Stellers breed in small numbers and haul-out in slightly larger numbers throughout the year (USFWS, 2000), and Año Nuevo Island (LeBoeuf *et al.,* 1991).

Because relatively few sightings (n=46 sightings; n=51 individuals) occurred in the CDAS data set in the study area, insufficient data precluded mapping the Steller sea lion data by seasons. Most of the at-sea sightings occurred over the shelf, with some over the slope, mainly in the area between Cordell Bank and Año Nuevo Island.

On the Southeast Farallon Islands, numbers of Steller sea lions have continued to decline (1974-1996) with a rate of decline of 5.9% per year for adult females; a 4.5% per year decline for immatures; and a significant decline in maximum number of pups (Hastings and Sydeman, 2002). Although the reduced numbers of Steller sea lions on the Farallon Islands has been driven by reduced numbers of adult females during the breeding season, it is unknown whether reduced numbers of adult females and immatures during this period is due to reduced survival, or changes in geographic distribution (Hastings and Sydeman, 2002).

At the Año Nuevo rookery, counts of Steller sea lions indicate the rookery is apparently stable, with total counts (live pups and non-pups) of 444, 480 and 561 in 2002, 2003 and 2004, respectively (Lowry, pers. comm.; Pitcher *et al.,* 2007).

At the Southeast Farallon Island rookery, pup counts were 7, 13, and 22 in 2002, 2003, and 2004 respectively. Total live counts of Steller sea lions were 119, 94, and 107 in 2002, 2003, and 2004 respectively (Lowry, pers. comm.).

Until the early 1970's, Steller sea lions used to breed at Point Reyes Headlands but in recent years (2000-2006) numbers have been low (usually fewer than five but as high as 23; Allen, pers. comm., 2006). The Steller sea lions at Point Reyes Headlands are composed of adult and sub-adult males and immatures. Only one female with a large pup was reported by a credible observer over the past 5 years (Allen, pers. comm., 2006). Haulout sites north of San Francisco are located at Fish Rocks, Northwest Cape Rocks, Russian River Rock, Bodega Rock, Point Reyes, and the Farallon Islands. Another haulout site not on the map is located north of Fort Ross at "Sea Lion Rocks"; maximum counts at this site occur in June (approximately 50) and consist mostly of females with pups of the year (Mortenson, pers. comm., 2003).

Adult males and juveniles disperse widely during the non-breeding season, however little is known on the movement patterns of Steller sea lions off central California. Tracking studies are being conducted on Steller sea lions, but mostly off Alaska. Lander and Gulland, 2003 reported a rehabilitated post-release Steller sea lion pup that was raised in captivity, released at sea near southeast Farallon Island in April 1996, and then traveled north and arrived in Coos Bay, Oregon in May 1996, when the tracking signal stopped. In California, it's thought the males travel north after the breeding season. Genetic studies suggest the California Stellers mix primarily with animals within the eastern stock, most likely animals in Oregon and Southeast Alaska (Lander, pers. comm., 2006).

Current trends in populations as reported by Angliss and Outlaw, 2005, indicate counts in Oregon have shown a steady increase since 1976. However, during 1980-2001, overall counts in California declined over 50%, with numbers remaining between 1,500 - 2,000 non-pups during 1990 - 2001 (Angliss and Outlaw, 2005). In northern California, numbers appear to be stable (Angliss and Outlaw, 2005).

Overall, threats to Steller sea lions include incidental take by commercial fisheries, illegal shooting, entanglement in marine debris, declining trends in prey availability, disease, and contaminants (e.g., premature births accounted for 20-60% of pup mortality in the South Farallon Islands between 1973-1983). Organochlorine and trace metal contaminant levels are still elevated in central California Steller sea lions (NMFS Biological Opinion, 2000). In the study area, habitat concerns include reduced prey availability, contaminants, and disease (Sydeman and Allen, 1997).

Steller sea lions feed on walleye pollock, capelin, mackerel, rockfish, herring, salmon, octopus and squid (Riedman, 1990); they are also known to feed on other pinnipeds. Predators of Steller sea lions include killer whales and white sharks.

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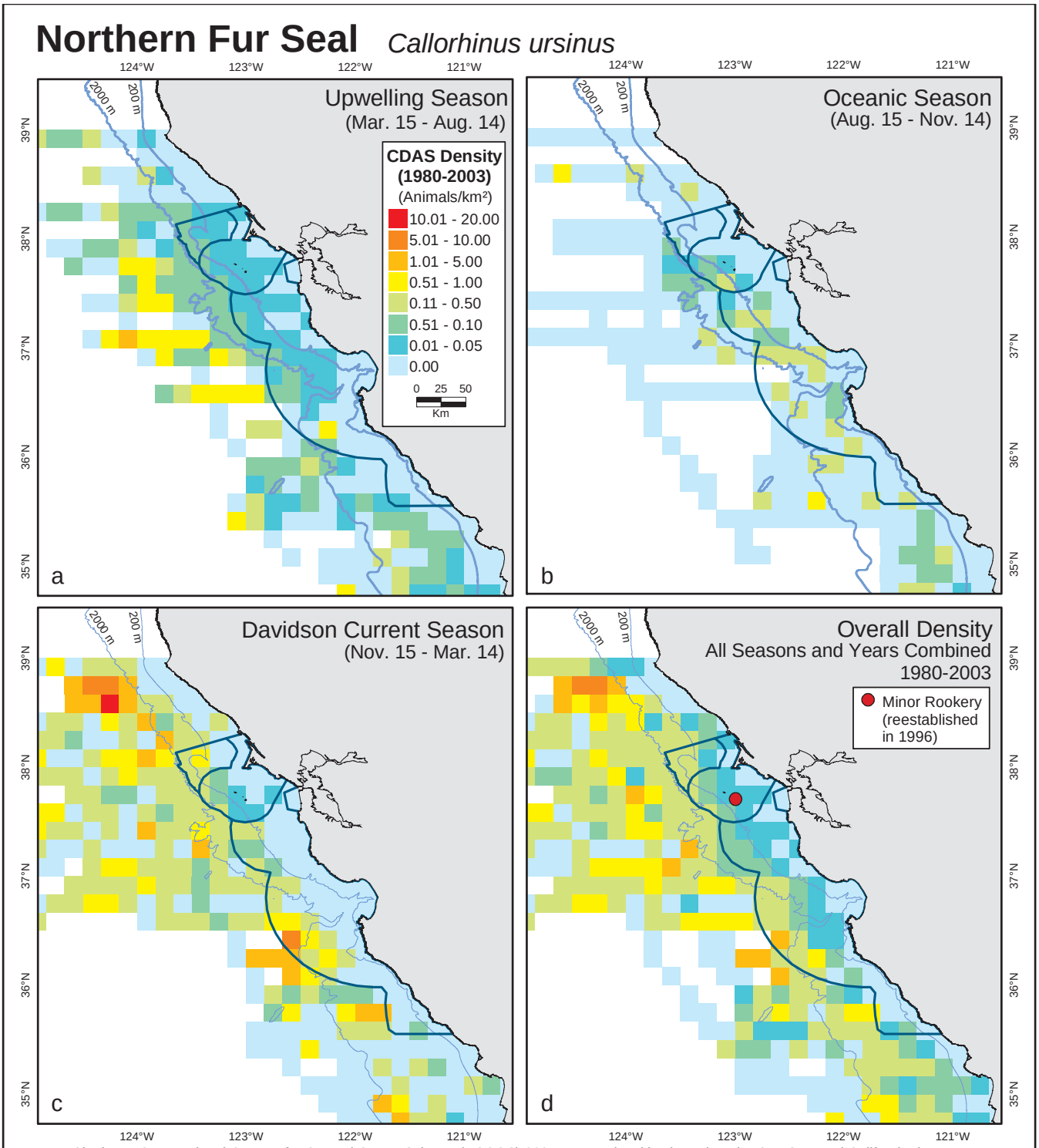

Figure 4.10. Maps for northern fur seal: seasonal and overall densities and rookery location. Densities from the CDAS central California data set (1980-2003) and rookery information from PRBO Conservation Science and the Farallon Islands National Wildlife Refuge.

ABOUT THESE MAPS

Figures 4.10a, b and c show the density (animals/km^2) of northern fur seals (*Callorhinus ursinus*) in three ocean seasons: Upwelling, Oceanic, and Davidson Current, displayed in cells of 10' latitude by 10' longitude. Figure 4.10d shows the overall density combining all three seasons. Densities are based on the combined data sets of several studies conducted from 1980-2003; see Data Sources below and the Data and Analyses section of this chapter for more information. The only known rookery for northern fur seal in the study area is included on Figure 4.10d.

The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no northern fur seals were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (1980-2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

Information on the northern fur seal rookery was provided in 2006, courtesy of PRBO Conservation Science and the Farallon Islands National Wildlife Refuge.

RESULTS AND DISCUSSION

Northern fur seals occur from the Okhotsk Sea and Honshu Island, Japan, the Bering Sea, and south to southern California. Within U.S. waters, two separate stocks of northern fur seals are recognized: an Eastern Pacific stock and a San Miguel Island stock (Angliss and Outlaw, 2005; Carretta *et al.,* 2006). During the breeding season, approximately 74% of the worldwide population is found on the Pribilof Islands in the southern Bering Sea; within U.S. waters and outside of the Pribilofs, approximately 1% of the population is found in the southern Bering Sea on Bogoslof Island, and on San Miguel Island off southern California (Carretta *et al.,* 2006). A small rookery recently was recently re-established at Southeast Farallon Island (see below). Rookery occupancy is characterized by males arrival in early June followed by female arrival mid-June. Males are generally at the rookery for two months; peak pupping occurs in mid-June – mid-July and lactation lasts about three to four months. The female goes to sea to feed after about one week and comes to shore to suckle her pup once a week. Molting occurs in August (Reidman, 1990).

The northern fur seal is one of the most pelagic of the pinnipeds, and during winter and early spring, is most abundant over the continental shelf and slope and deep ocean waters of mid-latitudes off western North America. Adult females and juveniles migrate to the central California study area (and Oregon and Washington) from rookeries on San Miguel Island in the southern California Bight (the San Miguel Island stock); (Carretta *et al.,* 2006), and from the Pribilof Islands (the Eastern Pacific stock) in the Bering Sea (Kajimura, 1980; Kenyon and Wilke, 1953; Pyle *et al.,* 2001; Ream *et al.,* 2005). Although both genders (adult females and juveniles) spend 7-8 months at sea (Roppel, 1984; Ream *et al.,* 2005), adult males remain closer to the breeding colonies (Kajimura, 1984; Loughlin *et al.,* 1999; Ream *et al.,* 2005). During their winter migration, female northern fur seals from the Pribilof Islands cue on a variety of oceanographic features and travel south in the California Current off Canada, British Columbia, Washington, and Oregon, and arrive off California beginning in February (Ream *et al.,* 2005).

In the CDAS data used for the marine mammal assessment (1980-2003), the northern fur seal was the second most abundant pinniped observed (total number sightings: n=1,474; total number individuals: n=2,088; maximum group size: n=26). In the study area, mapping results revealed distinct spatial/temporal patterns that reflect the pelagic

nature of the northern fur seal; greatest densities occurred in deep ocean habitats, mostly to the west of the National Marine Sanctuary boundaries, in the shelf-break, slope, and deep ocean habitats. The distinctly seasonal presence of this species in the study area is clearly evident in the maps: greatest densities occurred during the non-breeding period when animals migrate to the study area (Davidson Current [Nov-Mar] 0.17 animals/km^2) and remain until the early months of the Upwelling season [Mar-Aug] 0.10 animals/km^2). Lesser densities (0.04 animals/km^2) occurred during the Oceanic Season (Aug-Nov) and coincided with a time period when the largest abundance of breeding fur seals is found on the Pribilof Islands, and where 72% of the total numbers of seals have been estimated to congregate (Loughlin *et al.,* 1994).

Except for severe declines in 1983 and 1998 associated with El Niño Southern Oscillation events (ENSO), the San Miguel population off southern California has increased steadily since its discovery in 1968 (Carretta *et al.,* 2006). Severe declines associated with periods of unusually warm ocean conditions (e.g., ENSO) affect pup production and mortality rates at San Miguel Island and at the Pribilof Islands (DeLong and Antonelis, 1991; Allen, 1994; DeLong and Melin, 1999; Melin and DeLong, 2000; Keiper, 2001; and Keiper *et al.,* 2005). In the early 19th century, American, British, and Russian sealers removed the breeding population from the Southeast Farallon Islands (Pyle *et al.,* 2001). Beginning in 1996, however, the species has re-established a breeding population on the Southeast Farallon Island, and although fewer than 10 pups were produced each year (1997-2001), (Pyle *et al.,* 2001) recent counts (2006) indicate the numbers of northern fur seals on the Farallon Islands appear to be increasing (PRBO, unpublished data). Fur seal recovery on the Farallones appears to be in the initial stages of exponential growth; emigration is from San Miguel (Sydeman, pers. comm., 2006).

Status of the San Miguel Island northern fur seal stock is not considered to be “depleted” or listed as “threatened” or “endangered”; furthermore, because the estimated annual level of total human-caused mortality and serious injury does not exceed the potential biological removal (PBR), the San Miguel Island stock of northern fur seals is not classified as a “strategic” stock (Carretta *et al.,* 2006). Human-related sources of mortality of this stock include: takes of northern fur seals by commercial fisheries; strandings of seals entangled in fishing gear; and injuries caused by interactions with gear. Carretta *et al.,* (2006) reported the estimated mean mortality rate from 2000-2004 in observed fisheries and fisher self reports was zero northern fur seals per year for the San Miguel stock, but this number is considered a minimum mortality estimate. Estimated mortality from 2000-2004 for fishery-related strandings was 1.0 animal per year from the San Miguel stock. The most recent population estimate (2005) for the San Miguel Island northern fur seal stock is 9,424 animals (Carretta *et al.,* 2006).

The eastern Pacific stock of northern fur seals is considered separate from the San Miguel stock. The status of the Eastern Pacific stock of northern fur seals is considered “strategic” because it is “depleted”; the current (2006) population estimate is 721,935 animals, less than 50% of the estimate observed in the late 1950’s - 1.8 million animals (Angliss and Outlaw, 2006). From 1998-2004, pup production declined 6.2% per year on St. Paul island, and 4.5% on St. George Island. Human-related sources of mortality for the Eastern Pacific stock include commercial groundfish trawl fisheries in the North Pacific and foreign high-seas driftnet fisheries, however, estimated mortality rates from these fisheries are thought to be minimal. Other sources of mortality include illegal shooting, subsistence harvest and entanglement. A conservation plan for the Eastern Pacific stock of northern fur seal is being developed by NMFS to address levels of impacts and habitat concerns (Angliss and Outlaw, 2007).

Northern fur seals feed on a great diversity of seasonally abundant prey; off California the primary prey species include Pacific hake, northern anchovy, mesopelagic fishes, and market squid (Kajimura, 1984; Riedman, 1990).

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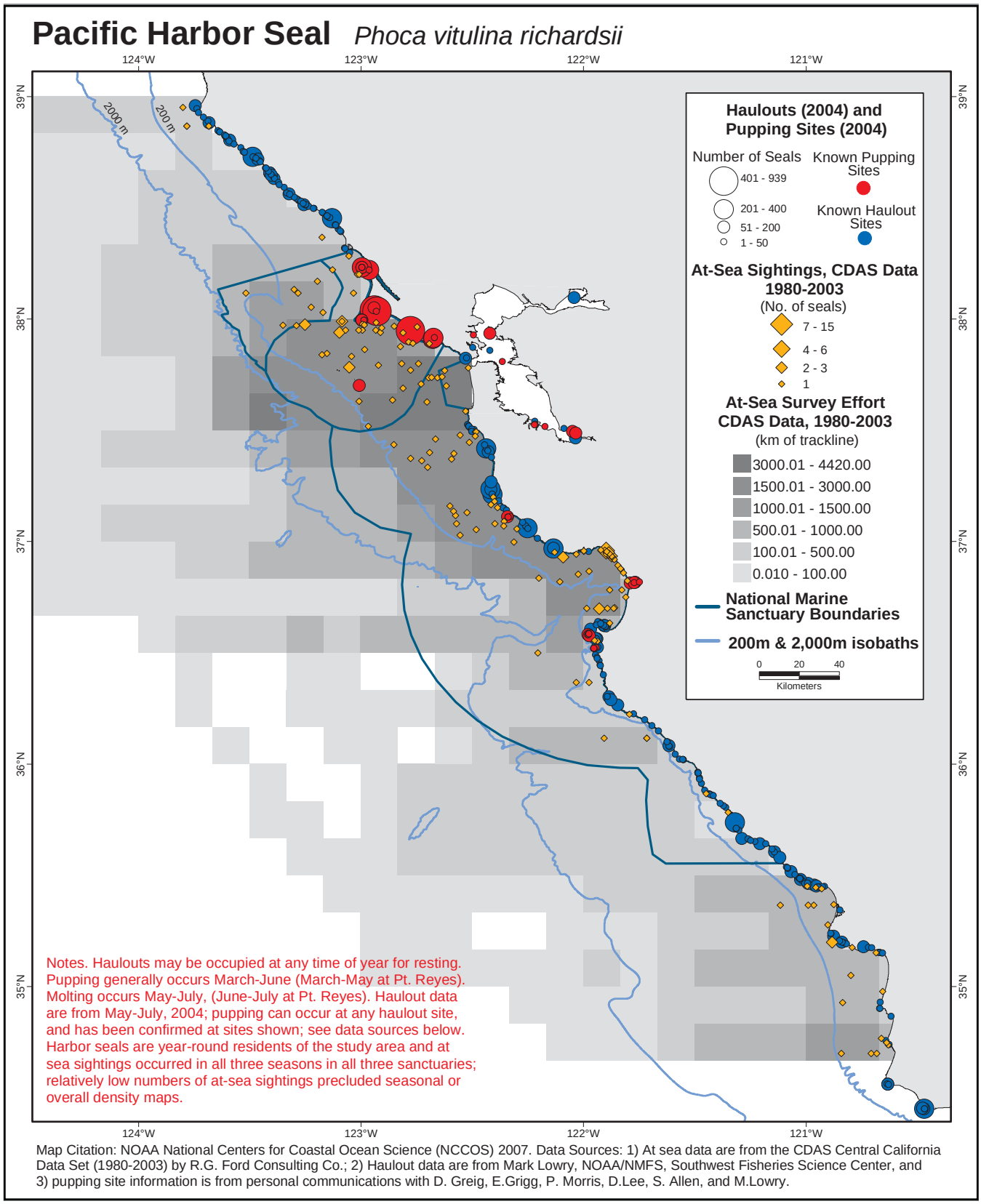

Figure 4.11. Overview map for Pacific harbor seal: at-sea sightings and survey effort from the CDAS central California data set (1980-2003). Haulout and pupping sites from NOAA's Southwest Fisheries Science Center, and pupping information from the following sources: D. Greig, E. Grigg, P. Morris, D. Lee, S. Allen and M. Lowry.

ABOUT THIS MAP

Figure 4.11 is an overview map for Pacific harbor seal (*Phoca vitulina richardsii*) summarizes the at-sea sightings and effort and the locations of haulouts and known pupping sites within the study area. At-sea sightings are based on eight surveys ranging from 1980-2003. For context, the combined, at-sea survey effort (kilometers of trackline) for all surveys in the CDAS data set (1980-2003) is shown, summarized in 10'x10' cells. Dark blue lines indicate the National Marine Sanctuary boundaries of Cordell Bank, Gulf of the Farallones, and Monterey Bay. Locations of haulouts and rookeries on the overview map are based on aerial survey data collected in May–July 2004; the number of harbor seals at these sites can vary significantly from year to year. See Figure 4.12 and related text for an inset map of harbor seal land use of the Pt. Reyes area.

DATA SOURCES AND METHODS

At-sea sightings and are based on the CDAS central California data set (1980-2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for additional information on the at-sea survey data sets. Due to insufficient harbor seal sightings associated with low densities, seasonal at-sea density maps were not produced. At-sea sightings show locations of animals seen, but sightings are affected by many factors, including time and location of survey effort, platform (e.g., plane or ship) oceanographic and meteorological conditions, and animal behavior (i.e., marine mammals are often submerged). At sea survey effort was summarized for pinnipeds by 10'x10' cell for this analysis.

The haulout information on the overview map are from aerial photographic survey data provided by Mark Lowry of the Southwest Fisheries Science Center, NOAA's National Marine Fisheries Service, La Jolla, CA. The overview map shows a summary of the numbers of seals observed hauled out during the molt period during an aerial photographic census conducted in California during 18 May – 19 July 2004. Each of three sections along the coast of California was surveyed on different dates to compensate for latitudinal differences in the timing of the molt (Lowry *et al.,* 2005). Surveys in central California were conducted 22-25 June 2004 and in northern California during 5-9 July and 18-19 2004. Surveys occurred during the low-low tide cycle. The Lowry survey is limited to molt season only and does not represent pupping sites or numbers. The latitude/longitude coordinates of harbor seals on land were used to plot the individual sightings. Locations of haulout sites are mapped coordinates provided by Mark Lowry. See Lowry *et al.,* (2005) and Allen *et al.,* (2004) for details on survey methods. Note that the haulout data shown on the Overview map is from a different source that shown on the Pt. Reyes map.

Information on pupping was from the following individuals: D. Greig, The Marine Mammal Center in Sausalito; E. Grigg at University of California (UC), Davis; P. Morris, UC, Santa Cruz; D. Lee, PRBO Conservation Science, S. Allen, National Park Service, Pt. Reyes National Seashore, and Mark Lowry, NOAA's Southwest Fisheries Science Center.

RESULTS AND DISCUSSION

The subspecies of Pacific harbor seal that occurs in the study area, *P. v. richardsii*, is distributed from the Pribilof Islands in Alaska to Baja California. There are three stocks recognized for this subspecies; the map presented here is the California stock. When Pacific harbor seals are ashore, they occur on sandy beaches, mudflats, rocks along the open coast, and in estuaries and rivers. Data from this study indicate that Pacific harbor seals forage

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throughout coastal waters; the at-sea distribution of harbor seals occurred mostly in shelf habitats of all three national marine sanctuaries.

Pacific harbor seals are present in the study area year round; they usually do not make extensive migrations, and tend to remain relatively close to their haulout sites. Pacific harbor seals usually occur less than five miles from shore and are generally not captured in aerial or at-sea surveys (S. Allen, pers. comm.). Pacific harbor seals have, however, been known to range farther than previously believed (Grigg, 2003). Results of 2002 tagging studies showed that individuals from San Francisco Bay traveled to Duxbury Reef and out to the Farallon Islands to forage (Allen, pers. comm., 2003; Nickel, 2003). This species has been documented to range up to 500 km (Allen Miller, 1988, unpub. data).

In the study area, breeding and pupping vary by latitude, and in general, breeding occurs March – June; pupping generally occurs March – June (March 1st – May 30th at Pt. Reyes); and molting generally occurs May – July. Duration of lactation is 21 – 42 days. Harbor seals feed on seasonally abundant prey that includes topsmelt, night smelt, white croaker, English sole (Harvey *et al.,* 1995), salmonids (Weise, 2001), squid and octopus (Riedman, 1990).

Overview Map – At-Sea Sightings and Effort. The CDAS data set shows harbor seals at sea were distributed in shelf habitats in relatively low densities in all three national marine sanctuaries; therefore, insufficient data precluded generating seasonal maps. Harbor seals are inconspicuous at sea and this may explain the relatively low numbers of animals surveyed in the CDAS data set (sightings: n=192; individuals: n=235). Furthermore, because at-sea sightings are influenced by survey effort (and the survey effort in CDAS surveys was unequal and coverage was less along the coast; see Figure 4.1), this overview map likely does not accurately represent the complete foraging/at-sea distribution of harbor seals in the study area. And although not evident in the maps, densities are generally higher in the Gulf of the Farallones than the rest of the study area because there are more and larger haulout sites in this area (Allen *et al.,* 2002).

Overview Map – Haulout and Pupping Sites. In the study area, haulout sites (Lowry, 2004) are shown along the coast from Pt. Arena south to Pt. Sal, and at the Southeast Farallon Islands; haulout sites on the overview map represent the numbers of seals hauled out during the molt period at a given instant during low-low tide, and do not account for the multiple environmental factors and disturbances that can affect haulout behavior at site-specific locations. Use of the haulout sites by harbor seals varies seasonally (Allen, pers. comm.). Factors that affect the number of seals onshore include: life history stage (e.g., breeding, pupping, molting), time of day, tidal state, weather conditions, disturbance related to human activities (Harvey and Goley, 2005) and year (Grigg *et al.*, 2004). Seals have a tendency to move regularly within a region, and individual seals may use several haulout sites through the year (Grigg, 2003). In general, however, seals use one site exclusively within the breeding and molt season and often use multiple sites during the rest of the year (Thompson, 1989 In: Grigg 2003 and Allen Miller 1988). Although pupping may occur at any of the haulout sites, within the study area, pupping occurs more commonly on mudflats and sandy beaches.

Data summarized on this map clearly indicate the widespread harbor seal use of the central coast (and within San Francisco Bay) during the breeding/pupping/molting season (May – July). Pupping sites include the Point Reyes area (see detailed map below) and except for the Channel Islands, the Point Reyes population of harbor seals represents the largest concentration of harbor seals in the State of California, accounting for ~20% of the mainland breeding population (Sydeman and Allen, 1999; Lowry and Carretta, 2003). Pupping sites are also located at Año Nuevo Island (Morris, pers. comm.), Elkhorn Slough, Hopkins Marine Station, Cypress Point, Fanshell Beach, Cypress Point, San Lorenzo River and Point Lobos (Greig, pers. comm.). Additional haulout sites along the coast south of San Francisco may exist at Pescadero and Bean Hollow (not mapped), but these sites are poorly documented (Greig, pers. comm.). Note also that a few pups (less than five) were also produced on South Farallon Island (USFWS, 2000; Lee, pers. comm., 2007). Although harbor seal mothers and pups haul-out on rocks offshore of the Año Nuevo mainland, it is not known whether they

deliver their pups in these locations or deliver out on the island and its offshore rocks and then move to the mainland offshore rocks as the pups become more competent swimmers (Morris, pers. comm., 2006). Within San Francisco Bay (SFB), pupping sites are also known to occur at Mowry Slough (encompasses Newark Slough) and Castro Rocks (major pupping sites). Smaller pupping sites within SFB include Greco Island, Corkscrew Slough, Corda Madera Marsh, and Yerba Buena Island (Grigg, pers. comm., 2006). Within the Delta, harbor seals haulout at Ryer Island in Grizzley/ Suisun Bay (numbers at this site have risen from 10 seals in 1993 to 53 in 2002) (Grigg, 2003; Read, pers. comm.). Pupping can occur at any haulout site, but the haulout sites listed above and mapped were known to have pupping.

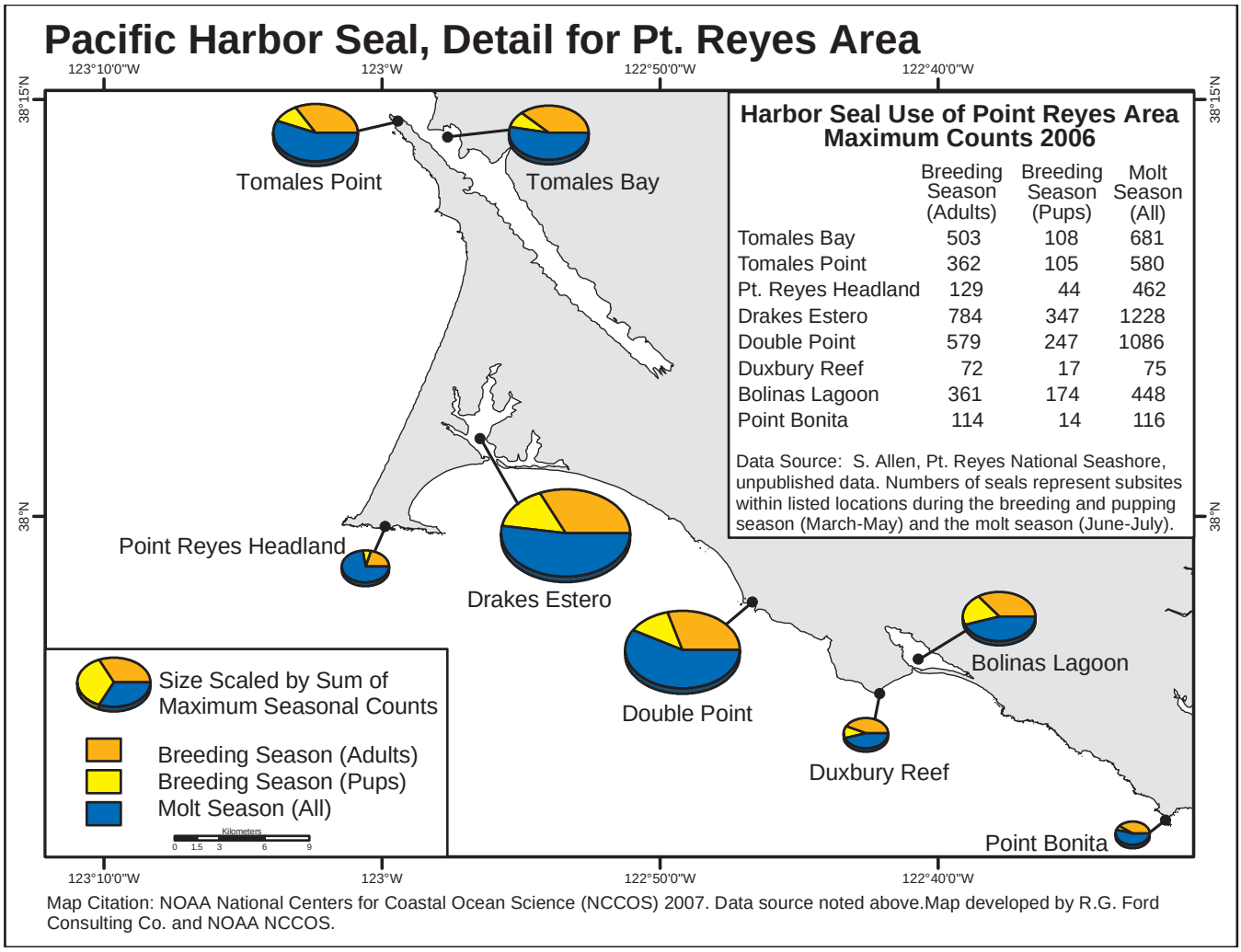
In California, 563 harbor seal haulout sites are widely distributed along the mainland and offshore islands, and include rocky shores, beaches and intertidal sandbars (Lowry *et al.,* 2005). Statewide, the population of Pacific harbor seals appears to be increasing, however the rate of increase is lower than in the 1980s and 1990s (Lowry *et al.,* 2005). Overall, the greatest number of seals in the study area occurred between 37.50º N and 37.99º N (Lowry *et al.,* 2005). Because a number of harbor seals are generally away from the haulout sites at all times, and because pups enter the water quickly after birth, a total count of harbor seals is not possible (Carretta *et al.,* 2002).

Strandings. Between January 1992 and December 2001, 940 Pacific harbor seals were stranded live along the central California coast (Colegrove *et al.,* 2005). Trauma (87%), malnutrition (51.8%) and respiratory disease (9.6%) were the most common causes of strandings; secondary factors included human interaction. An ocular disease coincided with a moderate ENSO in 1992-1993. In the past ten years, human interference in stranding events increased and were most commonly reported on beaches near heavily populated areas (Colegrove *et al.,* 2005).

Fisheries Interactions. Other human-related sources of injury and mortality include: set gillnet (halibut/angel shark), gillnet, hook-and-line fisheries, boat collisions, entrainment in power plants, illegal shootings, and all-terrain vehicle (ATV) collisions (Carretta *et al.,* 2006). Fishery mortality is considered to be significant because the average rate of incidental fishery mortality for this stock is likely to be greater than 10% of the calculated potential for biological removal (Carretta *et al.,* 2006).

Contaminants. Although there are no habitat issues of particular concern for the Pacific harbor seal, there is evidence that environmental contaminants and pollutants can affect reproductive success and may impair the seals' immune systems. Because harbor seals frequent coastal habitats often altered by industrial centers, heavy marine traffic, and urban and agricultural runoff, harbor seals typically experience relatively high exposures to contaminants. Harbor seals use coastal habitats, bays, and estuaries for resting, foraging, and reproduction, and are thus likely to be excellent indicators of the health of coastal/estuarine systems (Kopec and Harvey, 1995; Grigg, 2002). Maternal transfer of persistent marine contaminants (PCBs and DDE) to harbor seal pups in north/central California via milk has been documented (Neale *et al.,* 2005b); contaminant-induced immune alterations have also been found in north-central California harbor seals (Neale *et al.,* 2002; Neale, 2003). Although PCB residues decreased during the past decade in a comparison study on harbor seals within San Francisco Bay, they remained at levels great enough that adverse reproductive and immunological effects might be expected (Neale *et al.,* 2005; Grigg, 2003). Exploring causal links between chronic exposure and seal health has been identified as an area of future research in this at-risk population (Neal *et al.,* 2005a).

Other Threats. Marine debris is another threat to the seals (and most marine life) - nets, plastic materials or debris can be ingested accidentally or can become caught around their necks, strangling the seals as they grow. Natural predators of harbor seals include sharks (their primary predator), killer whales, and Steller sea lions (minimal predator).



	Breeding Season (Adults)	Breeding Season (Pups)	Molt Season (All)
Tomales Bay	503	108	681
Tomales Point	362	105	580
Pt. Reyes Headland	129	44	462
Drakes Estero	784	347	1228
Double Point	579	247	1086
Duxbury Reef	72	17	75
Bolinas Lagoon	361	174	448
Point Bonita	114	14	116

Figure 4.12. Detailed inset map of Pacific harbor seal haulouts in the Pt. Reyes area.

ABOUT THIS MAP

Figure 4.12 contains an inset map of the Pt. Reyes area contains locations of haulouts by Pacific harbor seal (*Phoca vitulina richardsii*) during the pupping and breeding season (mostly March – May) and the molting season (mostly June – July). Information on haulout, pupping and molting were collected from land-based surveys during 2006.

DATA SOURCES AND METHODS

Data on the location and use of haulout sites for the Point Reyes detail map were provided by Sarah Allen, Point Reyes National Seashore, National Park Service. Data are from March-July 2006 and were collected by biologists of the National Park Service and trained volunteers. Data were summarized for maximum counts during surveys. The map shows summary site information at Tomales Point (two sites), Tomales Bay (three sites), Point Reyes Headland, Drakes Estero, Double Point, Duxbury Reef, Bolinas Lagoon, and Point Bonita. Each site was surveyed a minimum of twice per week, primarily during low to medium tides, weather and logistics permitting. Each sub-site was surveyed separately and then totaled for each site. During a two-hour survey period, counts were made every half-hour during the breeding and pupping season (March-May) and the molt season (June-July). The Point Reyes map shows the relative importance of the various haulout areas and pattern of use at each site during 2006. Note that the haulout data in the Pt. Reyes area map is from a different source than that on the Overview map, Figure 4.11.

RESULTS AND DISCUSSION

A detailed map of harbor seal haulout locations was done for the Point Reyes area because: 1) the Point Reyes data sets were made available; and 2) mixing the aerial and land-based haulout data sets was not advised. Haulout sites along the Point Reyes coastline are located from Tomales Point south to Point Bonita. This detailed map of finer-scale data for the Point Reyes area was acquired from multiple surveys, and captured the time when greater numbers of harbor seals were on shore during the peak molt (June-July) in this area.

This map also summarizes habitat use (relative importance and pattern of use during breeding, pupping, and molting) of the haulout sites during 2006 at Tomales Point, Tomales Bay, Point Reyes Headland (area of Special Biological Significance), Drakes Estero, Double Point (area of Special Biological Significance), Duxbury Reef, Bolinas Lagoon, and Point Bonita. Harbor seals at Double Point and Drakes/Limantour Esteros is significant and accounted for more than 50% of total seals in the Point Reyes area that were counted during both breeding and molt seasons (Allen *et al.,* 2004; Manna *et al.,* 2006). During breeding and molting, relative abundance increases at Drakes Estero at the two sites, whereas during winter (and during herring spawns) relative abundance increases in Tomales Bay (Allen, pers. comm., 2006). Pupping also occurs to the north of Point Reyes on Bodega Rock and Bodega Point. See the overview map for Pacific harbor seal in the study area (Figure 4.11) and related description for additional information.

Monitoring and Trends at Pt. Reyes. Since 1976, long-term monitoring studies of harbor seals have been conducted at selected colonies by Sarah Allen (S. Allen, pers. comm.). Between 1997 and 2001 the population trend of harbor seals at Point Reyes appeared to be stable: annual maximum counts for the breeding seasons ranged between 2,481 and 3,506 harbor seals, and annual average counts ranged from 1,744.6 and 2,511.1 (range of SE = 122.5 to 379.0) (Allen *et al.,* 2004). The latest available data for 2006 yielded an average of 2,317 harbor seals (SE = 225; maximum=2,790), including 1,402 pups during the breeding season and a maximum of 4,560 (all age classes) during the molt (Manna *et al.,* 2006). In 2006, however, there was an overall decline (compared to the previous five years) in the number of pups produced at Pt. Reyes; this decline may be related to changes in marine conditions or human use patterns causing disturbance (Manna *et al.,* 2006). Upwelling was reduced in 2006 and this may have affected food availability for harbor seals, which, in turn, may have affected overall number of pups (Manna *et al.,* 2006).

Disturbance. The trend studies cited above have also documented disturbance of harbor seals at Drakes and Limantour Esteros (by people and boats) and at Tomales Bay (by motorboats). Reduced human disturbance (e.g., from clam digging) and the SEALS program (see below) likely contributed to an increase in presence of seals in Tomales Bay between 2000 and 2004 (Allen *et al.,* 2004). Harbor seals were also disturbed at Double Point, (one of the primary pupping sites at Pt. Reyes), due to commercial fishing near the haulout site (Allen *et al.,* 2004). Other primary pupping sites are located at Bolinas Lagoon, Tomales Point, Tomales Bay, and Drakes Estero/Limantour Estero (Allen *et al.,* 2004). Disturbance to seals at Drakes Estero/ Limantour Spit, was significantly reduced when a seasonal closure to boats (kayaks) was enforced by the National Park Service in 1995. However, disturbance by hikers and boats continues at Limantour Estero (Allen *et al.,* 2004), and, across all sites, hikers and boaters remain the two most frequent sources of human related disturbance (Manna *et al.,* 2006).

Education and Outreach. A monitoring project (designed by Sarah Allen, Senior Science Advisor, PRNS, and Gulf of the Farallones National Marine Sanctuary staff) was conducted from 1997-2005 at Bolinas Lagoon and Tomales Bay by the SEALS program. The Sanctuary Education Awareness and Long-term Stewardship (SEALS) program monitored the effects of human activities on seal behavior until it was stopped in 2005. Since then, disturbances have again increased. This interpretive enforcement program and education outreach was successful at reducing human disturbance on harbor seals in these areas.

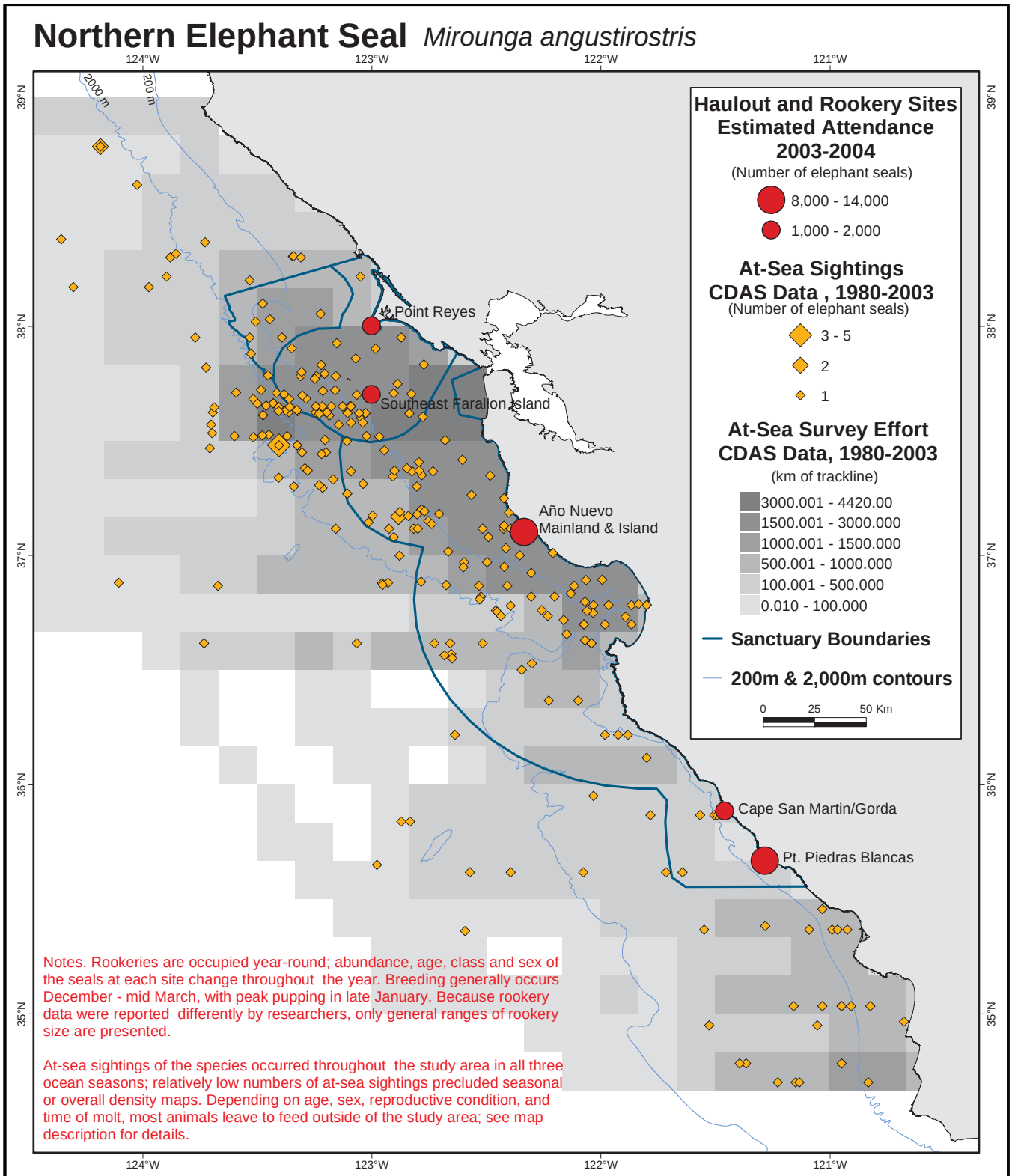


Figure 4.13. Map for northern elephant seal: at-sea sightings and survey effort from the CDAS central California data set (1980-2003); rookeries and haulout information from B. Hatfield, J. Buffa, W. Sydeman, P. Morris, R. Condit, and S. Allen.

ABOUT THIS MAP

Figure 4.13 shows at-sea sightings and survey effort of northern elephant seals (*Mirounga angustirostris*), along with the locations of rookeries in the study area. At-sea observations are based on combined data of several studies (see "Data and Analyses" section of this chapter). For context, the amount of combined survey effort (km of trackline) is also shown, summarized in 10'x10' cells. Dark blue lines indicate the National Marine Sanctuary boundaries of Cordell Bank, Gulf of the Farallones, and Monterey Bay; bathymetric contours for the 200 m and 2,000 m isobaths are also shown in light blue.

DATA SOURCES AND METHODS

At-sea sightings and effort for the northern elephant seal are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and mapping methods used.

Information on rookery locations and sizes was obtained from Brian Hatfield, USGS; Joelle Buffa, FWS; William Sydeman, PRBO Conservation Science; Pat Morris, UCSC; Richard Condit, Smithsonian Institution and Sarah Allen, National Park Service.

RESULTS AND DISCUSSION

The northern elephant seal breeding population consists of two populations (or stocks); the U.S. stock in California and the Baja California, Mexico stock (Carretta *et al.,* 2002; Carretta *et al.,* 2006). Because all age classes are not ashore at the same time, a complete population count of elephant seals is not possible. Based on an estimate of pups born in 2001, the California stock in 2001 was 101,000 seals (Carretta *et al.,* 2006). Current trends in pup counts of northern elephant seal colonies in the U.S. continue to increase throughout their range in California, but appear stable or decreasing in Mexico (Carretta *et al.,* 2006).

The northern elephant seal is present year-round in the study area; however, because they spend very little time at the surface and forage mostly offshore, at-sea sightings are rare, as evidenced by the relatively few sightings in the CDAS data set in the study area (n=278 sightings; n=285 individuals). Therefore, insufficient data precluded mapping the at sea sightings for northern elephant seal by season.

Northern elephant seals were widely distributed in the shelf, shelf-break, and slope habitats within the three national marine sanctuaries, and also in deep ocean habitats seaward of the 2,000 m isobath. They also occurred well to the north, west, and south of sanctuary boundaries. In the CDAS data sets, age classes of at-sea sightings of seals are unknown.

The northern elephant seal breeds, gives birth, and molts on islands and coastal regions in California, as well as offshore islands of Baja California. The breeding period in the study area is generally December through March (Stewart and Huber, 1993); pupping occurs three to six days after the female arrives at the rookery and lactation is about 22 – 29 days. Molting occurs April – August; females and juveniles molt in April-May; subadult males molt in May/June, and adult males molt in July/August; and yearlings molt in the fall. In the study area, northern elephant seals migrate between rookeries (within sanctuary boundaries) at the Farallon Islands, Point Reyes, Año Nuevo Island and the adjacent mainland, Piedras Blancas, and Cape San Martin. They also migrate to the north, where they spend eight to ten months of the year feeding. Adult males feed in the eastern Aleutian Islands and the Gulf of Alaska; adult females feed to the west and south of 45º N in deep, oceanic water (Le Boeuf *et al.,* 1993; Stewart and Huber, 1993; Stewart *et al.,* 1994).

At the five rookery sites in the study area, there are three peaks in abundance: 1) during the breeding/pupping season mid-December to mid-March, with peaks in pupping in late January; 2) during the molting season when females and juveniles are on shore from April to May; and 3) when yearlings and juveniles are on-shore September - November (S. Allen, pers. comm.; LeBoeuf and Laws, 1994).

Pups depart the pupping sites during the Upwelling Season and tagging studies indicate that pups from this region travel as far as Alaska (S. Allen, National Park Service, unpublished data); see also www.topp.org - Tagging of Pacific Predators.

Each year at Año Nuevo Island and the adjacent mainland, there are approximately 2,400 females and 300-400 males present, and approximately 2,200 pups are produced (Morris, pers. comm., 2003). Based on pup counts, the population there steadily increased through the mid 1990s, but now appears to be stable (Morris, pers. comm., credited to B.J. Le Boeuf). In 2004, 2,035 weaners were counted on Año Nuevo Island and mainland, and all live counts during February 2004 tallied 3,875 animals (Morris, pers. comm., 2006).

In contrast, the colony at Piedras Blancas has generally continued to increase (Hatfield, pers. comm.). In 2004, 3,000 pups were counted and the estimated number of elephant seals that use this colony is 10,500 – 13,500. To the north, at Gorda (Cape St. Martin), 300 pups were counted in 2004, and the estimated numbers that use the Gorda colony is 1,050 – 1,350. Total population at Pt. Reyes was estimated to be 2,000 in 2006 (S. Allen, pers.comm.).

Overall, productivity has declined at two major breeding sites on Southeast Farallon Island (Sydeman and Allen, 1999; Nusbaum, 2002), with erosion playing a major role in limiting the species' population (USFWS, 2000). In California, the net productivity rate for northern elephant seals also appears to have declined in recent years (Carretta *et al.,* 2002). However, the colony at Point Reyes Headlands has continued to increase by 5-10% per year (Sydeman and Allen, 1999; Allen, pers. comm., 2003).

Due to the high surf during the strong El Niño of 1998, extensive pup mortality occurred at the Point Reyes colony (Pettee, 1999), but also forced the relocation of the breeding area; some moved from the main colony at Point Reyes Headlands to South Beach and North Drakes Bay Beach (Pettee, 1999). During winter counts in 2003-2004, maximum adult elephant seals at Pt. Reyes (North Drakes Beach, Pt. Reyes Headlands, and South Beach) were 123, 483, and 35, respectively. In 2005-2006, maximum counts (based on direct counts) of adult elephant seals during the winter breeding season at Pt. Reyes (North Drakes Beach, Pt. Reyes Headlands, and South Beach) were 295, 459, and 79, respectively. The estimated number of pups born in 2006 at these three areas was 746 (S. Allen, pers. comm.).

Northern elephant seals have been known to haulout at other sites (e.g., Grimes Point), but only haulouts/rookery sites from 2003-2004 are shown on the map. Other rookeries/haulout sites south of the study area are located at the Channel Islands on San Nicolas Island, Santa Barbara Island, and San Miguel Island, and off Baja California, Mexico on Isla San Benito, Isla de Guadalupe, Isla Cedros, and Isla Los Coronado.

Human related sources of mortality include: takes from drift gillnet fisheries for swordfish and sharks (from both the U.S. and Mexico population), set gillnets (number of set gillnet vessels off Baja is unknown), hook-and-line fisheries, boat and automobile collisions, and illegal shooting (Carretta *et al.,* 2002; Carretta *et al.,* 2006).

Northern elephant seals are capable of prolonged deep dives and feed on deepwater fishes and invertebrates, including Pacific hagfish (*Eptatretus stouti*), ratfish (*Hydrolagus colliei*), Pacific hake, rockfish, sharks, rays, crab, squid, octopi, and euphausiids (Antonelis, Jr. *et al.,* 1987; Condit and LeBoeuf, 1984).

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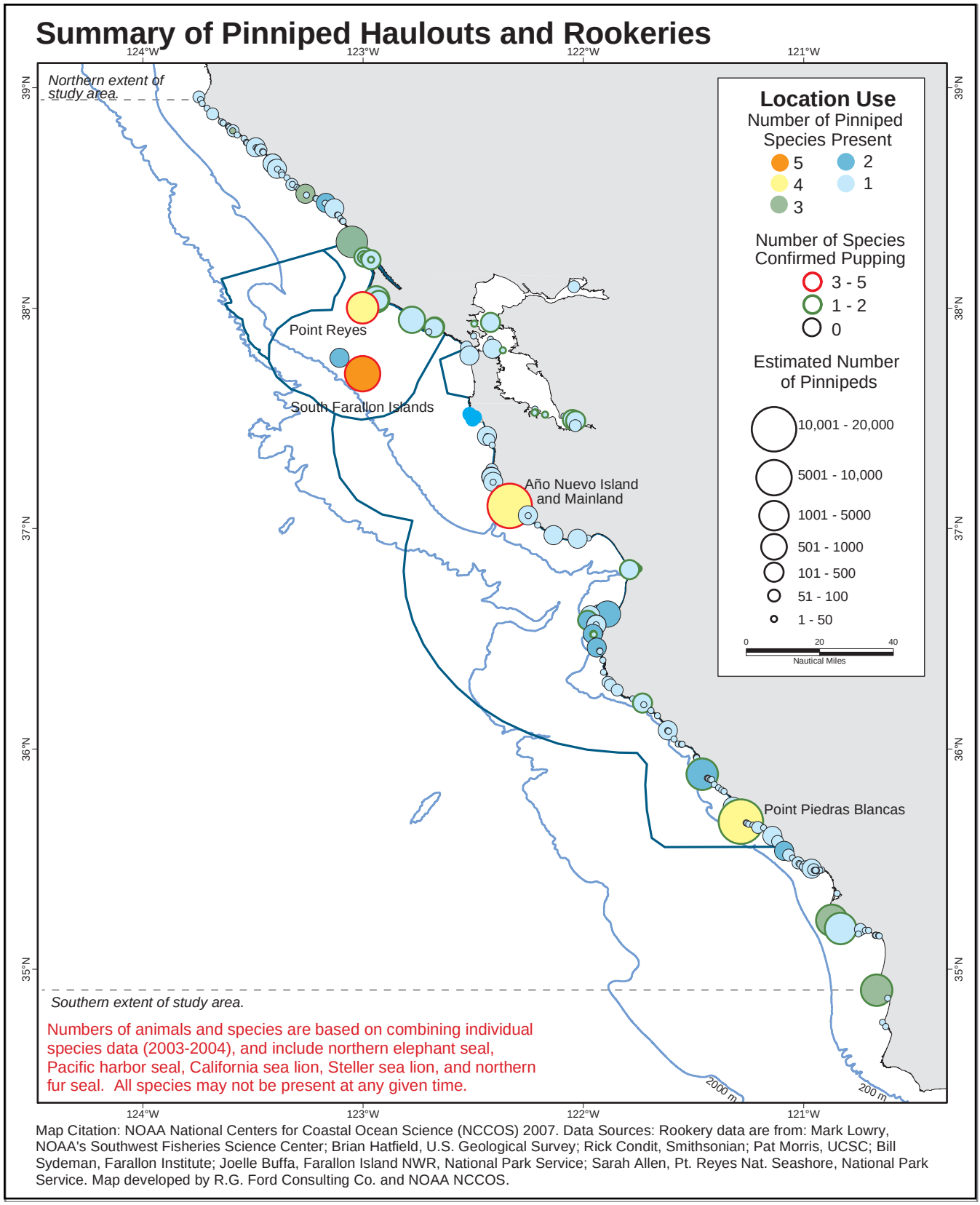

Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Sources: Rookery data are from: Mark Lowry, NOAA's Southwest Fisheries Science Center; Brian Hatfield, U.S. Geological Survey; Rick Condit, Smithsonian; Pat Morris, UCSC; Bill Sydeman, Farallon Institute; Joelle Buffa, Farallon Island NWR, National Park Service; Sarah Allen, Pt. Reyes Nat. Seashore, National Park Service. Map developed by R.G. Ford Consulting Co. and NOAA NCCOS.

Figure 4.14. Summary of pinniped shore zone use of haulouts and rookeries; see map and description for data sources.

ABOUT THIS MAP

Figure 4.14 contains a map of pinniped haulout and rookery sites in the north/central California study area and was developed to summarize pinniped coastal habitat use for important life cycle functions (breeding, pupping, and resting). Different subareas of a site are typically used by each species, but estimated numbers of pinnipeds using each haulout or rookery site have been combined to present a composite count for this display. The number of species using each site and the number of species producing pups at that site are indicated by the color and border of the symbols. Together with the summary bird colony map (Figure 3.42), this summary pinniped map demonstrates the importance of key coastal habitat to more than 20 marine bird and mammal species. Data for the following pinniped species are included: California sea lion, Pacific harbor seal, Steller sea lion, northern fur seal, and northern elephant seal. See also Figure 4.15, a map of estimated species richness for pinnipeds at sea.

DATA SOURCES AND METHODS

Pinniped haulout and pupping activities are monitored by a variety of sources; providers of the data used in this map are as follows: Mark Lowry of NOAA/NMFS' Southwest Fisheries Science Center provided pup and haulout data for California sea lion (2003-2004), Steller sea lion (2003-2004), and for the overview map for Pacific harbor seal (2004); Sarah Allen of Point Reyes National Seashore, National Park Service provided 2006 data for harbor seals at Pt. Reyes. William Sydeman of PRBO Conservation Science, and Joelle Buffa of the Farallon Islands National Wildlife Refuge, FWS provided information from 2004 on the northern fur seal rookery at Southeast Farallon Island; and haulout and pup data on northern elephant seals were provided by: Brian Hatfield, USGS; Joelle Buffa, FWS; Bill Sydeman, PRBO; Pat Morris, University of California, Santa Cruz; and Richard Condit, Smithsonian Institution.

Data from 2003-2004 were combined for each site from available pinniped haulout/rookery data. Counts from aerial surveys were used for Pacific harbor seal, California sea lion, and Steller sea lion. Harbor seal counts were from 2004; for both sea lion species the higher of the 2003 or 2004 counts was used. For northern elephant seal, the midpoint of the range of estimated total 2004 attendance was used, and northern fur seal numbers were also estimated. Species-specific counts were summed for each site; these totals were used to assign the various sites to generalized size classes in order to create an overall map that reflects the abundance and distribution of pinnipeds on shore.

RESULTS AND DISCUSSION

Although pinnipeds spend much of their lives in the water, they come ashore to breed, pup, and molt and rest. This map summarizes terrestrial habitat use of these marine mammals, still tied to the land, and clearly indicates how much of the central California coastline and offshore islands and islets are well used by the five species of pinnipeds in the study area.

The central California coast is characterized by a great diversity of shoreline habitat types, including boulder/rocky beaches, a variety of sandy beaches, sand spits, sand bars, estuaries, sloughs and mudflats. Some of these areas are exposed rocky shorelines where others are more protected from storms and high surf action. Besides habitat type, a variety of factors influence the choice of site selection that pinnipeds make for haulouts and rookeries, e.g., presence of marine predators, disturbance, currents, undersea topography, tidal height, and the proximity of the sites to regions of high ocean productivity (food). For example, in a study on haulout use and rookery characteristics of Steller sea lions, Ban and Trites (2007) reported site selection likely involves either an optimization or compromise of two factors: the nearness to favorable foraging areas, and the degree of difficulty in entering or exiting the water during different tidal heights. For all pinnipeds in the study area, availability and accessibility to suitable, undisturbed habitat for breeding and, most importantly, parturition (birthing), are crucial for long-term survival of pinniped populations. In addition to the great diversity of natural habitats, man-made structures (e.g., docks and piers used by California sea lions, and sometimes Steller sea lions), provide additional terrestrial habitat. Although all species prefer isolated and undisturbed areas, some species, such as the California sea lion and harbor seals, may habituate to human presence.

The timing ashore at the breeding and rookery/pupping sites varies among species. Four of the

five pinnipeds in the study area (California sea lion, Steller sea lion, harbor seal, northern fur seal) use terrestrial habitats for breeding in spring and early summer; whereas the northern elephant seal breeds December through March. The patterns revealed in this summary map reflect both the year-round and seasonal use; year-round use (e.g., harbor seals and California sea lions) is more widespread, whereas seasonal use (e.g., elephant seals) is more concentrated. Except for northern elephant seals that fast during breeding, pupping and lactation, one of the most important criteria for habitat selection for the pinnipeds in the study area is likely proximity to productive foraging areas in the waters off central California.

Based on this analysis and set of data (2003-2004), pupping for all five pinniped species occurs on the Southeast Farallon Islands, and is reported for four species on Año Nuevo Island and Mainland, and three species at Point Reyes.

Spatial patterns of occupancy among species varied between widespread use throughout the year (most of the one-species sites presented on the map are harbor seals) and more concentrated seasonal use, e.g., the elephant seal during winter breeding season. Note also that the relatively high animal counts at Año Nuevo Island and mainland, Point Piedras Blancas, Southeast Farallon Island, and Point Reyes are driven by: 1) the occupancy of elephant seals during their winter breeding/pupping season; 2) California sea lions after their breeding/pupping season and before their next breeding/pupping season (fall-winter-early spring); and 3) relatively large numbers of harbor seals that are present year round at Point Reyes. The pattern of high species richness and relatively greater numbers of individuals at these four locations highlights the importance of these areas for the four species discussed above, and also highlights the importance of Southeast Farallon Islands for the northern fur seal that recently (1996) started breeding/pupping at these islands.

In summary, the shoreline along the north/central California study area is intensely used by five pinnipeds for haulouts, pupping, molting and resting. The amount of use at each site varies annually and is determined by a variety of conditions (e.g., disturbance, accessibility, prey availability). In the study area, harbor seals use islands, remote mainland coasts, bays, estuaries, and sloughs; their terrestrial distribution was widespread along the full extent of the coast in the study area. California sea lions use islands, remote mainland beaches, and piers, and their distribution was also relatively widespread. In contrast, distribution is more concentrated for species that use specific islands and mainlands for breeding/pupping. For example, Steller sea lions use islands and rocky islets, elephant seals use islands and remote mainland beaches, and northern fur seals use islands.

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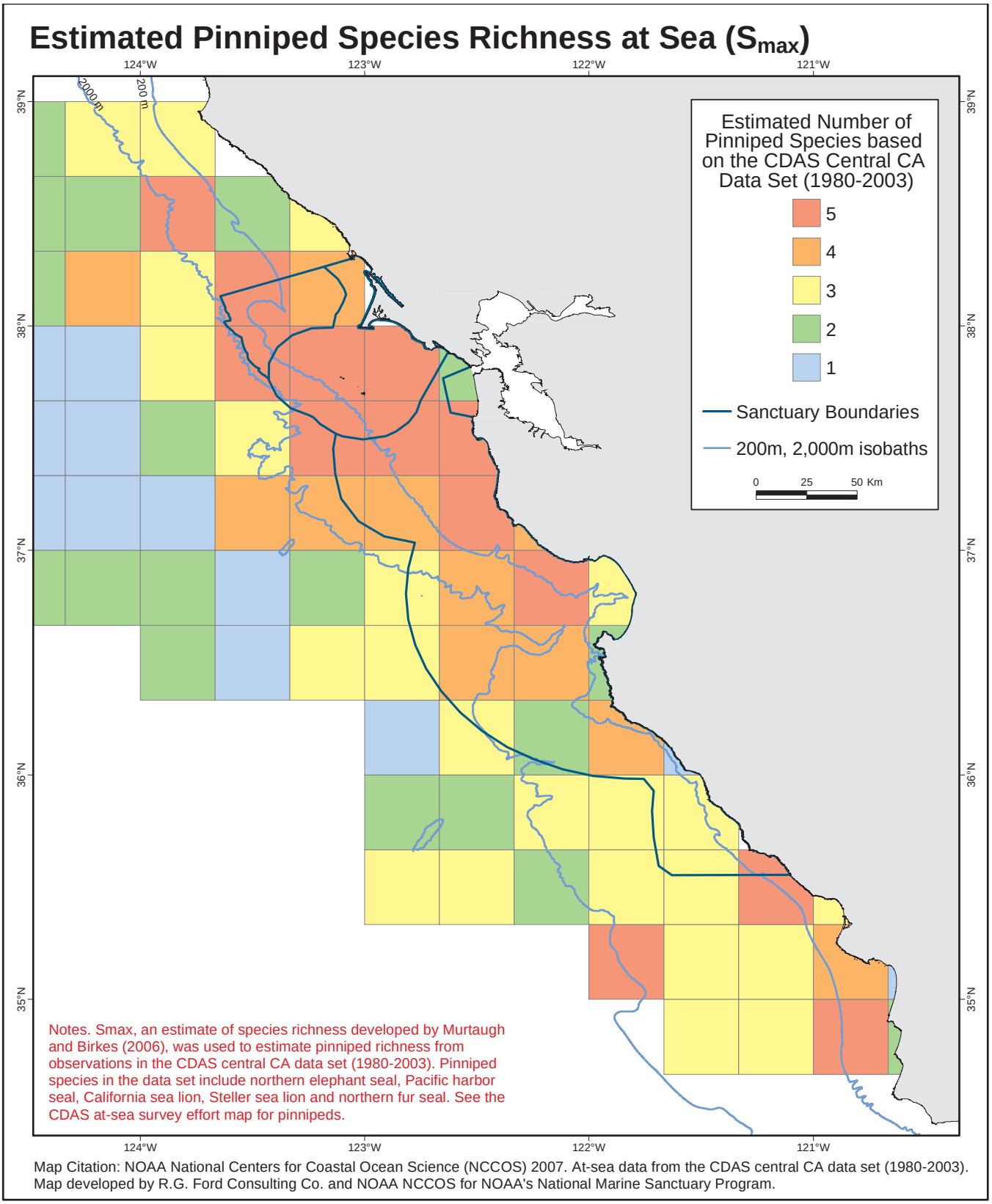

Figure 4.15. Map of estimated species richness for pinnipeds (seals and sea lions), based on the CDAS central California data set (1980-2003).

ABOUT THIS MAP

Figure 4.15 is a map of species richness for pinnipeds (seals and sea lions), at sea off north/central California, based on the CDAS central California data set (1980-2003). Richness refers to the number of species that are

in a geographic region, and is an indicator of community structure and composition. Richness is not a measure of community diversity, which combines both number of species and relative density into a single index. Richness is an explicit measure of the number of species present in a community and is independent of their relative abundances.

The color and mapping intervals were selected to emphasize spatial structure and to highlight significant areas. Areas not surveyed appear white; no information is available for these areas. See below and the Data and Analyses section of this chapter for more information on the data and methods.

DATA SOURCES AND METHODS

Observations of marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using the Marine Mammal and Seabird Computer Data Analysis System (CDAS), developed by the R.G. Ford Consulting Co. This data set contains data from eight major survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area, and offshore to the extent of data availability. See the Data and Analyses section of this chapter for information on the at-sea survey data sets.

The number of species in a community or geographic region is a basic descriptive parameter that has been widely studied and utilized (Ludwig and Reynolds, 1988). In practice, however, estimating the number of species is difficult because there is a strong relationship between sampling intensity and the number of different species detected, a situation exactly analogous to the species-area curve described by MacArthur and Wilson, 1967. In general, the number of species detected increases as the intensity of sampling increases. The relationship is typically asymptotic, and eventually additional sampling effort within the same geographic region yields no new species. The estimates of species richness presented here are based on approximations of the asymptotic limit of the species-sampling relationship. Although measures of richness are designed to be independent of effort, Figures 4.1 and 4.2 show summary maps of CDAS sampling effort for pinnipeds and cetaceans for comparison.

To estimate pinniped richness S_{max} was used, a statistical species richness estimator developed by Murtaugh and Birkes (2006). This metric has been shown to work well on the type of data used in this study. This method infers the asymptotic limit of the species curve, i.e. the estimated number of species that would be found if the survey effort were very large, estimated using the relative frequency of observations of different species. For our purposes, we defined a single observation as being the sighting of either one individual or of a group, since the detection of an individual was equivalent to detecting the entire group. For pinnipeds, richness estimates were calculated for 20' x 20' latitude-longitude cells.

RESULTS AND DISCUSSION

The CDAS survey database (1980-2003) for north/central California includes sightings of five pinniped species. Except for the occasional Guadalupe fur seal, all pinniped species known to occur in the study area were recorded in the CDAS database.

Combining all years and seasons of the at-sea CDAS data, the distribution of pinniped species richness at sea showed several patches of high species richness. These areas occurred over the shelf, slope, and deep ocean habitats, both within and outside of the National Marine Sanctuary boundaries in the study area. Richness estimates for these species ranged from one to five, with five being the maximum number of pinnipeds evaluated for this study (Guadalupe fur seal was not included).

Relatively high richness estimates of four and five pinniped species occurred in the following areas:

- throughout and adjacent to all of the Cordell Bank NMS, including one 20' cell about 30 km west and another 20' cell 25 km northwest;
- throughout and adjacent to all of the Gulf of the Farallones NMS (GFNMS);
- throughout over half of the Monterey Bay NMS area, including the shelf and slope from the GFNMS bound south to about Pt. Año Nuevo, where the high richness area widens to include waters over the shelf, slope and deepwater habitats associated with Monterey Canyon, as well as an area off Pt. Sur, including Sur shelf and Sur canyon system;
- three 20' shelf and upper slope cells extending south from Pt. Piedras Blancas to just off Pt. Sal; and
- one 20' cell, about 80 km west of Pt. San Luis and straddling the 2,000 m contour.

All study area cells in the CDAS Central CA data set had at least one pinniped species recorded in it, and over half of the cells had three-to five pinniped species; average pinniped richness was 2.73 pinniped species per cell. This average is likely low, as pinnipeds are likely undersampled at sea in the study area.

These areas of estimated species richness are likely associated with important foraging areas and pinniped haulouts and rookeries, such as the major haulouts at Point Reyes, the Farallon Islands, Point Año Nuevo, and Pt. Piedras Blancas; see Figure 4.14, the summary pinniped haulout and rookery map.

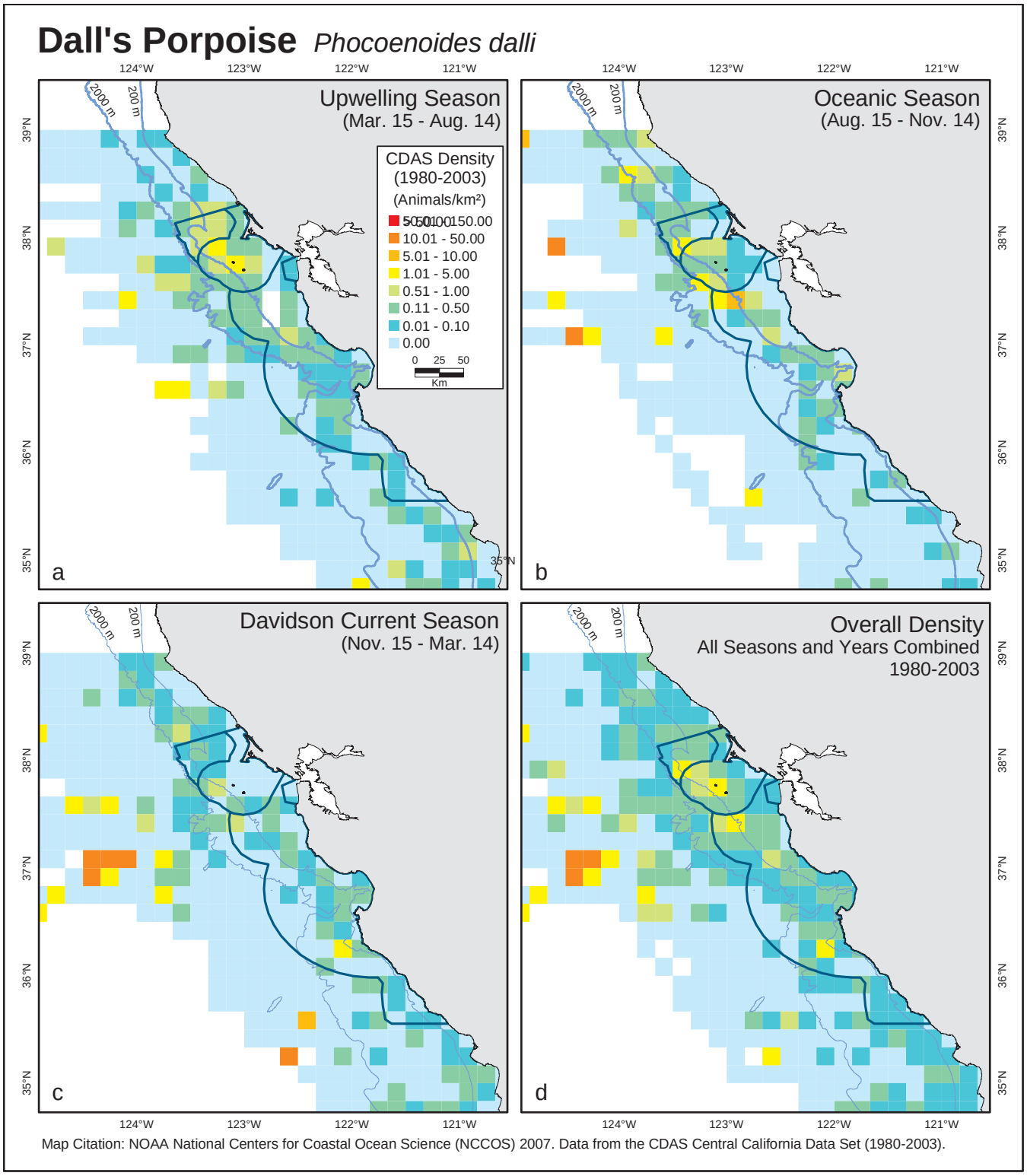

Figure 4.16. Maps for Dall's porpoise: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figure 4.16a, b and c show the densities (animals/km²) of Dall's porpoise (*Phocoenoides dalli*) in the Upwelling, Oceanic, and Davidson Current seasons, displayed in cells of 10' latitude by 10' longitude. Figure 4.16d shows the overall density combining all three seasons. Densities are based on combined data of several ship-based and aerial survey studies conducted from 1980-2003; see Data Sources below and the Data and Analyses section of this chapter for more information. The color and mapping intervals

were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no Dall's porpoise were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

Dall's porpoise is widely distributed and endemic to temperate waters of the North Pacific Ocean; it is one of the most commonly sighted cetaceans in the study area and can be found year-round in Monterey Bay, especially near canyon edges (Monterey Bay Whale Watch, 2007). And although it is commonly seen off southern California in winter, the southern end of this population's range is not well-documented (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Although this species occurs outside the U.S. Exclusive Economic Zone (EEZ), within the Pacific U.S. EEZ, Dall's porpoises are divided into two discrete, non-contiguous areas: (1) waters off Washington, Oregon, and California, and (2) Alaskan waters (Carretta *et al.,* 2004).

In the study area and the CDAS central California data set (1980-2003), Dall's porpoise was the fourth most numerous small cetacean, with 818 sightings of 3,342 individuals. This species was the most commonly sighted (number of sightings) of the small cetaceans and was present during all seasons. Overall density distribution of Dall's porpoise was widespread over the shelf, slope, and deep ocean habitats; densities were slightly greater in the northern half of the study area. The distribution of Dall's porpoise is highly variable among years and appears to be affected by oceanographic conditions (Forney and Barlow, 1998). North-south movement of this species occur as oceanographic conditions change on seasonal and interannual time scales (Green *et al.,* 1992; Barlow, 1995; Forney *et al.,* 1995). In general, the absence of sightings of this species in the CDAS data set may reflect the distribution of spatial and temporal survey effort rather than absence from the survey area; the maps shown likely do not reflect the total distribution of the species in the study area.

See an additional map (Figure 4.29) for Dall's porpoise later in this chapter; the data are from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

There are no known habitat issues of concern for the Dall's porpoise and the species is not listed as "threatened", "endangered", or "depleted". Insufficient data, however, prohibit evaluation of potential trends in abundance (Carretta *et al.,* 2004).

Due to drift gillnet fisheries for sharks and swordfish, human-related sources of mortality and serious injury may occur off Baja California, Mexico, where drift gillnetting occurs along the entire Mexican coast (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Off California, Oregon, and Washington, low levels of mortality have been documented in the domestic groundfish trawl fisheries, however, the total fishery mortality and serious injury for this stock is considered to be insignificant (Carretta *et al.,* 2004). In the Western and Central North Pacific, relatively large numbers of Dall's porpoise have been recorded as mortalities in passive fishing gears (Alverson *et al.,* 1995).

Dall's porpoise feeds mostly on Pacific hake (*Merluccius productus*), northern anchovy (*Engraulis mordax*), Pacific saury (*Cololabis saira*), juvenile rockfish (*Sebastes spp*), and cephalopods (Koskii *et al.,* 1998; Morejohn, 1979).

Sophie Webb

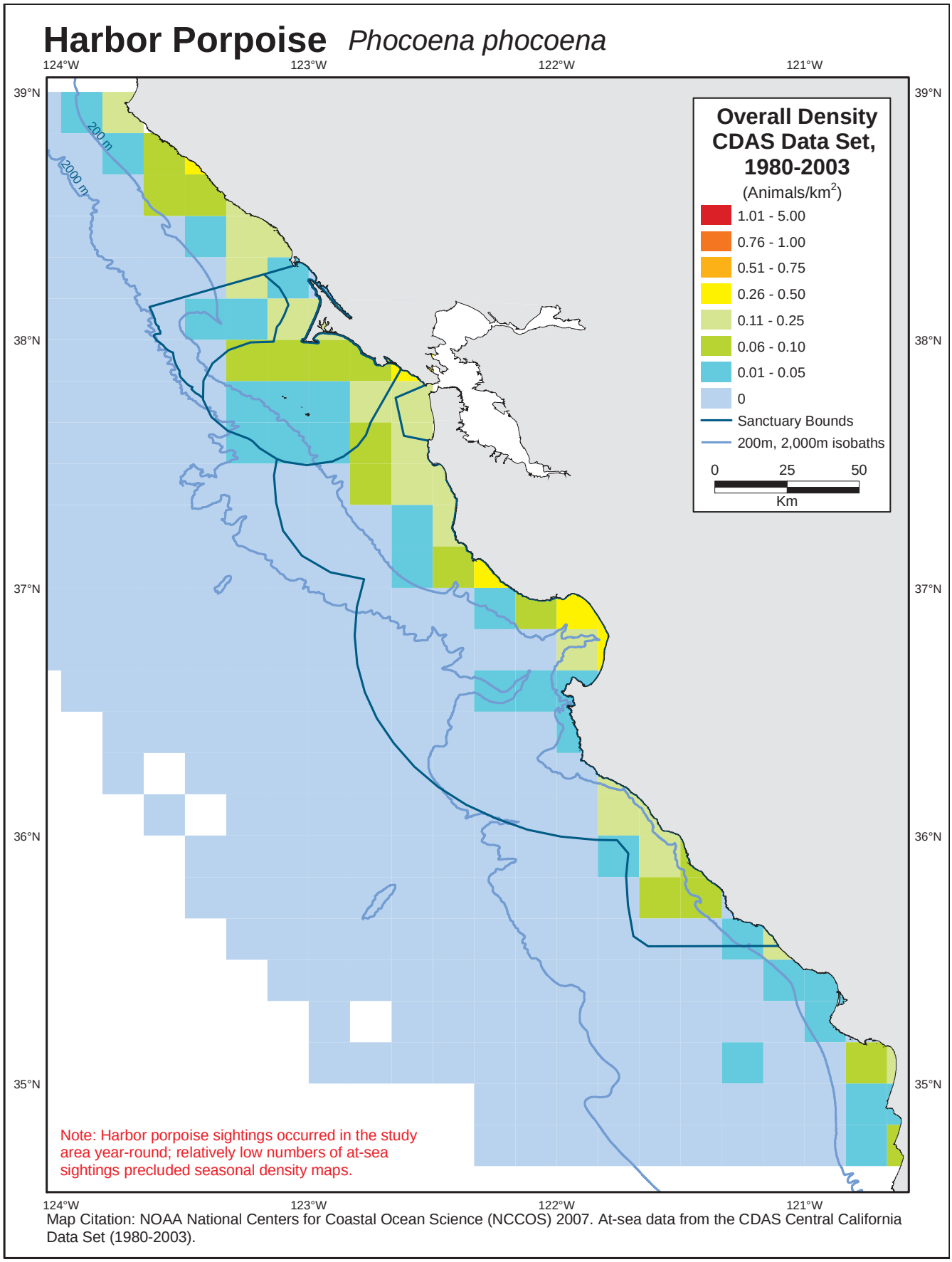

Figure 4.17. Map for harbor porpoise: overall density from the CDAS central California data set (1980-2003).

ABOUT THIS MAP

Figure 4.17 shows the overall density for harbor porpoise (*Phocoena phocoena*) in the CDAS central California data set (1980-2003). Cell size is 10' latitude by 10' longitude, and contain data in all available seasons from 1980-2003. Corrections to density estimates were made for sightability, time spent underwater, or not seen. The harbor porpoise is one of the most commonly sighted cetaceans in the study area. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no harbor porpoises were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

Although protected under the Marine Mammal Protection Act, the harbor porpoise is not listed as Federally threatened or endangered under the Endangered Species Act. Eight stocks of harbor porpoise are identified off the coasts of California, Oregon and Washington and Alaska; three of these stocks occur in the north/central California study area of this assessment: Morro Bay, Monterey Bay, and the San Francisco-Russian River (Carretta *et al.,* 2006). The harbor porpoise occurs year-round in the study area, mostly in the coastal ocean, and occasionally in bays, harbors and estuaries; confirmed estuarine sightings occurred in San Pablo Bay, San Francisco Bay, Tomales Bay and Elkhorn Slough (Harvey, Keiper, Allen, pers. comm.). In the CDAS central California data set (1980-2003), the harbor porpoise was the fifth most numerous small cetacean sighted, with 577 sightings and 1,160 individuals.

In the CDAS data used in this study, harbor porpoise occurred over the shelf, and mostly in nearshore areas over the inner shelf, and in all three central California national marine sanctuaries. Harbor porpoise sightings range to the north and south of the study area and although seasonal movements appear to be limited, they respond to seasonal or interannual changes in ocean conditions and food availability (Carretta *et al.,* 2001). The mapped occurrence pattern only confirms that harbor porpoises have been sighted in certain areas; rather than a real absence from an area, the absence of sightings may reflect insufficient survey effort.

See an additional map for harbor porpoise in Figure 4.29, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

Harbor porpoise stocks were impacted by incidental fishing mortality, mostly from gillnet fisheries, until the 2002 closure of this fishery, inshore of the 60 fathom (110 m) isobath.

Harbor porpoises feed on a variety of small, schooling fishes and cephalopods including squid, herring, anchovies, hake and rockfish. See tables in this chapter on population estimates, spatial occurrence and life history and management for more information on this species.

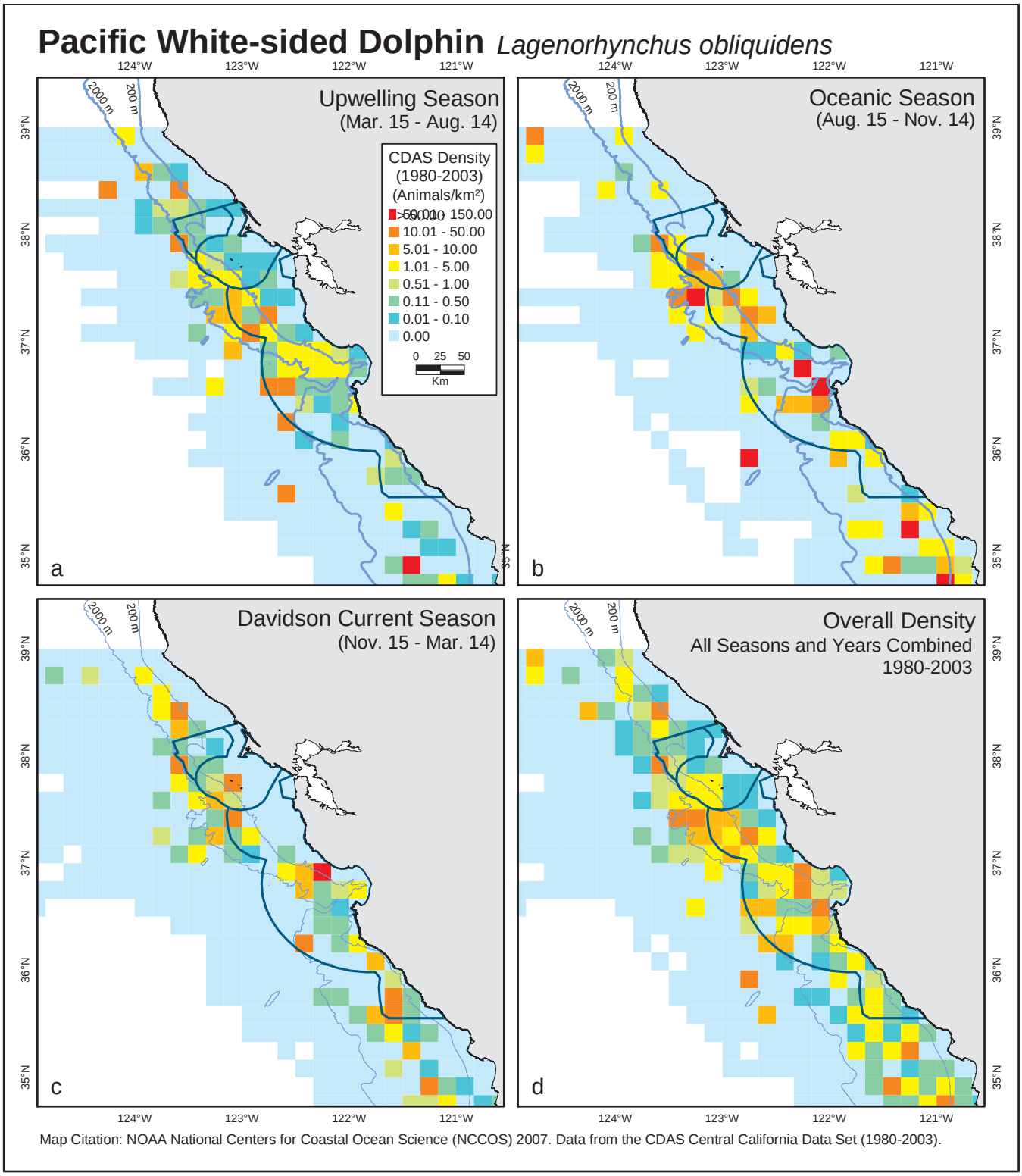

Figure 4.18. Maps for Pacific white-sided dolphin: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figure 4.18 a, b and c show the density (animals/km^2) of Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) in three ocean seasons - Upwelling, Oceanic, and Davidson Current, displayed in cells of 10' latitude by 10' longitude. Figure 4.18 d shows the overall density combining all three seasons. Densities are based on the combined data sets of several studies; see Data Sources below and the Data and

Analyses section of this chapter for more information. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no Pacific white-sided dolphin were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called 'Marine Mammal and Seabird Computer Data Analysis System' (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

The Pacific white-sided dolphin is an endemic species of the temperate waters of the North Pacific Ocean and is one of the most abundant dolphin species in the eastern North Pacific. Two forms are known to occur off the California coast (Carretta *et al.,* 2004; Walker *et al.,*1986; Chivers *et al.,* 1993), however, because there are no known differences in color patterns, it is currently not possible to distinguish animals without genetic or morphometric analyses (Carretta *et al.,* 2004). Pacific white-sided dolphins that occur within the U.S. Exclusive Economic Zone are divided into two discrete, non-contiguous areas: 1) Alaskan waters, and 2) waters off Washington, Oregon, and California. In the CDAS central California data set (1980-2003), the Pacific white-sided dolphin was the most abundant of the cetaceans (605 sightings of 41,984 individuals). Pacific white-sided dolphins occurred throughout the study area during all oceanographic seasons, mostly over the outer shelf, slope, canyons, and other deep ocean habitats. Densities were generally greater over the outer shelf and slope habitats and along canyon edges. Highest overall seasonal density in the CDAS data set was in the Oceanic season and lowest in the Upwelling season.

The occurrence of Pacific white-sided dolphins in the study area is highly variable; this species responds to oceanographic conditions on both seasonal and interannual time scales (Forney and Barlow, 1998). In a study in Monterey Bay (Black, 1994), group size and relative abundance of the Pacific white-sided dolphin varied seasonally and were greater during the Oceanic and Davidson Current Seasons than during the Upwelling Season, when relative individual and group abundance was low and group sizes were small (not shown in maps). Also, in habitats over and near shelf-breaks and greater bottom relief, feeding behavior was observed more than other behaviors (Black, 1994). In general, the absence of sightings of Pacific white-sided dolphins in the CDAS data set may reflect the distribution of spatial and temporal survey effort rather than absence from the survey area; the maps shown likely do not reflect the total distribution of the species in the study area.

See an additional map for this species in Figure 4.28, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

There are no known habitat issues of concern for the Pacific white-sided dolphin and it is not listed as "threatened", "endangered", or "depleted". Insufficient data prohibit evaluation of potential trends in abundance (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Due to drift gillnet fisheries for sharks and swordfish, human-related sources of mortality and serious injury may occur off Baja California, Mexico, where drift gillnetting occurs along the entire Mexican coast. (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Off California, Oregon, and Washington, low levels of mortality of the Pacific white-sided dolphin have been documented in the domestic groundfish trawl fisheries; however, the total fishery mortality and serious injury for this stock is considered to be insignificant. (Carretta *et al.,* 2004; Carretta *et al.,* 2006).

Prey of the Pacific white-sided dolphin includes: Pacific whiting, northern anchovy, rockfish, Pacific saury, and market squid (*Loligo opalescens*) (Stroud *et al.,* 1981; Black, 1994).

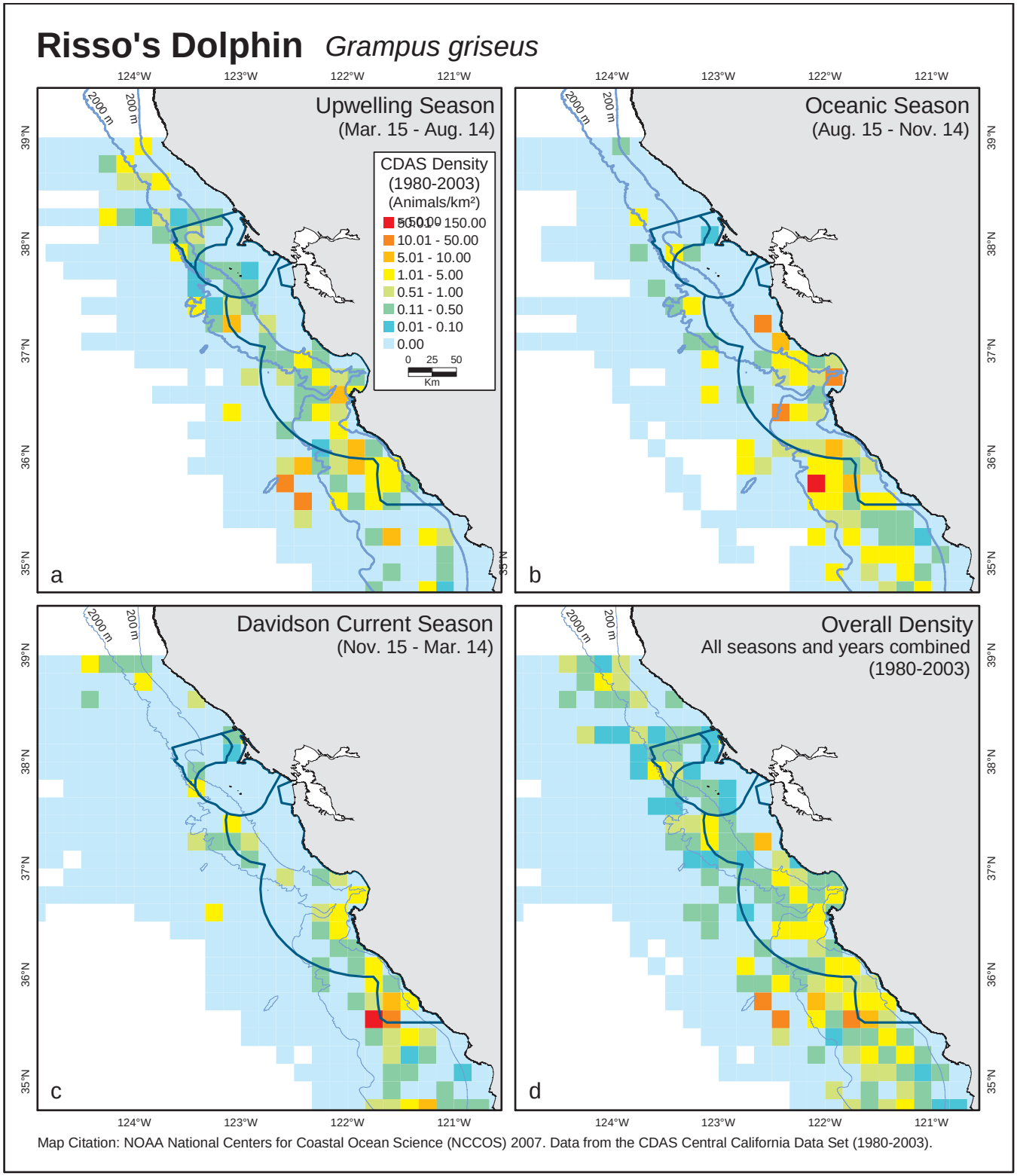

Figure 4.19. Maps for Risso's dolphin: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figures 4.19 a, b and c show the density (animals/km^2) of Risso's dolphin (*Grampus griseus*) in the Upwelling, Oceanic, and Davidson Current seasons, displayed in 10'x10' cells. Figure 4.19 d shows the overall density combining all three seasons. Densities are based on combined data of several ship-based and aerial survey studies conducted from 1980 to 2003; see Data Sources below and the

Data and Analyses section of this chapter for more information. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no Risso's dolphin were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

The Risso's dolphin is distributed in tropical and warm-temperate ocean waters world-wide (Carretta *et al.,* 2004), including waters off the U.S. west coast. Within the U.S. Exclusive Economic Zone, Risso's dolphins are divided into two, discrete, non-contiguous areas: 1) waters off Washington, Oregon, and California, and 2) Hawaiian waters. (Carretta *et al.,* 2004; Carretta *et al.,* 2006). The distribution of Risso's dolphin off California, Oregon, and Washington is highly variable, apparently in response to seasonal and interannual oceanographic changes (Forney and Barlow, 1998). Dolphins found off California during colder water months are thought to shift northward into Oregon and Washington as water temperatures increase in late spring and summer (Carretta *et al.,* 2001; Green *et al.,* 1992).

In the study area, the species is widely distributed over outer shelf, slope, canyon and deep ocean habitats, both in and beyond all three sanctuaries. Risso's dolphin was the third most abundant cetacean in the CDAS central California data set (1980-2003); 373 sightings of 17,042 individuals occurred across all seasons; the Davison Current seaon had the highest overall seasonal density and the Upwelling season had the lowest. Overall higher densities of Risso's dolphins occurred in the central and southern portions of the study area, mostly in waters of the Monterey Bay National Marine Sanctuary and to the west and south. In general, the absence of sightings of Risso's dolphins in the CDAS data set may reflect the distribution of spatial and temporal survey effort rather than absence from the survey area; the maps shown likely do not reflect the total distribution of the species in the study area.

See an additional map for this species in Figure 4.28, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December of 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

There are no known habitat issues of concern for the Risso's dolphin, and the species is not listed as "threatened", "endangered", or "depleted". Insufficient data prohibit evaluation of potential trends in abundance (Carretta *et al.,* 2004; Carretta *et al.,* 2006).

Due to drift gillnet fisheries for sharks and swordfish, human-related sources of mortality and serious injury may occur off Baja California, Mexico, where drift gillnetting occurs along the entire Mexican coast (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Off California, Oregon, and Washington, low levels of mortality of Risso's dolphin have been documented in the domestic groundfish trawl fisheries (Carretta *et al.,* 2004; Carretta *et al.,* 2006). The total fishery mortality and serious injury for this stock is considered to be insignificant. However, an additional mortality of unknown extent documented off Southern California is associated with the squid purse seine fishery (Carretta *et al.,* 2004; Carretta *et al.,* 2006; Heyning *et al.,* 1994).

Risso's dolphin feed almost exclusively on squid (Koski *et al.,* 1998; Orr, 1966).

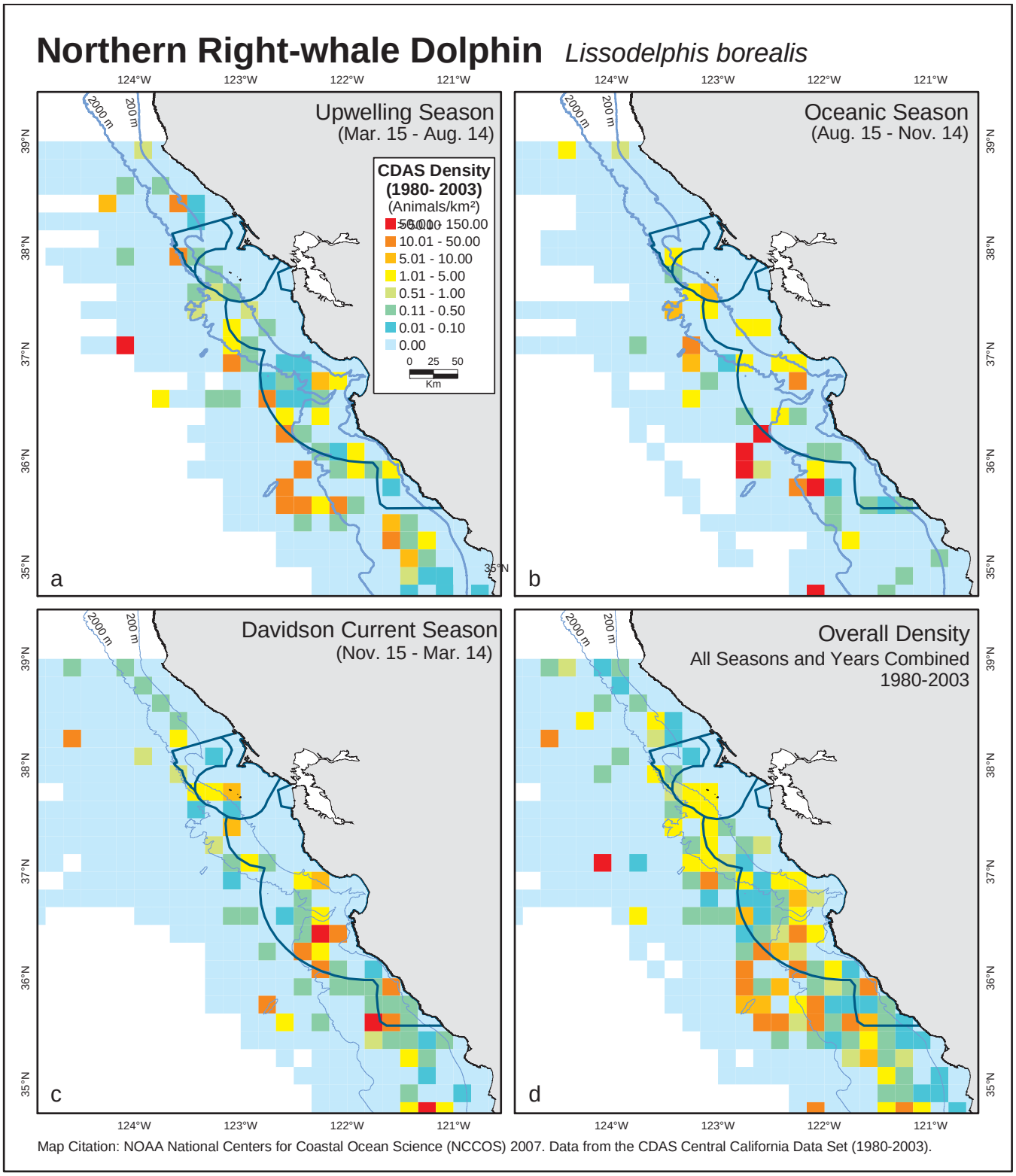

Figure 4.20. Maps for northern right-whale dolphin: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figures 4.20 a, b and c show the density (animals/km^2) of northern right whale dolphins *(Lissodelphis borealis)* in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 10' latitude by 10' longitude. Figure 4.20 d shows the corrected overall density combining all three seasons. Densities are based on the combined data sets of several studies conducted from 1980-2003; see Data Sources below and the Data

and Analyses section of this chapter for more information. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no northern right whale dolphins were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

The northern right whale dolphin is endemic to temperate waters of the North Pacific Ocean and occurs primarily in shelf, slope, and to some degree, deep ocean waters off the U.S. west coast. Although the southern end of this population's range is not well-documented, during cold-water periods, they likely range south into Mexican waters off northern Baja California (Carretta *et al.,* 2004; Carretta *et al.,* 2006). In the study area and the CDAS data set, this species occurred mostly over the outer shelf, slope, canyon, and deep ocean habitats, both within and beyond National Marine Sanctuary boundaries. The species was sighted in all three sanctuaries in all three ocean seasons, but mostly in the central and southern portion of Monterey Bay National Marine Sanctuary, and in waters to the west and south. In the CDAS central California data set (1980-2003), the northern right whale dolphin was the second most abundant cetacean, with 262 sightings of 33,856 individuals; overall seasonal density was highest in the Davidson Current season and lowest in the Upwelling season.

Northern right whale dolphins are found primarily off California during colder-water months and shift northward into Oregon and Washington as water temperatures increase in late spring and summer (Forney and Barlow, 1998). Although patterns of seasonal abundance have been observed throughout their range, there is no information to indicate that large numbers move between California, Oregon, and Washington waters (Green *et al.,* 1992).

The occurrence of northern right whale dolphin is highly variable; this species responds to oceanographic conditions on both seasonal and interannual time scales (Carretta *et al.,* 2001; Green *et al.,* 1992). In general, the absence of sightings of northern right whale dolphins in the CDAS data set may reflect the distribution of spatial and temporal survey effort rather than absence from the survey area; the maps shown likely do not reflect the total distribution of the species in the study area.

See an additional map for this species in Figure 4.28, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

Although human related sources of mortality and serious injury for the northern right-whale dolphin are associated with drift gillnet fisheries off California, Oregon, and Washington, entanglement rates vary among years and entanglements are relatively rare (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Commercial fisheries that may take this species include the thresher shark/swordfish drift gillnet fishery of California and Oregon (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Animals from this population of northern right-whale dolphins may also be taken in the drift gillnet fisheries for swordfish and sharks that exist along the entire Pacific coast of Baja California. Data are insufficient to evaluate trends in stock abundance and no habitat issues are known for this species (Carretta *et al.,* 2004; Carretta *et al.,* 2006). Although the northern right-whale dolphin is not listed as "threatened", "endangered" or "depleted", the total fishery mortality and serious injury for northern right-whale dolphins is greater than 10% of the calculated Potential Biological Removal (PBR) and cannot be considered to be insignificant and approaching zero mortality and serious injury rate (Carretta *et al.,* 2004).

Northern right whale dolphins feed on mesopelagic fishes (e.g., lanternfish) and squid (Leatherwood and Reeves, 1983).

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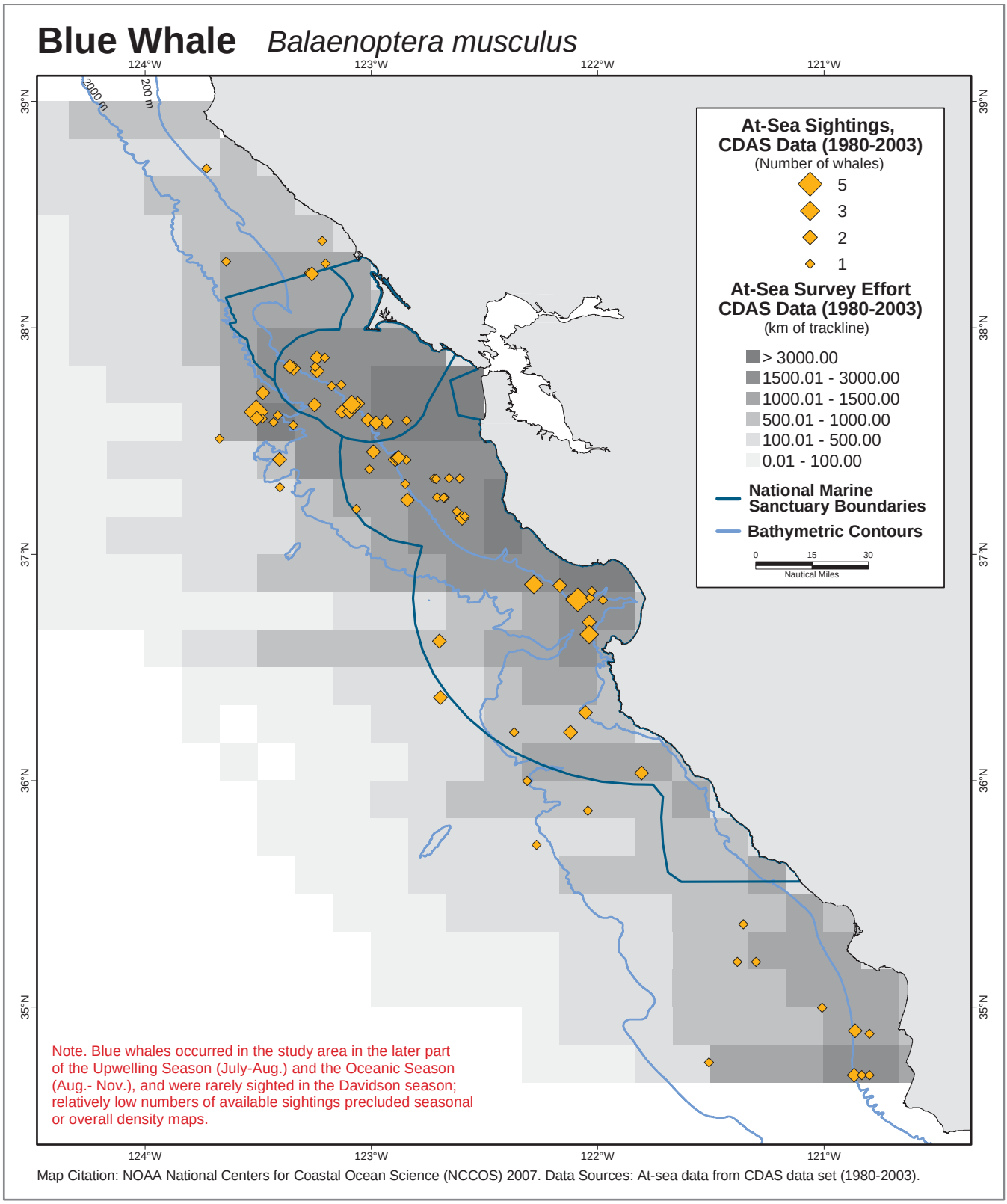

Figure 4.21. Map for blue whale: sightings and survey effort data from the CDAS central California data set (1980-2003).

ABOUT THIS MAP

Figure 4.21 shows the individual sightings of blue whales (*Balaenoptera musculus*) at sea, along with at-sea survey effort from the CDAS data set (1980-2003). Due to insufficient sightings in the CDAS data set (88 sightings of 133 individuals) for the study area, density maps were not generated for the

blue whale. At-sea sightings for cetaceans are from several studies (see "Data and Analyses" section of this chapter). For context, the combined survey effort is also shown, summarized in 10'x10' cells.

DATA SOURCES AND METHODS

At-sea sightings and effort for the blue whale are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and mapping methods used.

RESULTS AND DISCUSSION

The blue whale is listed as a Federally endangered under the Endangered Species Act. One population of blue whale of the Eastern North Pacific Stock (there may be as many as five populations - Carretta *et al.,* 2001; Reeves *et al.,* 1998) is present in waters off California generally from June through November; this population migrates south to waters off Mexico and as far south as the Costa Rica Dome. Arrival and departure times in the study area are highly variable both seasonally and interannually (Benson *et al.,* 2002; Calambokidis *et al.,* 1998). Based on best estimates of the average of ship line-transect and mark-recapture estimates, the population is estimated to be 1,744 (CV=0.28) (Carretta *et al.,* 2006).

Due to insufficient sightings in the CDAS data set for the study area, seasonal maps of blue whale density were not generated. Movement patterns, distribution, and occurrence of blue whales off California are related to their annual migration between foraging areas predominately off central California (but some north to British Columbia and south to Baja Mexico and the Costa Rican Dome), and the following breeding areas: 1) off the west coast of Baja California (September-December); 2) the Gulf of California (January-April); and 3) the Costa Rica Dome (Mate *et al.,* 1999). Although blue whales are often present in parts of all three central California National Marine Sanctuary waters, mostly from June through November, their occurrence and distribution during this feeding period is highly variable. Ninety-eight percent the sightings in the CDAS data set were in the Upwelling and Oceanic seasons, and most were in the Oceanic season.

In general, the absence of sightings of this species in the CDAS data set may reflect the distribution of spatial and temporal survey effort rather than absence from the survey area; the maps shown do not reflect the total distribution of the species in the study area.

See an additional map for this species in Figure 4.31, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

Blue whales aggregate and feed in areas where seasonally abundant and dense euphausiids (krill) occur at discrete depths in the water column (Benson *et al.,* 2002). Krill concentrate in the deep scattering layer along canyon and shelf-break edges, and in the daytime, move to the surface in swarms (Schoenherr, 1991; Croll *et al.,* 1998; Forney and Barlow, 1998). Blue whales are widely distributed from the shelf to the deep ocean, but in the study area, these whales were mostly in shelf-break and slope habitats. Blue whales occur in and beyond all three national marine sanctuaries in the study area. Though not directly shown in the data on this map, blue whales do occur in the Cordell Bank National Marine Sanctuary and off Bodega Bay (Calambokidis *et al.,* 1990b; Calambokidis *et al.,* 1998), as well as in waters around the Farallon Islands (Keiper, pers.comm.). However, occurrence is highly variable.

There is considerable interchange and interregional movements between blue whales that occur off southern California (from the Santa Barbara Channel and Southern California Bight) to areas in the Monterey Bay, Gulf of the Farallones, Bodega Bay, and northern California (Calambokidis *et al.,* 1998). In a study of the Monterey Bay area (Benson *et al.,* 2002), occurrence of blue whales in Monterey Bay was related to seasonal upwelling patterns that affect seasonally abundant, dense (and ephemeral) patches of euphausiids that occur during summer and fall (Benson *et al.,* 2002).

Human-related sources of mortality for blue whales include ship strikes (0.2 per year for 1998-2002) (Carretta *et al.,* 2006); this appears to be less than the calculated Potential Biological Removal (PBR) for this stock. No blue whale mortality or serious injury has been associated with the California gillnet fisheries, so total fishery mortality is near zero.

The increasing levels of anthropogenic noise in the world's oceans has become a habitat concern for this species (Carretta *et al.,* 2006).

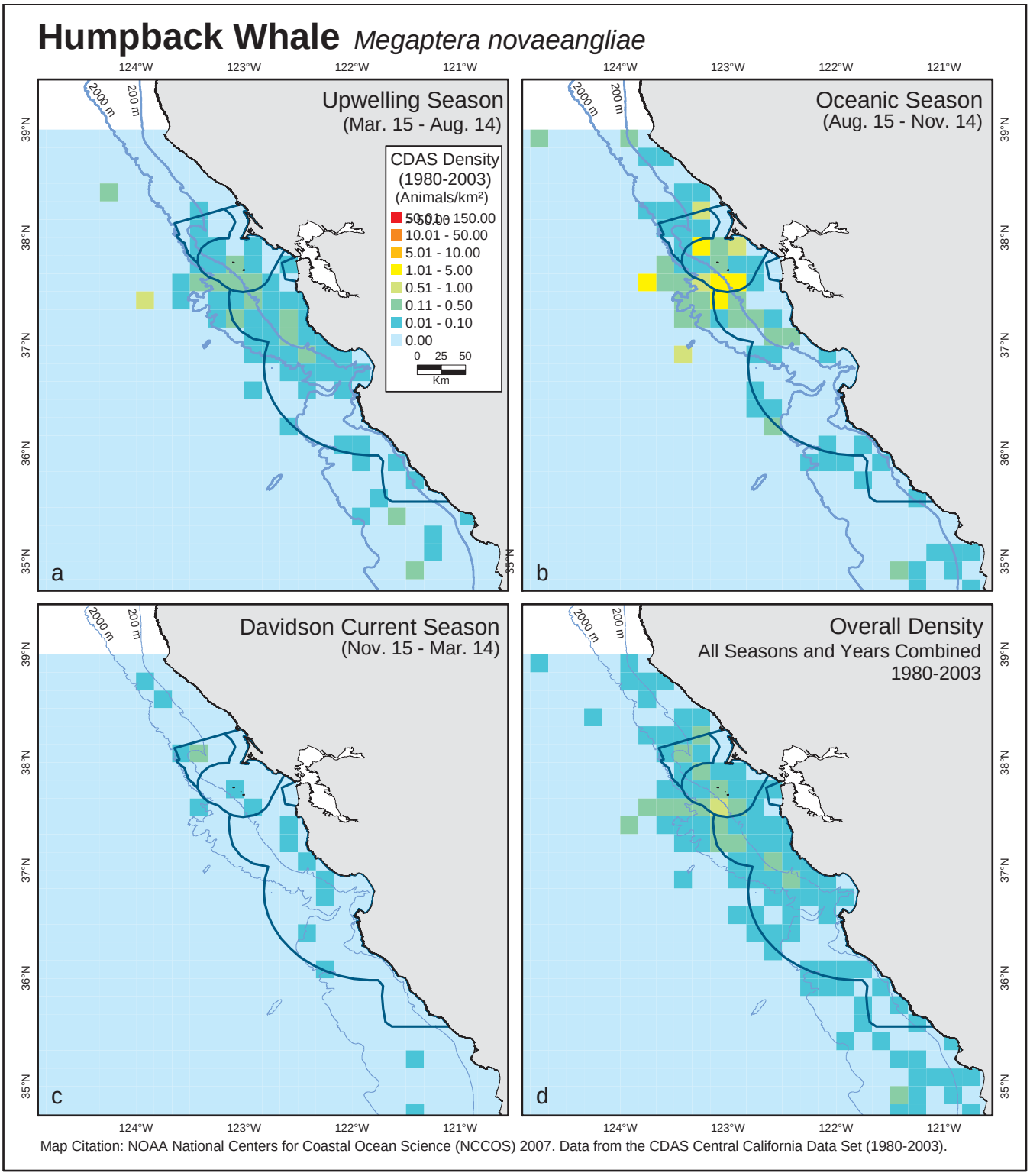

Figure 4.22. Maps for humpback whale: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figure 4.22 a, b and c show the density (animals/km^2) of humpback whales (*Megaptera novaeangliae*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 10' latitude by 10' longitude. Figure 4.22 d shows the overall density combining all three seasons. Densities are based on the combined data sets of several studies conducted from 1980-2003; see Data Sources below and the Data and Analyses section of this chapter for more information. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no humpback whales were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

The humpback whale is distributed worldwide in all ocean basins and is federally listed as endangered under the Endangered Species Act. In the North Pacific Ocean and within the U.S. Exclusive Economic Zone, there are at least three relatively separate populations: the eastern, central, and western North Pacific stocks (Carretta *et al.,* 2006). The eastern North Pacific stock (the California/ Mexico stock) is considered as a "depleted" and "strategic" stock under the MMPA. (Carretta *et al.,* 2006). The eastern North Pacific stock feeds in the waters off California, Oregon, Washington, and British Columbia in the summer, and in the fall, migrates to its wintering calving and mating areas off coastal mainland Mexico and Central America (Calambokidis *et al.,* 2001). Fidelity is extremely high among feeding areas and low-level interchange occurs between breeding areas (Calambokidis *et al.,* 2001). The eastern North Pacific humpback whales seen along the coasts of California, Oregon, and Washington in the spring, summer and fall are part of a distinct feeding aggregation, with little interchange with feeding areas in British Columbia or Alaska (Calambokidis *et al.,* 1996). Based on mark-recapture methods (Calambokidis *et al.,* 2004), the population size estimate for 2002/2003 for the eastern north Pacific stock of humpback whales was 1,391 (CV=0.22); this estimate is considered to be more precise than the estimate based on ship line-transect surveys in 1996 and 2001, which was 1,314 (CV=0.30).

In the central California CDAS data set used in this study, the humpback whale was among the most commonly sighted whales, and was distributed mostly over shelf and slope habitats; humpbacks are often found feeding along canyon edges where prey concentrate. Humpback whales are sighted from the Farallon Islands in all months (Pyle and Gilbert, 1996), though they are more frequently sighted off central California from March through November, with peaks in the summer and fall (Calambokidis *et al.,* 1996). Patterns of occurrence were evident in the seasonal maps: the seasonal summer/fall peak was evident in the Oceanic Season map, whereas a decline in sightings and abundance during the Davidson Current Season (winter) coincided with the humpback whale migration south in the fall. The distribution and abundance of humpback whales was more widespread during the Upwelling Season and more concentrated with greater density in the

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Oceanic Season, a pattern most likely related to the distribution and concentration of prey resources.

The Upwelling Season and beginning of the Oceanic Season is characterized by a seasonal peak in euphausiid (krill) density that occurs in July/August but can extend into the Oceanic Season. Krill abundance increases one to four months after seasonal peaks in primary production (Croll *et al.,* 1998). One of the dominant species of krill (*Thysanoessa spinifera*) forms dense shoals in the shelf region from Fort Ross south to the Channel Islands (Kieckhefer, 1994). Primary feeding sites of humpback whales in the study area are located at Monterey Bay (Benson *et al.,* 2002), Bodega Canyon, Cordell Bank, the Farallon Islands (Kieckhefer, 1992) and Pt. Reyes (S. Allen, pers. comm.). There is considerable interchange and inter-regional movement of humpback whales within a feeding season between the Santa Barbara Channel in the southern California Bight, Monterey Bay, and to the north off Eureka (Calambokidis *et al.,* 1996; Calambokidis *et al.,* 1998). During the Davidson Current Season, most humpback whales are in breeding/calving areas to the south, hence the relatively few sightings in the study area (1980, 1982, and 1993) during this season.

In the study area, the CDAS data shows humpback whales were more concentrated in areas of the Gulf of Farallones and Cordell Bank National Marine sanctuaries, and the northwest corner of the Monterey Bay National Marine Sanctuary, and adjacent slope areas. Rather than a real absence from an area or time period, the absence of sightings of a species may reflect insufficient survey effort. Overall seasonal densities for humpback whale in the CDAS data set were highest in the Oceanic season and lowest in the Davidson Current season.

See an additional map for this species in Figure 4.31 from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

Human related sources of injury and mortality include: fisheries interactions with California's drift gillnet fishery; entanglement in polypropylene line and fishing gear such as crab pot lines; ship strikes; and other anthropogenic sources (Carretta *et al.,* 2006; NMFS unpub. data). Annual humpback whale mortality and serious injury in California's drift gillnet fishery is likely greater than 10% of the Potential for Biological Removal, and may not be approaching zero mortality/serious injury rate (2005, NMFS unpub. data).

In support of the need for coordination of conservation measures by diverse countries sharing migratory or trans-boundary species, Canada, Mexico, and the United States have developed a North American Conservation Action Plan (NACAP 2005, see Commission for Environmental Cooperation, 2005) for the humpback whale. Ship collisions and entanglements in fishing gear appear to be the greatest sources of mortality and injury for humpback whales. Food availability, climate change, noise disturbance, and loss of prey habitat may also threaten their recovery (Commission for Environmental Cooperation, 2005). Key tri-national collaborative conservation actions identified for the humpback whale include: 1) support the SPLASH initiative (Structure of Population Levels of Abundance and Status of Humpbacks (see below); 2) reduce entanglement; 3) prevent ship strikes; 4) address impacts of ecotourism; and 5) address acoustic impacts (Commission for Environmental Cooperation, 2005). The increasing levels of anthropogenic noise in the world's oceans is a habitat concern, particularly for baleen whales that may communicate using low-frequency sound (Carretta *et al.,* 2006). Potentially detrimental sound sources in the ocean include: Naval activities (Low Frequency Active sonar, mid-range sonar); oceanographic experiments, such as the Acoustic Thermometry of Ocean Climate (ATOC); seismic air-gun surveys; and vessel traffic (Commission for Environmental Cooperation, 2005).

An international, collaborative research effort to study humpback whales in the North Pacific was initiated in 2004, with proposed completion in 2007. The objectives of SPLASH include determining: 1) the abundance of humpback whales for each feeding and wintering area in the North Pacific; 2) trends in population size; 3) the identity and boundaries of feeding areas, especially in previously unstudied areas; 4) population structure and migratory movements; and 5) human impacts, including

entanglement. (http://www.cascadiaresearch.org/SPLASH/Proposal.htm).

In the study area, humpback whales feed on seasonally abundant, small schooling fishes (e.g., northern anchovy, Pacific sardine, Pacific herring) and euphausiids (krill, primarily *T. spinifera* and *E. Pacifica*; Kieckhefer, 1994). However, humpbacks are considered to be generalist feeders that also feed on copepods, sand lance, capelin, herring, juvenile salmon, Arctic cod, juvenile walleye Pollock, Atlantic mackerel, and some cephalopods (Commission for Environmental Cooperation, 2005).

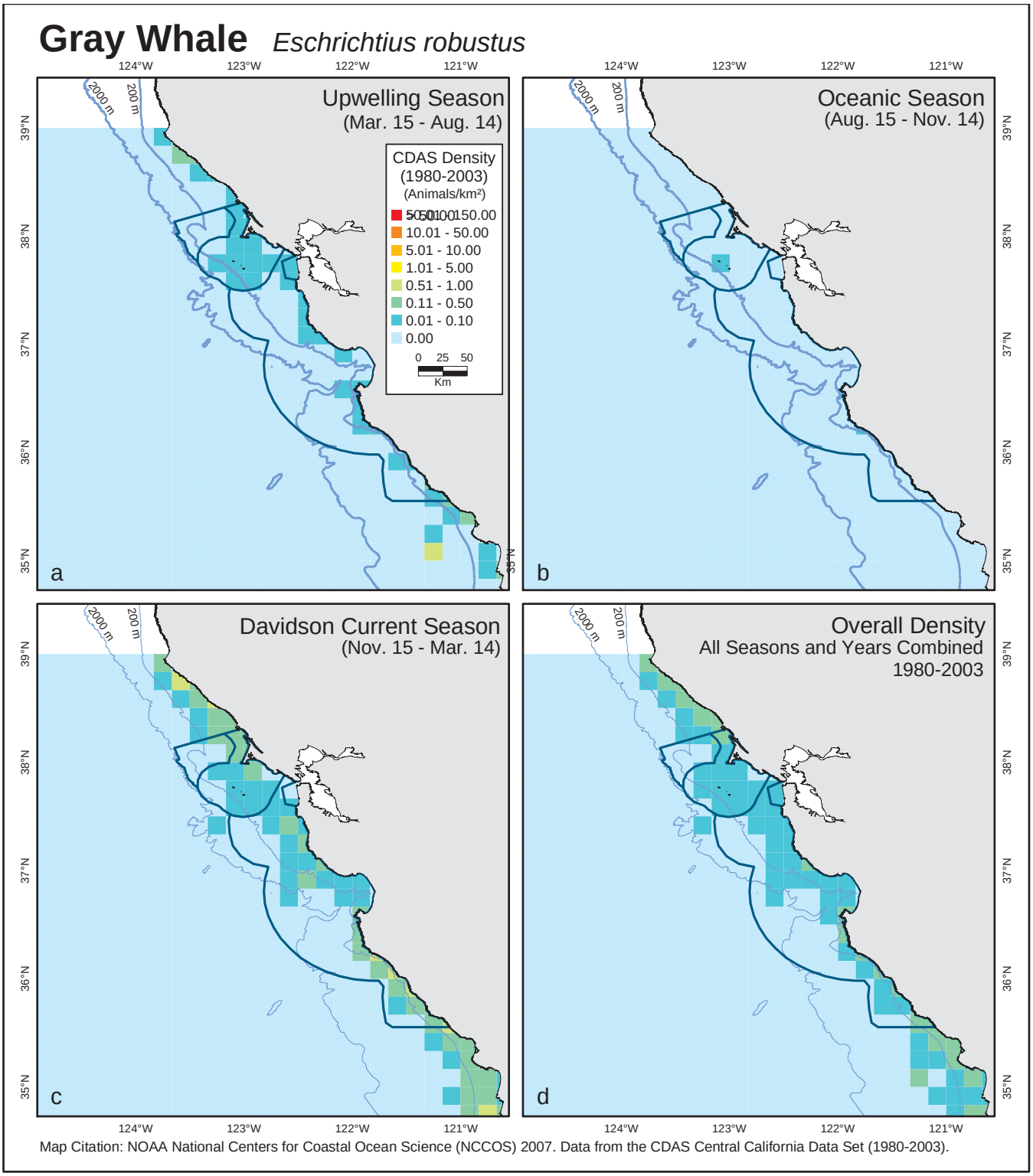

Figure 4.23. Maps for gray whale: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figures 4.23a, b and c show the density (animals/km^2) of gray whales (*Eschrichtius robustus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 10' latitude by 10' longitude. Figure 4.23 d shows the overall density combining all three seasons. Densities are based on the combined data sets of several studies conducted from 1980-2003; see Data Sources below and the Data and Analyses section of this chapter for more information. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among species. Cells that were surveyed but in which no gray whales were observed have a density of zero. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Densities for marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. This data set contains data from eight survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area. See the Data and Analyses section of this chapter for information on the at-sea survey data sets and methods used to estimate density.

RESULTS AND DISCUSSION

Two stocks of gray whales have been recognized in the North Pacific: the Western North Pacific or 'Korean stock', which lives along the coast of eastern Asia; and the Eastern North Pacific stock, which lives along the west coast of North America (Angliss and Outlaw, 2005),

The eastern North Pacific stock of the gray whale migrates south from summer feeding grounds in the northern Bering and Chukchi seas, into waters off Southeast Alaska, British Columbia, Washington, Oregon, and California. Most whales begin their migration from Alaska in November and December and travel south along the west coast of North America to their winter breeding and calving areas in lagoons along the coast of Baja California, Mexico. (Rugh *et al.,* 2001). Calves are generally born from January to mid-February (Rice *et al.,* 1981). The southward migration includes (in the order of sex and age-class) females in late pregnancy, females that have recently ovulated, adult males, immature females, and lastly, immature males. In the study area, this southward migration generally occurs from December through February and peaks in January.

The northward migration generally occurs from February through May in the study area; it peaks in March and includes (in the order of reproductive condition, sex, age-class) newly pregnant females, adult males, immature females and males, and last in this migration, the females with calves. The females with calves migrate northward through the study area during April and May, and sometimes June. Some animals do not undertake the full migration and remain in coastal waters from Kodiak Island, Alaska, to central California through the summer (Darling *et al.,* 1998; Calambokidis and Quan, 1999; Dunham and Duffus, 2001).

The strong seasonal patterns of the gray whale evident in the maps reflect the seasonal biological cycle of this species. During the Upwelling Season (the end of the northward migration), gray whales are distributed in the coastal and shelf habitats throughout the study area, en route to their northern feeding grounds. During the Oceanic Season they are virtually absent (because they are at their summer feeding grounds to the north); and during the Davidson Current Season, densities are highest

Wayne Perryman

because much of their southern and northern migrations pass through the study area during this period. Overall density patterns of the gray whale reflect the nearshore and coastal occurrence on the shelf as it moves through the study area. Gray whales also have been seen regularly off Point Reyes, Tomales Bay, Drakes Bay, and the Farallon Islands during non-migratory periods (Allen, pers. comm.).

In the study area and CDAS central data sets, the gray whale was the second most numerous baleen whale. Based on analysis of the CDAS data, the greatest concentrations of gray whales occurred along the coast near Cypress Point, south of Point Sur to Lopez Point, and north of the boundaries for Gulf of the Farallones and Cordell Bank national marine sanctuaries.

Overall, the Eastern North Pacific gray whale stock has been increasing (Angliss and Outlaw, 2005); however, variations in population estimates have been reported. Abundance estimates by Rugh *et al.,* (2005) were the following: in 1997/98, 29,758 (CV=10.49%; 95% CI = 24,241 to 36,531), the highest estimate since 1967/68; in 2000/01, 19,448 (CV=9.67%; 95% CI=16,096 to 23,498); and in 2001/02, 18,178 (CV=9.79%; 95% CI=15,010 to 22,015). The lower estimates were probably related to the high mortality rates (see below) observed in 1999 and 2000 (Rugh *et al.,* 2005). However, the lower abundance estimates in 2001-02 may be attributed to a true drop in the population size (see Rugh *et al.,* 2005). Angliss and Outlaw, 2005, report the minimum population estimate (N_{min}, estimated by calculating the lower 20th percentile of the log-normal distribution of the population estimate) of 17,752 gray whales (CV=0.069); (Wade and Angliss, 1997).

Variations in population estimates may have been due in part to the following: 1) undocumented sampling variation; 2) differences in the proportion of the gray whale stock migrating as far as the central California coast (survey location at Granite Canyon); 3) responses to environmental limitations as the population approaches carrying capacity (Angliss and Outlaw, 2005); and 4) decline following high mortality rates observed in 1999 and 2000 (Rugh *et al.,* 2002; Gulland *et al.,* 2005). Also during this period (1999-2000), a greater number of visibly emaciated whales were observed, suggesting a decline in food resources as a possible cause for this observation (Le Boeuf *et al.,* 2000).

In 1999 and 2000, strandings along the west coast of North America increased approximately seven times (in 1999) and nine times (in 2000); the annual mean of 41 animals reported between 1995 and 1998, with highest numbers reported in Alaska and Mexico (Gulland *et al.,* 2005). This event was designated “an unusual mortality event”. Factors that may have contributed to the high number of strandings (1999: 273; 2000: 355) include: starvation, chemical contaminants, and biotoxins, infectious diseases, ship strikes, fisheries interactions, detection effort and reporting, and wind and current effects on carcass deposition (Gulland *et al.,* 2005). The underlying cause of starvation as a potentially significant contributing factor remains uncertain (Gulland *et al.,* 2005). While the stranding rate was much higher in 1999 and 2000 than in previous years, it may not indicate a higher mortality rate (Angliss and Outlaw, 2005); this stranding event appears to have been short-term. Counts of dead gray whales have dropped to levels below those seen prior to this event: only 21 and 26 strandings were reported in 2001 and 2002, respectively, and dead gray whale stranding have continued to be relatively low through 2006, with eight in 2003, 18 in 2004, 7 in 2005, and 11 in 2006 (Cordaro, pers. comm., 2006).

Low calf production in 1999, 2000, and 2001 appeared to be correlated with environmental conditions (Perryman *et al.,* 2002). Time of ice retreat in the spring off Alaska and calf production the following year were correlated, suggesting variations in calf production are likely the result of climate variables associated with seasonal changes in ice distribution in the Bering and Chukchi Seas (Perryman *et al.,* 2005 - 16th Biennial Conference on the Biology of Marine Mammals, 2005). These seasonal changes may influence the duration of whale feeding (and thus nutritional status prior to the southbound migration). Although ice distribution explained interannual variations in calf production (1,527 in 2004; 256 in 2000), observed longer-term variations in calf production are likely the result of

climate variables related to system-wide, bottom-up productivity (Perryman *et al.,* 2005).

Tracking of human-related causes of mortality and serious injury from 1999-2003 indicate that no gray whales were seriously injured or killed incidental to the coastal and inland waters set gillnet fishery or the thresher shark/swordfish drift gillnet fishery. A minimum annual mean of 7.4 gray whale mortalities resulting from interactions with commercial fishing gear is considered to be insignificant (Angliss and Outlaw, 2005). The annual subsistence take of the eastern stock of gray whales by Russian aboriginals and the Makah Tribe was 122 whales during the five-year period from 1999 to 2003 (Angliss and Outlaw, 2005).

Other sources of mortality include ship strikes, with a mortality rate of 1.2 gray whales reported per year. However, because ship strikes are likely unreported, either because the whales do not strand or do not have obvious signs of trauma, it is not possible to quantify the actual mortality of gray whales from ship strikes (Angliss and Outlaw, 2005).

Overall, the estimated annual level of human-caused mortality and serious injury (includes mortalities from commercial fisheries, Russian harvest, and ship strikes) does not exceed the Potential Biological Removal (PBR), and therefore this stock of gray whales is not classified as a strategic stock, and is no longer considered endangered or threatened under the endangered Species Act (ESA; Angliss and Outlaw, 2005). However, events associated with the 1999-2000 stranding event could be indicative of a population near carrying capacity (Gulland *et al.,* 2005).

Gray whales are opportunistic foragers, feeding mostly on benthic invertebrates (e.g., gammarid amphipods (Leatherwood and Reeves, 1983)), mysid shrimp, herring eggs/larvae, crab larvae, ghost shrimp (Darling *et al.,* 1998), and surface swarms of euphausiids (krill) (Benson *et al.,* 2002). Although most individuals of gray whales in the study area were non-feeding migrants, some individuals on their northern migration do feed on a regular basis near the South Farallon Islands, at the mouth of Tomales Bay and Drakes Bay (Allen, pers. comm., 2002). Gray whales also feed in San Francisco Bay (in some years: 1999, 2000-2001) (Oliver *et al.,* 2001); and Monterey Bay (Benson *et al.,* 2002). Gray whale calves are preyed upon by killer whales.

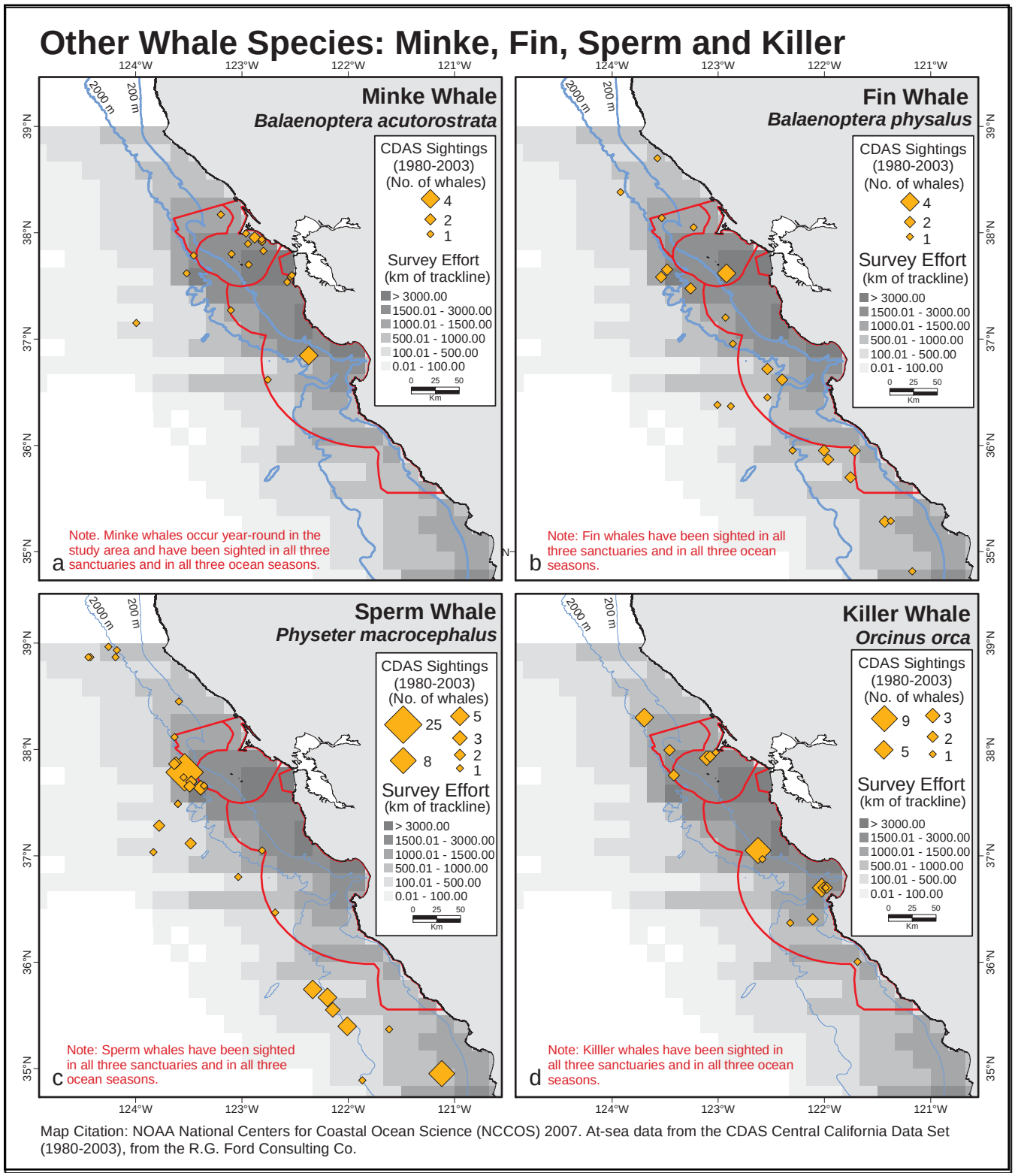

Figure 4.24. Maps for other whales: minke, fin, sperm and killer: sightings and effort data from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Limited sighting data was available in the CDAS data set (1980-2003) for minke whale, fin whale, sperm whale and killer whale. But since these cetacean species occur in the study area, maps of the available sightings in CDAS (Figures 4.24 a, b, c and d) were developed to indicate the presence of these species in the study area and the three central California National Marine Sanctuaries. Due to limited data in the CDAS data set for these species, seasonal or overall density maps were not made and it was difficult to identify spatial and temporal patterns from the existing data.

See additional maps for these species in Figures 4.29-4.31, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). These maps provide additional information on the range of the species off the coasts of California, Oregon and Washington.

Minke Whale (*Balaenoptera acutorostrata*)
The minke whale that occurs off central California is from the California/Oregon/Washington stock (one of two stocks found in U.S. North Pacific waters) and is present year round in the study area (Dohl *et al.,* 1983; Forney *et al.,* 1995; Barlow, 1997). The minke whale is not federally listed as threatened or endangered.

See Figure 4.24a; in the CDAS data analyzed in this study, scattered sightings of minke whales occurred in shelf, slope, and offshore waters in all three central California national marine sanctuaries, but most sightings were over the shelf. The pattern of sightings indicated on the map only confirms that minke whales have been sighted in a certain location in the study area and in a specific sanctuary. Rather than a real absence from an area or time period, the absence of sightings of a species may reflect insufficient survey effort.

Fin Whale (*Balaenoptera physalus*)
The fin whale that occurs off central California is from the California/Oregon/Washington stock (one of three stocks found in U.S. waters in the Pacific) and is present year round (Dohl *et al.,* 1983; Forney *et al.,* 1995). The fin whale is federally listed as an endangered species.

See Figure 4.24b; in the CDAS data analyzed in this study, scattered sightings of fin whales occurred in shelf, slope, and offshore waters in all three central California national marine sanctuaries, but most sightings were over the slope. Fin whales also occurred in offshore waters to the north, west, and south of the three sanctuaries. The pattern of sightings indicated on the map only confirms that fin whales have been sighted in a certain region and in a specific sanctuary. Rather than a real absence from a region (or sanctuary), the absence of sightings may reflect insufficient survey effort.

Sperm Whale (*Physeter macrocephalus*)
The sperm whale that occurs off central California is from the California/Oregon/Washington stock (one of three stocks found in U.S. waters in the Pacific) and is federally listed as an endangered species. Sperm whales are widely distributed across the entire North Pacific, and although seasonal movements of sperm whales in the North Pacific are unclear, it is thought that males move north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands, while females and young sperm whales usually remain in tropical and temperate waters year-round (Angliss and Outlaw, 2005). Off California, sperm whales occur year-round (Dohl *et al.,* 1983; Forney *et al.,* 1995; Barlow, 1997), with peak abundance from April through mid-June and from end August through mid-November (Rice,1974).

See Figure 4.24c; in the CDAS data analyzed in this study, sperm whale sightings were widely scattered and occurred along the western boundaries of all three central California national marine sanctuaries and beyond (to the north, west, and south), mostly over the slope and deep ocean habitats. The pattern of sightings indicated on the map only confirms that sperm whales have been sighted in certain areas; rather than a real absence from an area or time period, the absence of sightings of a species may reflect insufficient survey effort.

The California/Oregon/Washington stock of sperm whale is listed as "endangered" under the Endangered Species Act and therefore is considered "strategic" and "depleted" under the Marine Mammal Protection Act. Increasing levels of anthropogenic noise in the oceans may be a habitat

issue for deep-diving whales that use sound to hunt their prey (Carretta *et al.,* 2007). Sperm whales along the U.S. west coast feed primarily on squid (e.g., jumbo or Humboldt squid, *Dosidicus gigas*), but also some fishes and other invertebrates.

Killer Whale (*Orcinus orca*)
Five stocks, or types, of killer whales are recognized within the U.S. Pacific Exclusive Economic Zone (Carretta *et al.,* 2006); Killer whales that occur off central California occur year-round and are mostly from three recognized stocks: 1) the Eastern North Pacific Offshore stock; 2) the Eastern North Pacific Transient stock; and 2) the Eastern North Pacific Southern Resident stock. A fourth stock, or ecotype has been suggested, the LA pod, and it also occurs in the study area (Black *et al.,* 2002).

The 'transient' type is the most frequently sighted type of killer whale off central California (Black *et al.,* 1997); transients has been observed from southern California to Alaska. 'Transients' feed on marine mammals, travel in small groups often over long ranges, and are usually vocally quiet (Black *et al.,* 2002). Transients were often found at the edge of Monterey Canyon.

The 'offshore' type is not well known but does occur in the study area and has been observed (at least) in Monterey Bay and off Pt. Reyes (S. Allen, pers. comm.); this type is more vocal, travels in larger groups, and feeds on fishes and squid.

The southern 'resident' type is primarily sighted in inland marine waters of Washington and southern British Columbia, but it has also been observed once in Monterey Bay; this type preys mostly on fish, lives in close family groups, and is quite vocal.

The "LA pod" type has been observed from the Farallon Islands to the upper Gulf of California (Sea of Cortez) (Black *et al.,* 2002). See the mammal population estimate table and the life history table in this chapter for more information on this species.

Although the killer whale species is not federally listed as threatened or endangered, the Eastern North Pacific Southern Resident stock of killer whales is listed as Federally threatened, under the Marine Mammal Protection Act; this stock is also classified as a "strategic stock". The stock was designated as "endangered" by the State of Washington in April 2004. This stock is found primarily in the Pacific Northwest but is occasionally seen off California (NCCOS, 2005).

See Figure 4.24d; in the CDAS central California data set analyzed in this study, scattered sightings of killer whales occurred in all three central California national marine sanctuaries in shelf and slope habitats, the south rim of the Monterey Canyon, and several sightings to the west of Pt. Reyes. The pattern of sightings indicated on the map only confirms that killer whales have been sighted in certain areas and in all three central California sanctuaries. Rather than a real absence from an area or time period, the absence of sightings of a species may reflect insufficient survey effort.

The species occurs year-round in the study area, and killer whales are most frequently sighted in Monterey Bay from January-May and from September through November (Monterey Bay Whale Watch, 2007).

Known prey of the killer whale types, when feeding in Monterey Bay, include the following. For Transient killer whales: gray whale calves, California sea lions, harbor seals, elephant seals, Dall's porpoise, Pacific white-sided dolphins, long-beaked common dolphin and seabirds; for Offshore killer whales: salmon, small schooling fish and blue shark; and for Resident killer whales: Chinook salmon; (Black *et al.,* 2002). For the LA Pod: great white sharks and likely other prey off Farallon Islands (Pyle *et al.,* 1997).

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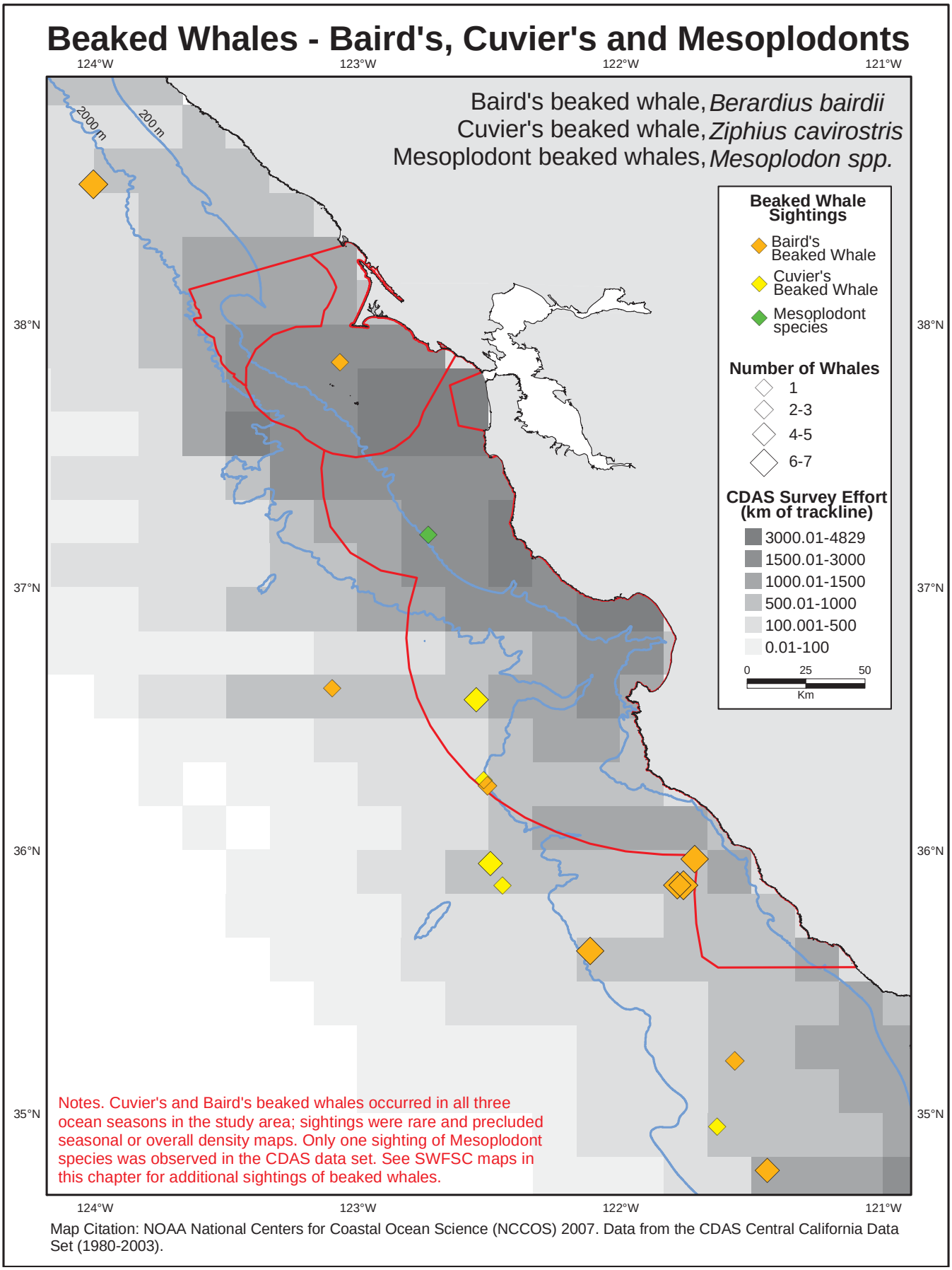


Figure 4.25. Map for beaked whales: sightings and effort data from the CDAS central California data set (1980-2003).

ABOUT THIS MAP

Baird's beaked whale (*Berarduis bairdii)*
Cuvier's beaked whale *(Ziphius cavirostris)*
Mesoplodont beaked whales *(Mesoplodon* spp.)

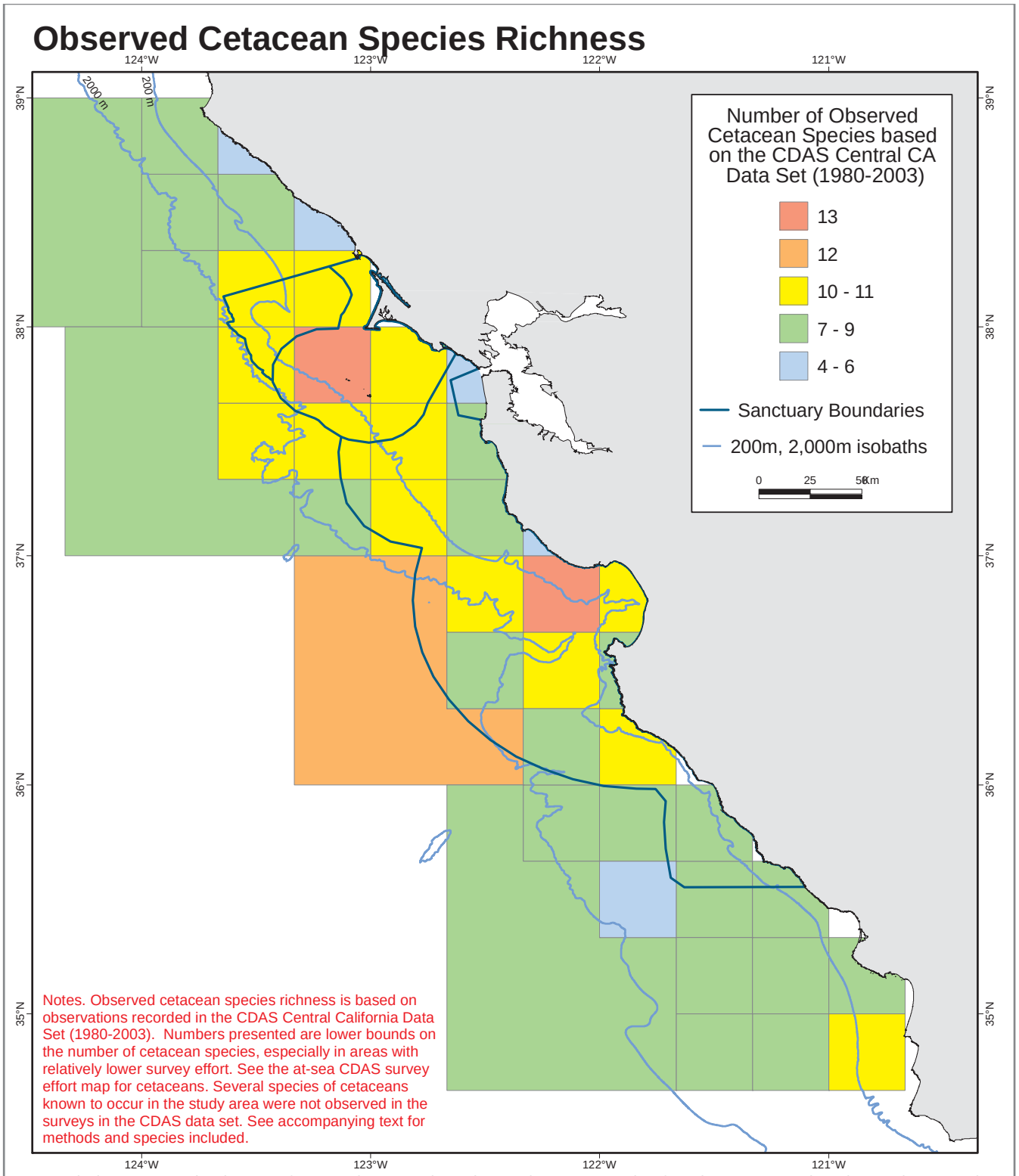
Limited sighting data were available in the CDAS data set (1980-2003) for beaked whales. But since these beaked whale species occur in the study area, a map of available sightings in CDAS (Figure 4.25) was included to indicate their presence in the study area and the three central California National Marine Sanctuaries. Due to insufficient data, it was difficult to identify spatial and temporal patterns of distribution.

See additional maps for these species in Figure 4.30, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). These maps provides additional information on the range of the species off the coasts of California, Oregon and Washington.

Due to the rarity of sightings, species of beaked whales in the study area have been grouped. Data in the CDAS central California data set (1980-2003) used in this analysis included sightings of Baird's beaked whale (*Berarduis bairdii*), Cuvier's beaked whale (*Ziphius cavirostris*), and unidentified beaked whale (*Mesoplodon* spp). Baird's beaked whales are distributed along continental slopes and throughout deep waters of the North Pacific; Cuvier's beaked whale is the most commonly sighted beaked whale in U.S. West Coast waters (Carretta *et al.,* 2006); and Mesoplodont species are distributed along continental slopes and throughout deep waters in the North Pacific Ocean. Six species known to occur off Washington, Oregon and California are: Blainville's beaked whale (*M. densirostris*), Perrin's beaked whale (*M. perrini*), Lesser beaked whale (*M. peruvianus*); Steijneger's beaked whale (*M. stejnegeri*), Gingko-toothed beaked whale (*M. gingkodens*), and Hubbs' beaked whale (*M. carlhubbsi*) (Carretta *et al.,* 2006).

Beaked whales are among the least understood marine mammals and most of the current knowledge of beaked whales is based on studies of stranded specimens (Cox *et al.,* 2006). See Cox *et al.,* (2006) for a review of several recent mass strandings that have led to suggestions that exposure to anthropogenic sounds negatively affects beaked whales.

Beaked whale sightings were widely scattered and occurred to the north of Cordell Bank National Marine Sanctuary, within the boundaries of the Gulf of the Farallones and Monterey Bay national marine sanctuaries, and to the west and south of these sanctuaries, in shelf-slope and deep ocean habitat. The sightings indicated on the map only confirm that beaked whales have been sighted in the study area and in a specific sanctuary; rather than a real absence from an area or time period, the absence of sightings of a species reflects insufficient survey effort.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS central CA data set (1980-2003). Map developed by R.G. Ford Consulting Co. and NOAA NCCOS.

Figure 4.26. Map of observed species richness for cetaceans (whales, dolphins and porpoises) based on the CDAS central California data set (1980-2003).

ABOUT THIS MAP

Figure 4.26 is a map of observed species richness for cetaceans (whales, dolphins and porpoises) off north/central California, based on the CDAS central California data set (1980-2003). Richness refers to the number of species that are in a geographic region, and is an indicator of community structure and composition. Richness is not a measure of community diversity, which combines both number of species and relative density into a single index. Richness is an explicit measure of the number of species present in a community and is independent of their relative abundances.

The color and mapping intervals were selected to emphasize spatial structure and to highlight significant areas. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Observations of marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using the Marine Mammal and Seabird Computer Data Analysis System (CDAS), developed by the R.G. Ford Consulting Co. This data set contains data from eight major survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area, and offshore to the extent of data availability. See the Data and Analyses section of this chapter for more information on the data and methods.

The number of species in a community or geographic region is a basic descriptive parameter that has been widely studied and utilized (Ludwig and Reynolds, 1998). In practice, however, estimating the number of species is difficult because there is a strong relationship between sampling intensity and the number of different species detected, a situation exactly analogous to the species-area curve described by MacArthur and Wilson, 1967. In general, the number of species detected increases as the intensity of sampling increases. The relationship is typically asymptotic, and eventually additional sampling effort within the same geographic region yields no new species. The estimates of species richness presented here are based on approximations of the asymptotic limit of the species-sampling relationship. Although measures of richness are designed to be independent of effort, Figures 4.1 and 4.2 in this chapter show summary maps of CDAS sampling effort for pinnipeds and cetaceans for comparison.

Estimation of species richness for cetaceans was more complex than for pinnipeds because the level of effort was different for each species. Variation in sampling effort occurred because detectability of cetacean species was extremely variable. Variability in the detectability of different species meant that the area sampled also varied among species. We know of no method for estimating richness that is robust to this situation, and therefore estimated cetacean species richness as simply the number of different species observed in each 20' cell. This method entails sampling bias since it underestimates species richness in poorly sampled cells. We only used cells in which a minimum number of observations of groups, *Nmin*, were made. The value of *Nmin* was determined by regressing the number of species detected in each sampled cell on the total number of groups observed in that cell (*N*), excluding cells with fewer than a specified minimum number of observations. In general, richness is highly correlated with number of observations when the number of observations is low, and ceases to be correlated when the total number of observations becomes large. *Nmin* was therefore defined as the minimum number of observations for which the regression of richness on *N* ceased to be significant at $p=0.05$. For the cetacean data, we found that *Nmin*=25. In other words, if only cells with 25 observations or more are used, there is no correlation between richness and the number of observations within a cell. Therefore the number of species observed in the cell provides an unbiased estimate of species richness in that cell. This approach reduces the number of 20' cells for which richness can be estimated, since cells that were sparsely sampled or had few observations fell below *Nmin*. Hence, offshore data were aggregated into larger blocks (60' x 60') because sampling effort there was less intense. In several cases irregularly-shaped blocks were used (seven 20' blocks rather than nine 20' blocks) because one of the 20' blocks was sufficiently well sampled to satisfy *Nmin*. The

resultant coverage was reasonably complete within the study area, especially over the continental shelf.

RESULTS AND DISCUSSION

The CDAS survey database (1980-2003) for north/central California includes sightings of 19 cetacean species in the study area; this includes over 65% of the cetacean species occurring in the study area. Three uncommon or rare cetacean species that were not observed on any of the surveys in the CDAS database were the pygmy sperm whale, the dwarf sperm whale, and the striped dolphin.

The cetacean species richness map showed two 20' cells of highest species richness (13 species) that were similar geographically to those of the pinnipeds: 1) the northwestern area of the Gulf of the Farallones, which includes the Farallon Islands and extends east to Pt. Reyes; and 2) a 20' cell south and east of Pt. Año Nuevo and its upwelling center, encompassing the shelf off Santa Cruz and the north rim and slope of the Monterey Canyon.

These two cells coincide with important upwelling and retention regions. The 20' cell off Point Reyes is associated with the strong persistent upwelling center to the north at Point Arena that transports cold nutrient rich water south to Point Reyes and the Gulf of the Farallones (Kaplan and Largier 2006; see also Largier *et al.*, 2006). The 20' cell south and east of Point Año Nuevo coincides with upwelling that occurs between Point Año Nuevo and Davenport (Rosenfeld *et al.,* 1994; Pennington and Chavez, 2000). The spatial and temporal structure of upwelling is very complex and results in complex physical (and biological) oceanography around Point Reyes and Point Año Nuevo that likely play an important role in retention and transport of marine mammal prey. The two cells of highest cetacean richness noted above were also cells of highest richness for the pinnipeds.

Over the lower slope off Monterey Bay, 12 cetacean species (dark orange) were recorded in a large 1° cell between 36º and 37º north latitude; although the richness in this cell is likely influenced by cell size, it is significantly higher in richness than adjacent large cells to the northwest and southeast. The entire area of Cordell Bank NMS had ten species, Gulf of the Farallones NMS had 10-13 species, and the Monterey Bay NMS had richness values ranging from 4-13 species, with most of the MBNMS area having a cetacean richness of 10 or more species.

Because of the method used to estimate cetacean richness, these values reflect minimum richness values; the actual cetacean richness of these cells is likely higher for most, if not all cells.

The following eight species were found in all three of the highest (12-13) richness areas: blue whale, humpback whale, minke whale, killer whale, Pacific white-sided dolphin, northern right whale dolphin, Risso's dolphin, and Dall's porpoise. Both red areas also included gray whale, common dolphin, bottlenose dolphin, and harbor porpoise. Also, Baird's beaked whale was recorded near the Farallon Islands and fin whale was recorded in Monterey Bay. In addition to the eight common species noted above, the large offshore block included sightings of fin whale, sperm whale, Baird's beaked whale, and Cuvier's beaked whale.

Estimates of cetacean richness throughout the study area probably reflect the variability in coastal, shelf and shelf-slope habitats where there are multiple microhabitats defined by factors such as depth, currents, fronts, upwelling etc. This variability is evident in both the pinniped and cetacean maps, and shows general similarities to the results for marine bird diversity (see Figure 3.42). A number of smaller, discrete areas attract marine mammals because more food is available owing to the complex oceanographic factors. Higher numbers of cetacean species are likely found in these areas because of their unique bathymetric features, coupled with the complex physical and biological oceanography that affect food web development and the availability and abundance of prey.

Additional Data from the Cetacean Stock Assessment Surveys from NOAA's Southwest Fisheries Assessment Center (SWFSC)

The following cetacean maps are based on data from NOAA's marine mammal stock assessment program, conducted by NOAA's Southwest Fisheries Science Center (SWFSC). Maps for 18 cetacean species (or species stocks) are included below (Figures 4.27-4.32) to provide additional mapped information that was available for these species. Most of these maps result from the broad-scale, cetacean ship surveys, although aerial survey information is included for the California coastal stock of the bottlenose dolphin, Figure 4.32. This survey data is used to develop stock estimates and trend analyses for most marine mammals that occur off the coasts of California, Oregon and Washington.

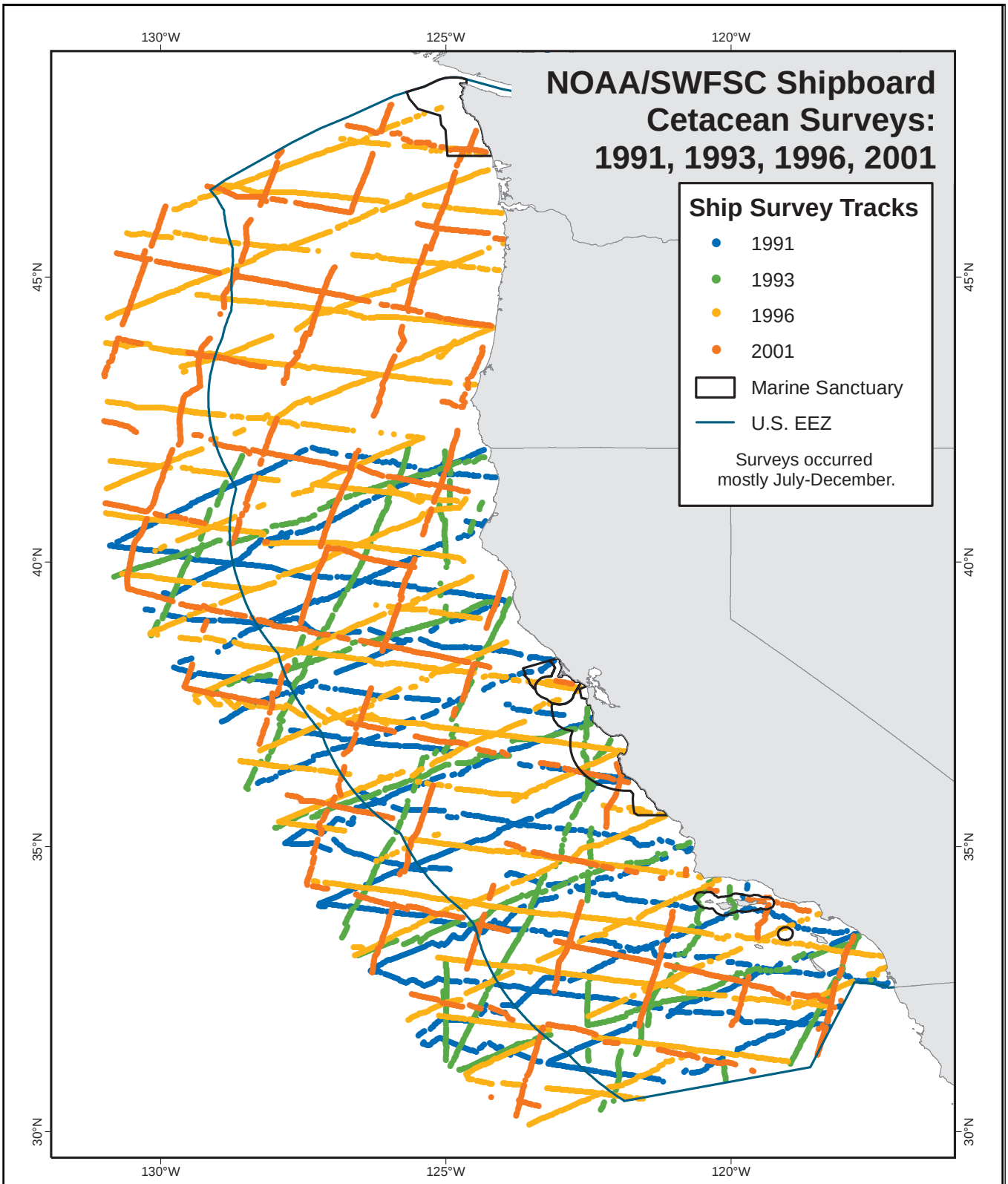
Like the CDAS data, the SWFSC data do not represent the distribution of the species, but do provide an indication of the broader spatial extent of the species. Since the SWFSC data were not incorporated into the CDAS central California data set and maps, they are presented separately, below.

Except for the coastal bottlenose dolphin data (May-July, 1990-2000), the data for these maps were provided in Phase I of this assessment. The maps show cetacean sightings (species group size) and effort locations, generally for the late summer and fall seasons (ranging from July-December, the late Upwelling and Oceanic seasons) of the SWFSC cetacean ship surveys for four years: 1991, 1993, 1996 and 2001, off the coasts of California, Oregon and Washington. For Phase II, SWFSC data from all available years for each species or species stock was combined into one map, to better understand their spatial extent.

For more information on the marine mammal stock assessment survey data used in this assessment, contact Dr. Jay Barlow at Jay.Barlow@noaa.gov or visit the following websites for additional information on the SWFSC marine mammal surveys and stock assessments:

http://www.nmfs.noaa.gov/pr/sars/species.htm
or
http://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=148&id=1247

Two additional descriptions were developed for species that were mapped using SWFSC data but not CDAS data - bottlenose dolphin and short-beaked common dolphin; these descriptions are included after the SWFSC maps, below.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from shipboard surveys of cetacean stock assessments (1991, 1993, 1996, 2001) by NOAA/NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA.

Figure 4.27. Map of survey effort locations for shipboard cetacean surveys conducted in 1991, 1993, 1996 and 2001 by NOAA's Southwest Fisheries Science Center.

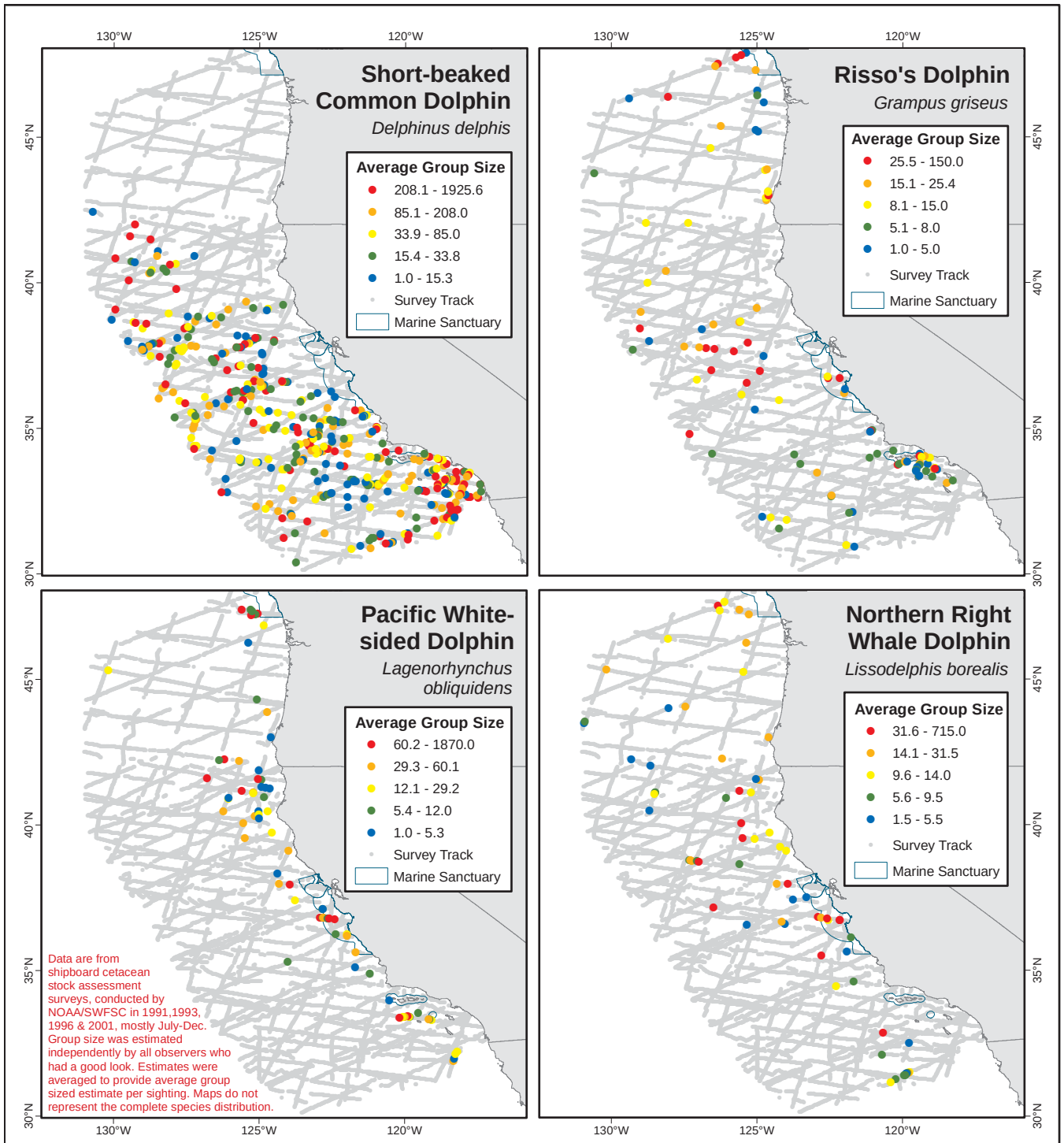
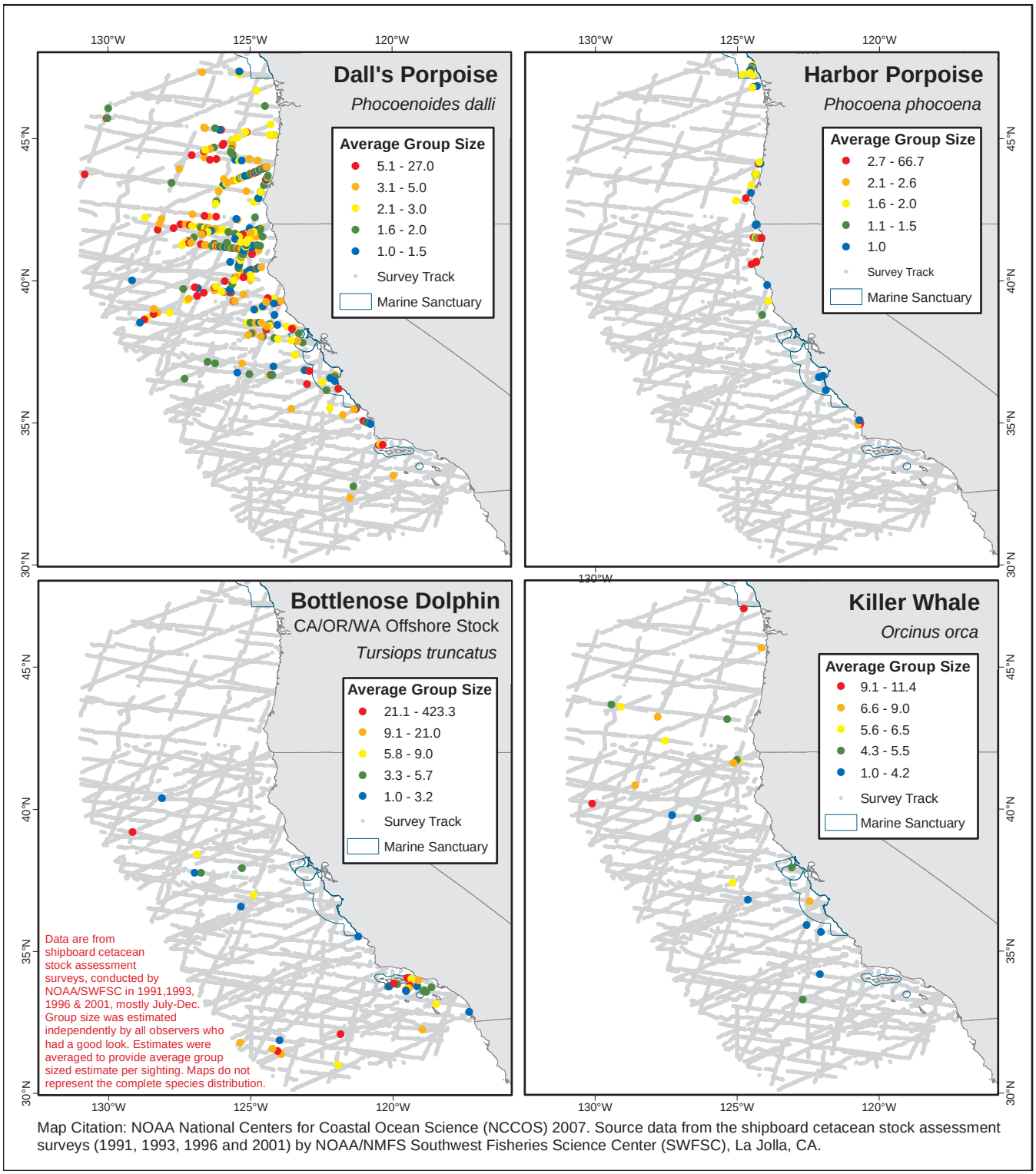
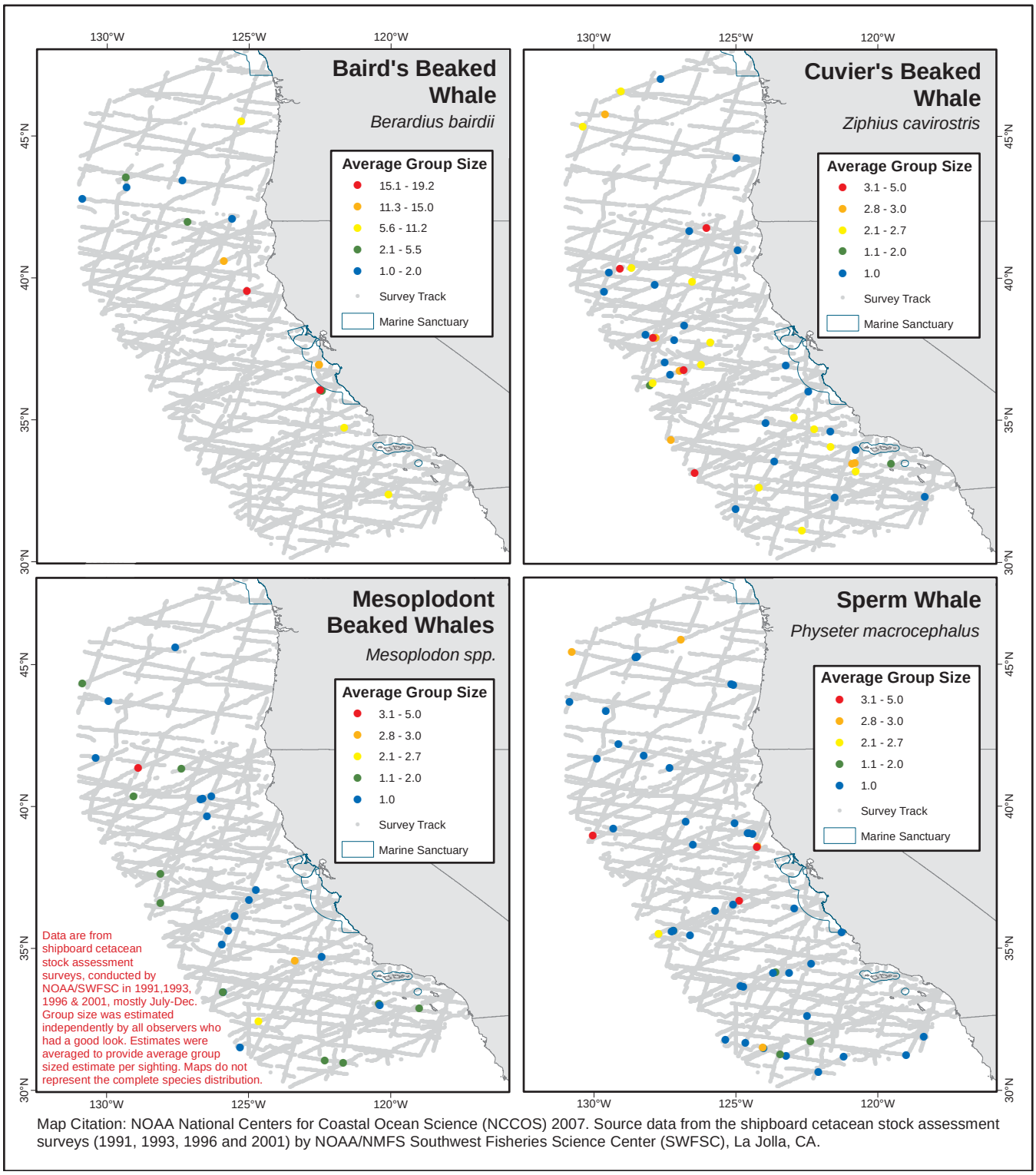


Figure 4.28. Maps of sighting and effort locations for: short-beaked common dolphin, Risso's dolphin, Pacific white-sided dolphin and northern right whale dolphin. Data from NOAA's Southwest Fisheries Science Center, marine mammal stock assessment program.



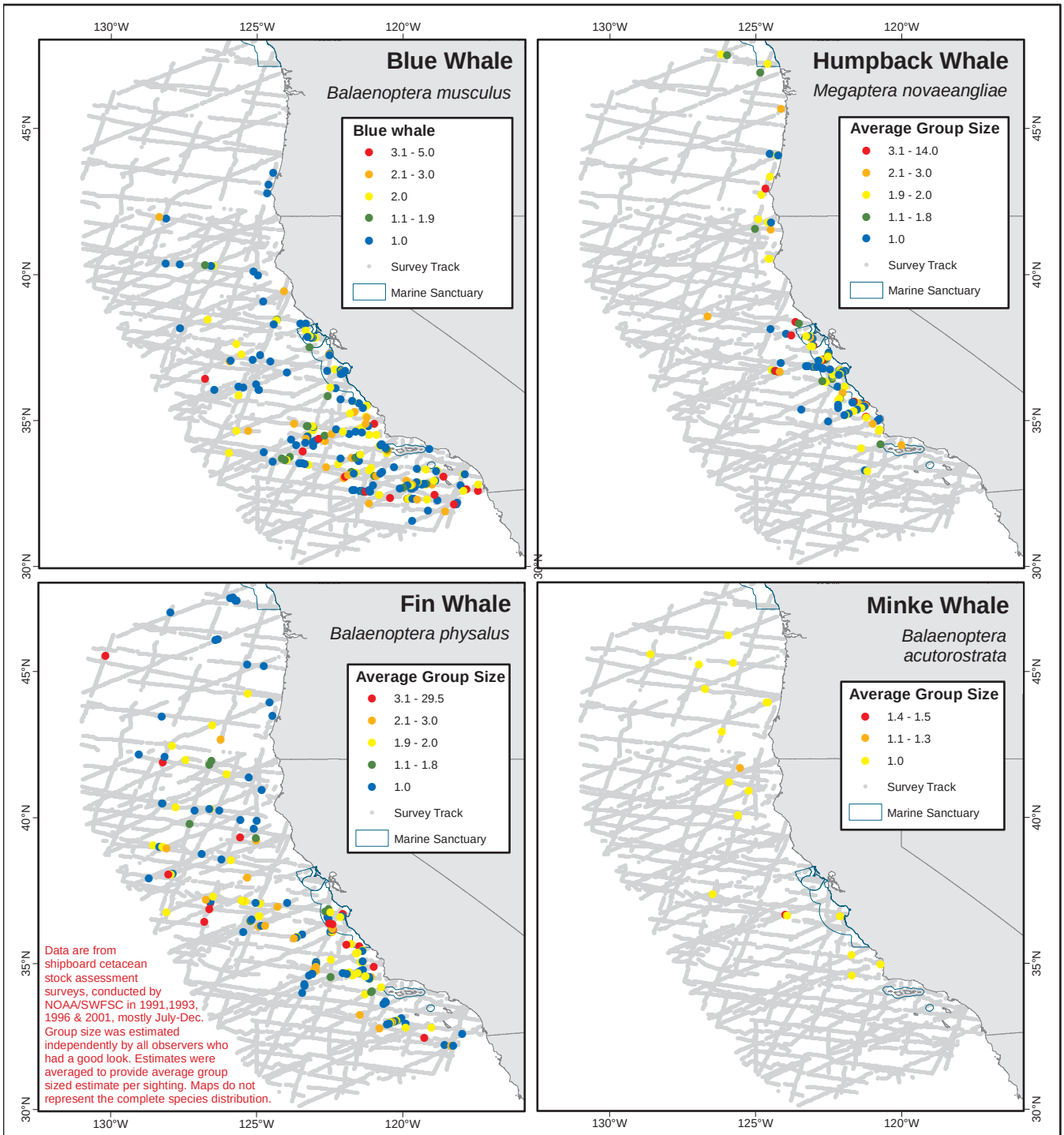
Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from the shipboard cetacean stock assessment surveys (1991, 1993, 1996 and 2001) by NOAA/NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA.

Figure 4.29. Maps of sighting and effort locations for: Dall's porpoise, harbor porpoise, bottlenose dolphin (CA/OR/WA offshore stock) and killer whale. Data from NOAA's Southwest Fisheries Science Center, marine mammal stock assessment program.



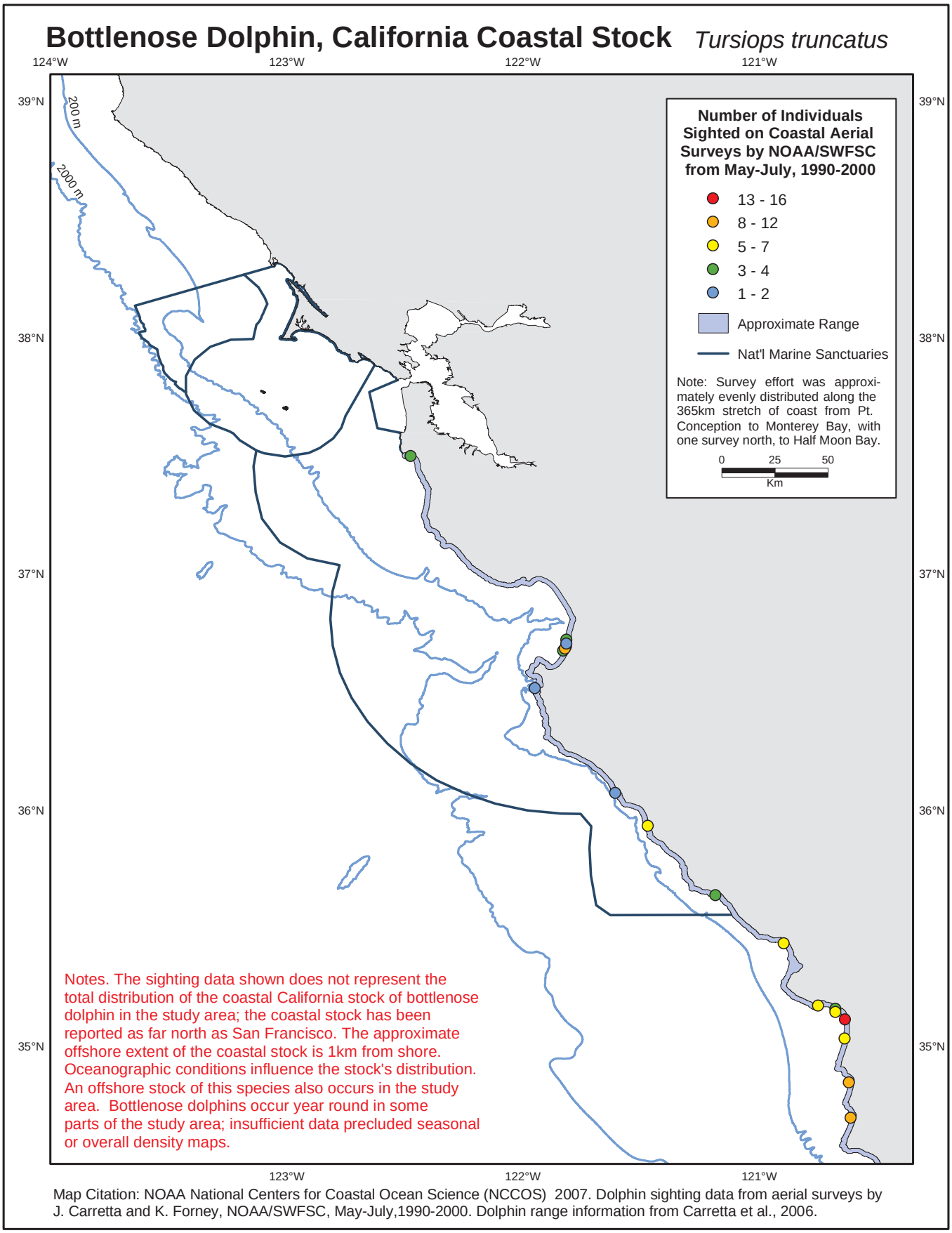
Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from the shipboard cetacean stock assessment surveys (1991, 1993, 1996 and 2001) by NOAA/NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA.

Figure 4.30. Maps of sightings and effort locations for: Baird's beaked whale, Cuvier's beaked whale, Mesoplodont beaked whales and sperm whale. Data from NOAA's Southwest Fisheries Science Center, marine mammal stock assessment program.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from the shipboard cetacean stock assessment surveys (1991, 1993, 1996 and 2001) of NOAA's Southwest Fisheries Science Center (SWFSC), in La Jolla, CA.

Figure 4.31. Maps of sighting and effort locations for: blue whale, humpback whale, fin whale and minke whale. Data from NOAA's Southwest Fisheries Science Center, marine mammal stock assessment program.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Dolphin sighting data from aerial surveys by J. Carretta and K. Forney, NOAA/SWFSC, May-July,1990-2000. Dolphin range information from Carretta et al., 2006.

Figure 4.32. Map for bottlenose dolphin, California coastal stock, sightings and estimated range in study area. Data from NOAA's Southwest Fisheries Science Center, marine mammal stock assessment program.

Description for Bottlenose Dolphin

Two maps (Figures 4.29 and 4.32) are shown for the bottlenose dolphin (*Tursiops truncatus*) in the study area; both maps use data from NOAA's Southwest Fisheries Science Center. Off California, there are two stocks or populations of this species: Figure 4.32 contains sightings and an estimated range from coastal aerial surveys in 1990-2000 for the California Coastal stock in the study area; and Figure 4.29 contains sightings from shipboard surveys (1991-2001) for the California, Oregon and Washington offshore stock. The sightings only confirm that bottlenose dolphin have been sighted in certain areas; rather than a real absence from an area or time period, the absence of sightings of a species may reflect insufficient survey effort. A map was not made from the CDAS central California data set, 2003, but this data set includes 14 sightings of 45 bottlenose dolphins, mostly in the nearshore waters of Monterey Bay. The most northerly sighting of this species in the CDAS data set is in the Gulf of the Farallones Marine Sanctuary, about 25 km due west of San Francisco.

Bottlenose dolphin occur throughout the world in tropical and warm temperate waters (Carretta *et al.,* 2006). The California coastal stock generally occurs within one kilometer of shore, over the inner shelf; this stock occurs mostly off southern California and into Mexican waters, but moves northward into central California during warm-water periods and was sighted as far north as San Francisco (Carretta *et al.,* 2006) The offshore stock has been sighted mostly in the southern California Bight; north of there the sightings are well offshore, over the slope and deep offshore waters, to 41°N; they may move north into waters off Oregon and Washington during warm water periods.

As of 2007, these two stocks are not listed as "threatened" or "endangered" under the Endangered Species Act nor as "depleted" under the Marine Mammal Protection Act. Habitat issues for the coastal stock include pollution levels, especially DDT residues; no habitat issues were identified for the offshore stock (Carretta *et al.,* 2006). Coastal bottlenose dolphins eat a wide variety of fish, squid, and crustaceans while offshore bottlenose dolphins prefer squid. Bottlenose dolphins are sometimes preyed upon by killer whales or large sharks.

Description for Short-beaked Common Dolphin

Figure 4.28 includes a sighting map for the short-beaked common dolphin *(Delphinus delphis)* off the coast of California, Oregon and Washington; this map is based on data from shipboard surveys (1991, 1993, 1996 and 2001) by NOAA's Southwest Fisheries Science Center. A map was not made of sightings from the CDAS central California data set, 2003, but that data set includes 35 sightings of 2,255 common dolphins, mostly seaward of the 200 m contour. The most northerly sighting of this species in the CDAS data set is in the Gulf of the Farallones Marine Sanctuary, about 10 km southwest of Pt. Reyes.

This species is the most abundant cetacean off California and occurs from the coast out to at least 500 km offshore; off central California, it mostly occurs well offshore, over slope habitats and beyond). The weighted average abundance estimate for the California, Oregon and Washington stock is 449,846 (CV= 0.25), and is based on two ship surveys (1996 and 2001, Barlow, 2003). There may be two stocks of this species off California, but this has not yet been formally recognized.

The distribution of the California stock of a similar species, the long-beaked common dolphin (*Delphinus capensis*) partially overlaps some of the distribution of the short-beaked common dolphin; the long-beaked common dolphin occurs mostly off southern California and Baja California generally within about 90 km of the coast; the short-beaked-common dolphin occurs nearshore but mostly occurs offshore (it has been sighted to out to 550 km) and north to approximately 42°N in the SWFSC surveys. The California stock of the long-beaked common dolphin is estimated to be less than one tenth the size of the short-beaked stock off California, Oregon and Washington. (Carretta *et al.,* 2006). This species was not mapped because there were few sightings for the study area in the available data bases.

The short-beaked common dolphin is widely but discontinuously distributed in tropical and temperate waters of the Atlantic and Pacific; the species appears to select areas with a surface water temperature of 10°C-20°C, but it may follow warm-water currents beyond its normal distribution. In the

study area off north/central California, the species occurred over the continental shelf and slope, but mostly offshore beyond the slope. Off southern California, the offshore form is associated with conspicuous features of the bottom relief such as seamounts and escarpments, preying at night on organisms associated with the deep-scattering layer (Carwardine, 1995).

Although this species is the most abundant cetacean off California, there are relatively fewer sightings of this species in the survey data used in this assessment; most sightings in the study area for this assessment occurred offshore over the deep ocean. The abundance of short-beaked common dolphins off California varies with seasonal and interannual changes in oceanographic conditions (Carretta *et al.,* 2007); during warm-water years the species occurs further north, into waters off central and northern California. The absence of sightings on this map may reflect insufficient survey effort, rather than a real absence from a area.

As of 2007, this species is not listed as “threatened” or “endangered” under the Endangered Species Act nor as “depleted” under the Marine Mammal Protection Act. Short-beaked common dolphins typically feed in groups and mostly at night on small schooling fishes (e.g., sardines and anchovies) and squid.

4.4 CHAPTER SUMMARY

Over 60 maps for 23 mammal species were developed for this document using the data sets compiled in the CDAS central California data set (1980-2003), as well as data from NOAA's Southwest Fisheries Science Center (SWFSC). Results indicated that the marine mammals of the study area are widely distributed from the estuaries to the deep ocean, and while some species are found in particular habitat zones, such as over the shelf or in deep waters offshore, most species are distributed over a variety of bathymetric zones. Marine mammals use the sanctuary waters and adjacent land areas for feeding, breeding, wintering, migration, resting, and also as a nursery area. Several mammal species (e.g., sperm whale, beaked whales) dive deep in the water column in pursuit of prey.

The broad-scale spatial coverage of the SWFSC maps for 17 cetacean species developed from the NMFS/SWFSC marine mammal stock assessment shipboard surveys provided additional information for these species off Washington, Oregon and California. These data, (ranging from July-December for the years 1991, 1993, 1996 and 2001) provide an understanding of the larger spatial extent of species distributions off the west coast of Washington, Oregon and California.

This section summarizes the assessment of marine mammals occurring off north/central California, and includes additional information not presented earlier in this chapter or in Phase I of this work. Table 4.4 is an updated summary of selected life history and management characteristics, Table 4.5 is a summary of species stock population and status, and Table 4.6 is a summary of the spatial and temporal patterns of marine mammals observed in the national marine sanctuaries off central California and in the study area. The information in these three tables is intended to complement and summarize the data in the species maps, summary mammal maps (Fig. 4.24, 4.25. and 4.26), and map descriptions. Table 4.6 was initially developed using available at-sea and land-based (haulout) survey data from 1980 to 2006 and from literature sources. It was then reviewed by several experts (see table notes); reviewer comments were then incorporated into the final table.

All marine mammals in this analysis are protected under the Marine Mammal Protection Act. Many marine mammal species and stocks in this analysis have small population sizes and special protection status; the latest available information on population sizes and trends are shown in Table 4.5. Eight species or species stocks have Endangered Species Act (ESA) status. Of the 36 species or stocks presented in the table, 36% (13/36) have population estimates under 2,000 animals. Population size estimates for most of these species are periodically updated, and additional information can be found at http://www.nmfs.noaa.gov/pr/sars/species.htm. The information for southern sea otter is provided through the Fish and Wildlife Service, Ventura Office.

Overview of Occurrence Patterns

The CDAS central California data set (1980-2003) was evaluated for the study area encompassing the three national marine sanctuaries off north/central California: ocean waters between Point Arena (38°54'36"N) and Point Sal (34°54"0"N), and offshore to the extent of data availability. Areas and time periods associated with higher marine mammal densities, sightings, and terrestrial habitat use (e.g., rookeries) were identified in the analysis when possible (see individual and summary mammal maps and descriptions).

Overall Temporal Patterns Observed

The marine mammal fauna of the study area include species with a variety of temporal occurrence patterns that often can be characterized based on their breeding, feeding and migration activities (see Tables 4.4 and 4.6). Resident breeding mammal species include the southern sea otter, Pacific harbor seal, northern elephant seal, Steller sea lion, and likely harbor porpoise and bottlenose dolphin. The California sea lion and northern fur seal are also resident breeders, but their rookeries are only minor at this time. Pinniped attendance at rookery sites varies by species, sex and age class and some portions of the population (e.g., males, females, immatures) move away from the rookeries and even out of the study area after breeding to feed (e.g. northern elephant seals, northern fur seals, Steller sea lions and California sea lions). Species that occur year-round but that exhibit highly variable seasonal shifts in distribution include Dall's porpoise, Risso's dolphin, Pacific white-sided dolphin, and northern right whale dolphin. Species that come to feed seasonally in the study area include northern fur seal, and blue, humpback and killer whales. The

Table 4.4. Summary life history and management information for selected marine mammals off north/central California.

		Protection & Population Status in the Study Area		Occurrence & Breeding in Study Area			Primary Prey Types					
Common Name	**Scientific Name**	**Protection Status (FE, FT, SE, ST - see notes 2 & 3 below)**	**Population Trends of Species and/or Stocks (Increasing, Decreasing, Relatively Stable, Unknown)** [5]	**Temporal Occurrence**	**Period of Primary Occurrence**	**Breeding Period**	**Benthic Invertebrates**	**Plankton**	**Euphausiids (krill)**	**Other Pelagic Invert's (e.g. squid, octopus)**	**Fishes**	**Other Vertebrates (e.g., mammals, birds)**
Southern sea otter	*Enhydra lutris nereis*	FT subspecies	Increased 5% per year from 2001-2007	Year-round	All months	June/July-Oct/Nov	X			X		
California sea lion	*Zalophus californianus*		Increasing, except for declines during El Niño events	Year-round; seasonally abundant	Aug-Mar	Mar-June				X	X	
Steller sea lion	*Eumetopias jubatus*	FT Distinct Population Segment	Overall, species is increasing, but decreases are occurring in CA.	Year-round	All months	mid-May to mid-July				X	X	
Northern fur seal	*Callorhinus ursinus*		Increased steadily except for declines in 1983 & 1998 ~ El Niño events	Year-round; seasonally abundant	Feb-May	mostly June-July				X	X	
Pacifc harbor seal	*Phoca vitulina richardsi*		Stable	Year-round	All months	Mar-July				X	X	
Northern elephant seal	*Mirounga angustirostris*		Increasing in CA, stable or decreasing in Mexico	Year-round; seasonally abundant	At-sea - unknown at this time; at rookeries Nov-Mar	mid-Dec thru mid-Mar				X	X	
Dall's porpoise	*Phocoenoides dalli*		Unknown	Year-round	No trend	Unknown				X	X	
Harbor porpoise (Northern CA, San Francisco/ Russian River, Monterey stocks)	*Phocoena phocoena*		San Francisco/Russian River & Monterey stocks are stable; Morro Bay stock is increasing.	Year-round	Unknown at this time	Unknown				X	X	
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*		Unknown	Year-round	No trend	Unknown				X	X	
Risso's dolphin	*Grampus griseus*		Unknown	Year-round	No trend	Unknown				X	X	
Bottlenose dolphin (California coastal & offshore stocks)	*Tursiops truncatus*		CA coastal stock: Stable from 1987-1998; offshore stock - no trend	Year-round	No trend	Unknown?				X	X	
Short-beaked common dolphin	*Delphinus delphis*		Unknown	Not detected in CDAS data	No trend	Unknown				X	X	
Northern right whale dolphin	*Lissodelphis borealis*		Unknown	Year-round	No trend	Unknown				X	X	
Killer whale (Eastern N. Pacific Southern Resident)	*Orcinus orca*	FE Distinct Population Segment	Unknown	Year-round	No trend	Unknown				X	X	X
Baird's beaked whale	*Berardius bairdii*		Unknown	Unknown	Insufficient data	Unknown				X	X	
Cuvier's beaked whale	*Ziphius cavirostris*		Unknown	Unknown	Insufficient data	Unknown				X	X	
Mesoplodont beaked whales	*Mesoplodond spp.*		Unknown	Unknown	Insufficient data	Unknown				X	X	
Sperm whale	*Physeter macrocephalus*	FE	Unknown	Seasonal	No trend	not in study area				X	x	
Gray whale	*Eschrichtius robustus*	Delisted Federal 1994	Increasing ~ 1.9% from 1967/69-2001/02; but pop'n had a sharp drop from 29,758 in 97/98 to 18,178 in 01/02.	Year-round; seasonally abundant	Dec-Apr	Off Baja CA Mex. mostly Dec-Jan	X	X	X		x	
Blue whale	*Balaenoptera musculus*	FE	Unknown	Mostly seasonal	Jun-Nov	not in study area			X			
Humpback whale	*Megaptera novaeangliae*	FE	Increasing 6-7%/yr[1/9]	Year-round; seasonally abundant	Mostly Apr-Dec [1/11]; year-round off Farallon Is.	not in study area			X	X	X	
Fin whale	*Balaenoptera physalus*	FE	Unknown	Mostly seasonal	Aug-Nov	not in study area			X		X	
Minke whale	*Balaenoptera acutorostrata*		Unknown	Year round	No trend	Unknown?			X		X	

Notes

1. Superscripts indicate sources as follows: 1-USGS, 2002; 2-Carretta et al.; 2001; 2a-Carretta et al. 2002; 3-P.Morris pers.comm., credited to B. Le Boeuf; 4-Hastings and Sydeman, 2001; and 5-USFWS, 2000. 6-Sydeman & Allen, 1999; 7-Gerrodette et al.,1985; 8-Calambokidis pers.comm.; 9-Forney et al., 2000; 10-Rugh et al., 2002, 11-Monterey Bay Whale Watch: http://www.montereybaywhalewatch.com/marlife.htm
2. All marine mammal species have legal protection under the Marine Mammal Protection Act of 1972; species identified as Federally Endangered (FE), Federally Threatened (FT) are identified. Although not listed above, sei and right whales are also identified as Federally endangered.
3. None of the marine mammal species shown above are listed as state endangered (SE), state threatened (ST) or species of special concern (SSC) in California at this time. - 5/14/07
4. This table was developed by Tracy Gill at NOAA, with help from Carol Keiper, Oikonos Ecosystem Knowledge.

Table 4.5. Summary of protection, populations and trends for selected marine mammal species occurring off north/central California.

Species	Stock	Scientific name	Federal Protection Status in Study Area[9]	Population Trend	Population Size Estimate (no. of animals)	Minimum Population Size (no. of animals)	Strategic & Depleted Stock or Species	Date Stock Assessment Reports Last Revised
Southern sea otter	California	*Enhydra lutris nereis*	FT subspecies	Increasing	28,181	2,692	Y	11/01/06
California sea lion	U.S.	*Zalophus californianus*		Increasing	244,000-237,000	138,881	N	12/15/03
Steller sea lion	Eastern U.S.	*Eumetopias jubatus*	FT Distinct Population Segment	Increasing	47,885	44,555	Y	05/15/06
Northern fur seal	San Miguel Island	*Mirounga angustirostris*		Increasing	9,424	5,096	N	12/15/06
Pacific harbor seal	California	*Phoca vitulina richardsi*		Stable	34,233	31,600	N	11/01/05
Northern elephant seal	California breeding	*Mirounga angustirostris*		Increasing	101,000	60,547	N	10/31/02
Dall's porpoise	California/Oregon/ Washington (CA/OR/WA)	*Phocoenoides dalli*		Unknown	98,617 (CV=0.33)	75,915	N	12/15/03
Harbor porpoise	Morro Bay	*Phocoena phocoena*		Increasing	1656 (CV-0.39)	1,206	N	03/15/05
Harbor porpoise	Monterey Bay	*Phocoena phocoena*		Stable	1,613 (CV=0.42)	1,149	N	03/15/05
Harbor porpoise	San Francisco- Russian River	*Phocoena phocoena*		Stable	8,521 (CV=0.38))	6,254	N	03/15/05
Pacific white-sided dolphin	CA/OR/WA	*Lagenorhynchus obliquidens*		Unknown	59,274 (Cv=0.50)	39,822	N	12/15/03
Risso's dolphin	CA/OR/WA	*Grampus griseus*		Unknown	16,066 (CV=0.28)	12,748	N	12/15/03
Bottlenose dolphin	California Coastal	*Tursiops truncatus*		Stable	323 (CV=0.13)	290	N	12/15/06
Bottlenose dolphin	CA/OR/WA Offshore	*Tursiops truncatus*		Unknown	5,065 (CV=0.66)	3,053	N	12/15/03
Striped dolphin	CA/OR/WA	*Stenella coeruleoalba*		Unknown	13,934 (CV=0.53)	9,165	N	12/15/03
Short-beaked common dolphin	CA/OR/WA	*Delphinus delphis*		Unknown	449,846 (CV=0.25)	365,617	N	12/15/03
Long-beaked common dolphin	California	*Delphinus capensis*		Unknown	43,360 (CV=0.72)	25,163	N	12/15/03
Northern right-whale dolphin	CA/OR/WA	*Lissodelphis borealis*		Unknown	20,362 (CV=0.26)	16,417	N	12/15/03
Killer whale	Eastern N. Pacific Offshore	*Orcinus orca*		Unknown	466	361	N	12/15/03
Killer whale	Eastern North Pacific, Southern Resident	*Orcinus orca*	FE Distinct Population Segment	Increasing	91	91	Y	12/15/06
Short-finned pilot whale	CA/OR/WA	*Globicephala macrorhynchus*		Unknown	304 (CV=1.02)	149	N	11/01/05
Baird's beaked whale	CA/OR/WA	*Berardius bairdii*		Unknown	228 (CV=0.51)	152	N	12/15/03
Cuvier's beaked whale	CA/OR/WA	*Ziphius cavirostris*		Unknown	1,884 (CV=0.68)	1,121	N	12/15/03
Mesoplodont beaked whales	CA/OR/WA	*Mesoplodon spp.*		Unknown	1,247 (CV=0.92)	645	N	12/15/03
Sperm whale	CA/OR/WA	*Physeter macrocephalus*	FE	Unknown	1,233 (CV=0.41)	885	Y	12/15/03
Humpback whale	Eastern North Pacific	*Megaptera novaeangliae*	FE	Increasing	1,391 (CV=0.22)	1,158	Y	11/01/05
Blue whale	Eastern North Pacific	*Balaenoptera musculus*	FE	Unknown	1,744 (CV=0.28)	1,384	Y	03/15/05
Fin whale	CA/OR/WA	*Balaenoptera physalus*	FE	Unknown	3,279 (CV=0.31)	2,541	Y	12/15/03
Sei whale	Eastern North Pacific	*Balaenoptera borealis*	FE	Unknown	56 (CV=0.61)	35	Y	12/15/03
Minke whale	CA/OR/WA	*Balaenoptera acutorostrata*		Unknown	1,015 (CV=0.73)	585	N	12/15/03
Gray whale	Eastern North Pacific	*Eschrichtius robustus*		Increasing?	18,178 (2001/02)	17,752	N	02/06/05

Notes
1. Southern sea otter: 2,818 animals is a 3-year running average of unadjusted spring counts for 2005-2007, and represents the population size estimate. The minimum population size estimate represents the spring 2006 raw count. Population size is from USGS (http://www.werc.usgs.gov/otters/ca-surveydata.html) and the minimum population estimate is from the draft stock assessment report (SAR) for southern sea otter, from FWS, Ventura, CA.
2. Unless noted otherwise below, the data in this table is from Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker, B. Hanson and M. Lowry. 2007. U.S. Pacific Marine Mammal Stock Assessments: 2006. U.S. Dept. of Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-398. 321pp.
3. Information for Steller sea lion and gray whale in Angliss, R.P. and R.B. Outlaw. 2007. AK Marine Mammal Stock Assessments, 2006. U.S. DOC., NOAA Tech. Memo. NMFS-AFSC-168. 244 pp.
4. Population estimate for humpback whale is from Calambokidis *et al.,* 2004.
5. Most of the information in this table refers to Marine Mammal Population Act (MMPA), except for the information on Protection status, which is determined through the Endangered Species Act (ESA).
6. Three species included in this table were not mapped for this assessment: striped dolphin, long-beaked common dolphin and short-finned pilot whale.
7. This table was developed by Tracy Gill and reviewed and revised by Tom Eagle, Jim Carretta and Naomi Lundberg.
8. At the end of this project, a NOAA/SWFSC technical memorandum was identified that includes 2005 abundance estimates for many of the species above in the study area. It was too late to update this table but a digital copy of the report can be downloaded from http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-406.PDF
9. All marine mammal species have legal protection under the Marine Mammal Protection Act of 1972; species identified as Federally Endangered (FE), Federally Threatened (FT) are identified.

Table 4.6. Summary of estimated spatial and temporal occurrence for selected marine mammals In ocean waters off north/central California.

Species or Species and Stock	Occurrence in National Marine Sanctuaries (NMS)[3,4]			Spatial Occurrence Over Bathymetric Zones in the Study Area[3,4,5,6]					Temporal Occurrence in Study Area[3,4,5,6,7]		
	Cordell Bank NMS	Gulf of Farallones NMS	Monterey Bay NMS	Nearshore (Coast to 50m isobath)	Inner Continental Shelf (coast to 100m isobath)	Outer Continental Shelf (100m–200m isobaths)	Continental Slope (200m–2,000m isobaths)	Deep Ocean, beyond the Slope (>2000m isobath)	Upwelling Season (3/15-8/14)	Oceanic Season (8/15-11/14)	Davidson Current Season (11/15-3/14)
Southern sea otter *	NS	NS				NS	NS	NS			
California sea lion *											
Steller sea lion *											
Northern fur seal *											
Pacific harbor seal *							NS	NS			
Northern elephant seal *											
Bottlenose dolphin, CA coastal stock **	NS						NS	NS			
Harbor porpoise (central CA) **							NS	NS			
Dall's porpoise											
Risso's dolphin				NS							
Pacific white-sided dolphin				NS							
Short-beaked common dolphin	NS										
Northern right-whale dolphin				NS	NS						
Killer whale											
Baird's beaked whale				NS	NS	NS					
Cuvier's beaked whale				NS	NS	NS					
Other beaked whales: *Mesoplodont spp.*				NS	NS				NS		NS
Sperm whale				NS	NS						
Blue whale											
Humpback whale											
Fin whale											
Minke whale											
Gray whale								NS			

Key:

NS or no tone: Not sighted or 1-2 total sightings in available data sets; see below.

Present; sightings were mostly Rare or Uncommon at sea (e.g., sightings occurred once a month to once a year)

Present; sightings were mostly Common or Frequent at sea (e.g., sightings occurred almost daily to every few weeks)

* Indicates breeding occurs in the study area.

** Indicates breeding likely occurs in study area.

Notes:

1. The intent of this table is to provide a summary of where and when marine mammals occur in the study area off north/central California, from Pt. Arena ro Pt. Sal. This table was developed in spring-summer 2007, and is based on a combination of expert opinions (see below) and the following sources: the CDAS central CA data set (1980-2003), the NOAA/SWFSC mammal surveys (1991-2001), NMFS stock assessment reports (e.g., Caretta et al., 2006), information from the Monterey Bay Whale watch site (http://www.gowhales.com/sighting.htm), and current sanctuary management plans.
2. This table was developed by Tracy Gill and Carol Keiper and reviewed and revised by David Ainley, John Calambokidis, Jan Roletto, Sarah Allen and Lisa Etherington.
3. Species may occur in the study area in areas and time periods not indicated; the absence of sightings may be due to insufficient survey effort than real absence from the area or season.
4. This table does not attempt to address relative abundance; it does contain a qualitative estimate of frequency of sightings in the study area. Frequency of sightings can vary annually and interannually. For example, a species can generally be considered rare in a certain location or time period, but occasionally occur in that place o time with common or frequent sightings.
5. The study area includes the ocean waters off north/central California, from Pt. Arena to Pt. Sal, CA, and offshore to the extent of data (~35-39°N x 120-130°W).
6. When different opinions were offered by researchers as to whether a species was not sighted or sighted (no tone or light) we chose to show the species as Present, rare/uncommon. If the difference was deciding between the lower and higher categories of sightings based on two sources, we chose the dark tone.
7. Species may have been sighted in the study area in all three seasons, but may not be considered year-round, as some species move out of the study area for part of the year for feeding or breeding.

gray whale is a seasonal migrant through the study area on its way to feeding and breeding grounds.

Seasonal Patterns Observed

Based on the data used in this analysis, the patterns of occurrence for the large and small cetaceans, pinnipeds, and fissiped species in the three ocean seasons (described in Chapter 2) are summarized below and in Table 4.6. Some species occurred in the study area in all three ocean seasons, but were not present year-round. For example, the gray whale occurs in the study area mostly during the Davidson Current and Upwelling seasons (mostly November-May), but is mostly gone by the end of May, and much of the population is absent from the study area for about 2.5 months of the Upwelling season.

In general, seasonal patterns of occurrence were evident for some migrating species of large cetaceans (gray and humpback whales) and for the non-breeding pinnipeds that breed mostly outside the study area (northern fur seal and California sea lion). Seasonally abundant species that migrate to the study area to feed include the humpback and blue whale, California sea lion (non-breeders from the south), northern fur seal (non-breeders from the north and south), killer whales (to prey on seals, sea lions, and other marine mammals including gray whales), and a seasonally abundant migrant, the gray whale, that travels north from the breeding grounds in the winter/spring, and south from the feeding grounds in the late fall and winter.

Observations of Cetaceans in Three Ocean Seasons

Large Cetaceans.

- The humpback whale was one of the most commonly sighted (overall CDAS density, 0.04/km^2) pelagic baleen whales in the study area and, because of the seasonal biological cycle and migration of this species, humpbacks were seen most frequently during the Oceanic Season. Greatest densities in CDAS data set were in areas around the Farallon Islands, to the west and south of the islands, and over the outer shelf and upper slope.

- Although there were not enough sightings to make seasonal maps, the blue whale (like the humpback whale) migrates to north/central California to forage on seasonally-abundant euphausiids during summer and fall and is thus likely to be more abundant during the later part of the Upwelling season and Oceanic season.

- The gray whale was also a commonly sighted baleen whale (overall CDAS density, 0.03/km^2), found in coastal and shelf regions. Because of the seasonal biological cycle and migration of this species, gray whales were seen most frequently during the Davidson Current Season. Greatest overall densities were in these coastal areas: Point Arena to Bodega Bay, off Año Nuevo, and south almost in a continual band along the coast from Pt. Piños in Monterey Bay to Pt. Sal, the southern extent of the study area.

Small Cetaceans.

- The Pacific white-sided dolphin was the most abundant of the small cetaceans in the CDAS data set (overall CDAS density, 1.97/km^2); greatest densities for this species were in outer shelf and slope areas during the Oceanic season.

- The northern right whale dolphin was the second most abundant of the small cetaceans in the CDAS data set (overall CDAS density, 1.30/km^2). It occurred in all central California sanctuaries in all seasons, with greater densities occurring in the southern half of the study area, over the slope and beyond. Densities were somewhat higher during the Oceanic and Davidson Current seasons. Relatively high densities also occurred well beyond National Marine Sanctuary boundaries.

- Risso's dolphin was the third most abundant of the small cetaceans (overall CDAS density, 0.72/ km^2) in the CDAS data set, and overall, was more concentrated in the central and southern portions of the Monterey Bay National Marine Sanctuary and in areas beyond, to the south and west. Greatest densities occurred in outer shelf, and slope and canyon regions. Although densities were somewhat similar in all three ocean seasons, Risso's dolphin was more widespread during the Upwelling Season and more concentrated in the southern portion of the study area during the Oceanic and Davidson Current Seasons.

- The Dall's porpoise was the fourth most abundant small cetacean (overall CDAS density, 0.15/km^2), however this species was the most commonly sighted (number of sightings: n = 818) of the small cetaceans. Overall density distribution of Dall's porpoise was widespread on shelf, upper/lower slope, and deep ocean habitats with greatest densities in CBNMS, GFNMS (near the Farallon Islands), and the northern and southern regions of the MBNMS. Although Dall's porpoise occurred in the study area in all seasons, densities were somewhat greater during the Upwelling and Oceanic Seasons. During the Upwelling Season, density was somewhat greater in the Cordell Bank and Gulf of the Farallones National Marine Sanctuaries.

Less Common Cetaceans.
Due to insufficient information, no seasonal patterns in the data could be determined for the following species: bottlenose dolphin, harbor porpoise, fin whale, sperm whale, killer whale, and beaked whales.

Observations of Pinnipeds in Three Ocean Seasons

The most abundant pinniped in the study area, the California sea lion, was also present year-round (overall CDAS density, 0.29/km^2). The highest at sea densities occurred during the Oceanic season (0.58/km^2, just after the breeding season, with highest overall at-sea densities occurring along inner Monterey Bay, off Carmel, and just south of Estero Bay. In general, densities were also greater in areas near haulout and rookery sites, such as Año Nuevo and the Farallon Islands. Seasonal trends in relative abundance and attendance at haulout sites were associated with warm-water periods (El Niño events). Sea lions were more numerous both at-sea and on land during these warm-water periods.

The northern fur seal was the second most numerous pinniped (overall CDAS Density of 0.11/km^2) seen in the study area. Although present in all seasons, this species was most abundant at sea during the Davidson Current Season (0.17/ km^2), and Upwelling Season (0.10/km^2). This distinct pattern occurred during their non-breeding period and coincided with their migration to north/central California from San Miguel Island and the Pribilof Islands. Northern fur seals migrate after the breeding/pupping season (mostly June-July at San Miguel Island in the southern California Bight and on Southeast Farallon Island); adult females and juveniles migrate from the rookeries (San Miguel, southeast Farallon Island, and the Pribilof Islands) and are therefore relatively abundant in the study area off northern/central California during the winter and early spring. Greatest densities of the northern fur seal in the study area were outside of National Marine Sanctuary boundaries.

Although all five pinniped species analyzed in this study were present in all three seasons in all three national marine sanctuaries, it was not possible to produce seasonal maps for the Steller sea lion, northern elephant seal, and Pacific harbor seal because at-sea sightings were relatively rare (less than 300 for each species). Steller sea lions, a threatened species, occur in relatively small numbers in the study area. Relatively infrequent sightings of northern elephant seals and Pacific harbor seals at sea are the result of diving behavior, time spent underwater, and small group size. These species are frequently sighted at haulouts and rookeries at specific times of year (see Table 4.4).

Observations of Southern Sea Otter

The southern sea otter is the only fissiped species in the analysis. It is a year-round resident in the study area, occurring mostly along the coast and inner shelf. Some sea otters shift their range seasonally, and males in particular tend to migrate to the range peripheries during the winter and early spring. In the study area, highest spring densities (5.2 - 10.8 otters per km^2) occurred off Monterey Bay peninsula, and moderate densities (0.51 - 1.0 otters per km^2) occurred from Pt. Año Nuevo to Pt. Estero.

Overall Spatial Patterns Observed: Associations with Bathymetric Areas

A visual inspection of the species maps and spatial occurrence summary (Table 4.6) revealed distinct spatial patterns relative to the bathymetrically-defined zones: near-shore (Coast to 50 m isobath), Inner Continental Shelf (coast to 100 m isobath), Outer Continental Shelf (100 m - 200 m isobath), Continental Slope (200 m – 2,000 m isobath), Deep Ocean (>2,000 m isobath). These patterns may be influenced by factors other than water depth, for example, proximity to rookeries, haulouts, or upwelling areas Bathymetric contours, however, are relatively easy to delineate and were therefore

used to evaluate spatial patterns. The mammal maps reflect animals that were sighted over these areas, at the surface, and do not imply occurrences at depths of the bathymetrically-defined zones.

Although some species were widely distributed in the study area and were found in all bathymetric zones (California sea lion, Steller sea lion, northern fur seal, northern elephant seal, short-beaked common dolphin, killer whale, blue whale, humpback whale, fin whale, Minke whale; see Table 4.6), most species occurred more frequently in one or two zones. For example, species that appeared more frequently in one zone included: the southern sea otter and harbor porpoise mostly in the nearshore, and the killer whale and Baird's beaked whale mostly over the continental slope. Species that occurred more frequently in two zones (near-shore and shelf) were the California sea lion, Pacific harbor seal, Minke whale, and gray whale, whereas species that occurred more frequently in two offshore/outer continental shelf and shelf-slope zones were the northern elephant seal, and blue whale. Species that occurred more frequently in three offshore zones (outer continental shelf, continental slope, and deep ocean) were the northern fur seal, Dall's porpoise, Risso's dolphin, Pacific white-side dolphin, and northern right whale dolphin. One species, the humpback whale, was commonly sighted in four zones (near-shore through 2,000 m).

Areas of Relatively High Marine Mammal Richness in the Study Area

For pinnipeds on land at rookeries and haulouts, 4-5 pinniped species and over 5,000 pinniped individuals (Figure 4.14) occurred at each of these sites: southeast Farallon Island, Pt. Reyes, Año Nuevo island and mainland, and Pt. Piedras Blancas. For pinniped richness at sea (Figure 4.15), the CDAS data set indicated the shelf and slope from Cordell Bank and Bodega canyon south to just off Big Sur as well as areas off Pt. Piedras Blancas, and Estero and San Luis Obispo bays had 4-5 species in each 20' latitude-longitude cell.

Observed cetacean richness at sea (Figure 4.26) was mostly 10-13 species on the shelf and slope in and off Cordell Bank, Pt. Reyes, the Gulf of the Farallones, and Monterey Bay south to just off Big Sur. A large analysis block off Monterey canyon also had 12 species and a 20' cell off Pt. Sal, to the south, had ten cetacean species. These measures of observed cetacean species richness are lower bounds on the number of species, as some cetaceans known to occur in the area were not observed on the CDAS surveys, and marine mammals at sea are often underwater or otherwise difficult to see. Observed richness is also influenced by the amount of survey effort, which varies geographically (see Figures 4.1 and 4.2), and should be interpreted accordingly.

Observations of Marine Mammals Relative to National Marine Sanctuary Boundaries

- In this analysis, at least eight of the 23 marine mammals evaluated are relatively pelagic (deep ocean), highly mobile and widely distributed. These species were mostly sighted in two habitats: deep ocean habitats (northern fur seal, northern elephant seal, humpback whale, blue whale, Dall's porpoise and Risso's dolphin) and slope habitats (northern right-whale dolphin, Pacific white-sided dolphin). All eight species occur both in and outside of the National Marine Sanctuaries in the study area.

- Among the species of marine mammals mapped, relatively high densities of northern fur seals Dall's porpoise, Pacific white-sided dolphins, Risso's dolphin, and northern right-whale dolphins occurred westward, and to the north and south of the three central California National Marine Sanctuaries.

- Among the larger migratory cetaceans (humpback, blue, and gray whale), all occur both within and outside National Marine Sanctuary boundaries, but either migrate to sanctuary waters to feed (humpback, blue whale and sometimes gray whale), or migrate through sanctuary waters along the coast and over the continental shelf and slope en route to calving areas in the south or foraging areas to the north (gray whale).

- Within the study area, haulout sites for the northern elephant seal all occurred within National Marine Sanctuary boundaries. Haulout sites for the harbor seal, California sea lion and Steller sea lion also occurred within National Marine Sanctuary boundaries, but also both north (Steller sea lion, California sea lion, harbor seal) and south (California sea lion, harbor seal) of the boundaries.

- Rookeries for the northern elephant seals, Steller sea lion and California sea lion occurred within National Marine Sanctuary boundaries of the study area; however, during the El Niño of 1998, rookeries for California sea lion were located at Lion Rock and Point Sal Rock, to the south of National Marine Sanctuary boundaries.

- Southern sea otters occurred in coastal shelf waters, and a majority of these animals occur in Monterey Bay National Marine Sanctuary. The distribution of the species is expanding, and it occurs outside of the study area to the south to San Nicholas Island in the southern California Bight.

Summary Remarks

Most marine mammals in the study area are highly mobile marine predators that feed on a great diversity of prey and are attracted to regions in the study area that are well known for seasonally abundant (and also highly variable), high prey densities (e.g., Monterey Bay and Canyon, Cordell Bank, Gulf of the Farallones, off Pt. Reyes, and Año Nuevo, and along the shelf-break in these areas). For example, resident marine mammals (e.g., harbor seals) feed on locally available and seasonally abundant invertebrates or fish in relative proximity to their rookery/haulout sites, whereas the seasonal migrants (e.g., humpback and blue whales) use the study area as a foraging destination and feed on seasonally available krill or fish, a pattern reflected in their relative abundance during the Oceanic Season. Species' differences in habitat use relative to bathymetric features and ocean seasons are likely related to factors such as the distribution, abundance, and availability of various prey (species/sizes). The unique bathymetric features of the study area, coupled with the complex physical oceanography off central California, play an important role in the distribution of marine mammal prey and the corresponding distribution of mammals themselves. The importance of the study area relative to the distributional patterns of marine mammals in the area must be considered in the context of the variability of ocean climate and oceanography. For example, the frequency, duration, and cycles of ocean processes associated with the California Current System, and other cycles such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), strongly affect productivity, community structure, and ultimately, prey availability. The unique combination of a continental shelf that varies greatly in width, areas of high topographic relief (canyon edges, steep slopes, ridges, banks, shelf breaks, and seamounts), and the distinctive oceanographic features associated with seasonal upwelling (e.g., upwelling plumes, fronts, temporal and spatial variation in thermocline depth, surface and subsurface currents and eddies) affect the distribution patterns of organisms at many trophic levels. For example, large concentrations of small schooling fishes and euphausiids (krill) that are maintained by the seasonally high primary productivity (supported by seasonal coastal upwelling), often occur along canyons, shelf-breaks, seamounts, and downstream of major upwelling centers located off Point Arena, Point Reyes, Point Año Nuevo, and Point Sur, features that also are important areas for both large and small cetaceans.

Human Impacts to Marine Mammals in the Study Area

Marine mammals are generally long-lived organisms with low reproductive rates. As occupants of the California Current Ecosystem they are susceptible to not only ocean climate changes and associated prey availability and predators, but also anthropogenic threats and disturbances that include: disturbances at haulout and pupping sites, entanglement and ingestion of marine debris (including plastics), active and discarded (e.g., ghost nets) fishing gear, underwater noise, oil spills, and poor water quality (e.g., harmful algal blooms and domoic acid). Of particular concern is the threat of noise to beaked whales (Cox *et al.,* 2006). An emerging pattern is the use of marine mammals (e.g., southern sea otter, harbor seal, California sea lion) as sentinels of environmental contamination by Persistent Organic Pollutants (POPs). As more chemical compounds are transported into the world's oceans, significant concerns for many species of marine mammals are toxins from industrial and agricultural chemicals that concentrate in their blubber. Research suggests that Persistent Organic Pollutants (POPs) are contaminating coastal food chains, with killer whales being among the most contaminated marine mammals in the world (Ross *et al.,* 2000). Contaminants in the coastal environment originate from a combination of sources, including local (urban development and industry and agriculture), and more distant global origins (atmospheric transport of POPs). Ascertaining the extent to which local versus global sources are responsi-

ble for POP contamination represents an important scientific question which has important management implications. Assessment of potential risks from effects of pollutants on humpback whales has been recommended as an area of future research (Commission for Environmental Cooperation Secretariat, 2005).

Response to Short-Term Changes in Climate

Although it is likely that short periods of unusually warm or cool waters affect migratory species and shorter-ranging, more resident marine mammal species, it was not possible to determine effects of these events during this assessment. Distributional responses to the extremes of climate (e.g., El Niño vs. La Niña) may be confounded by: 1) issues associated with comparing different data sets; 2) small at-sea populations and therefore small sample size for some species (e.g., elephant seals, harbor seals); 3) changes in the distribution of migratory species that occur outside of the study area; 4) demographic lags to species' responses; 5) variable effects on different marine mammal prey; and 6) behavioral differences among species.

The California sea lion provides an example of a species shift in distribution in response to changing oceanographic conditions. The relative increase in at-sea abundance of this species during the El Niños of 1986-87, 1992-93, and 1997-98 (not presented in maps; see studies below), likely reflected a greater than usual influx of individuals in response to a reduction in food off southern California (Trillmich and Ono, 1991; Allen, 1994; Keiper, 2001; Keiper *et al.,* 2005). The greater numbers of sea lions at sea in the study area coincided with greater numbers that occurred at haulout sites in the study area. For example, during a relatively recent and significant El Niño (1998), an influx of immature sea lions hauled out at Double Point and at Point Reyes Headlands (Allen, per. comm.), and at the Farallon Islands (Sydeman and Allen, 1999).

Effects of Longer-term Climate Changes

The study area is subjected to ocean climate changes associated with physical and biological processes on multiple spatial and temporal scales. In addition to the seasonal and inter-annual changes (timing and intensity of upwelling), and changes within a particular climate period such as the shorter-term warm-water periods (El Niño), cold-water periods (La Niña), and neutral periods (i.e. neither warm nor cold), there is considerable inter-annual physical and biological variability (Fritz and Hinckley, 2005) in the longer-term changes associated with the Pacific Decadal Oscillation (PDO), Mantua and Hare, 2002). These multiple processes at multiple scales result in ecological changes in biological communities, and ultimately, in marine mammal populations. The longer-term processes of climate change (e.g., global climate change) can potentially alter food chain interactions and ecosystem dynamics (Mullin, 1998; Springer, 1998; Tynan and DeMaster, 1997) with potentially detrimental effects on the survival of marine mammal populations.

Direct effects of global climate change on marine mammals within the study area include effects of rising sea levels on seal haul-out sites, and species affinities for a specific range of water temperature in which they can physically survive (Learmonth *et al.,* 2006). Indirect effects of global climate change on marine mammals include changes in prey availability that affect abundance, distribution and migration patterns, susceptibility to disease and contaminants, and community structure. These effects will influence reproductive success and survival, and have significant consequences for populations (Learmonth *et al.,* 2006). Thus, monitoring at the population level relative to short- and long-term climate changes presents challenges to managers and highlights an even greater need for long-term research and monitoring.

In summary, because of the complex variability described above, the spatial and temporal at-sea occurrence patterns of marine mammals are characterized by high variability, and are strongly linked to the physical and biological processes that affect their prey, even without considering human effects on this ecosystem. The spatial and temporal patterns of marine mammals revealed (and not revealed) in this analysis were presented relative to depth domains and oceanographic seasons. Investigations using an ecological approach (that integrates oceanographic influences and processes that affect marine mammal prey, and anthropogenic and population factors) would provide insight into species-specific changes in the abundance and distribution of marine mammals on multiple space and time scales.

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