PHASE II: ENVIRONMENTAL SETTING AND UPDATE TO MARINE BIRDS AND MAMMALS

A Biogeographic Assessment off North/Central California: In Support of the National Marine Sanctuaries of Cordell Bank, Gulf of the Farallones and Monterey Bay

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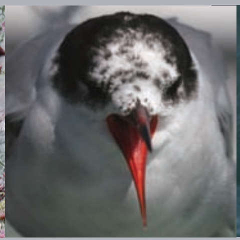


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FOR MORE INFORMATION

For more information or to download this report, please contact the NCCOS Biogeography Branch at 301-713-3028, visit: http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html or contact tracy.gill@noaa.gov

Photographs on the report cover (front and back) are from the following individuals; we greatly appreciate their contribution. Sophie Webb of Oikonos Ecosystem Knowledge provided all but two images; other photos were provided by Jan Roletto of the Gulf of Farallones National Marine Sanctuary, who took the photo of the spouting whale on the back, and Nick Metheny, who took the photo of common murres, the third small image from the left on the back.

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Phase II: Environmental Setting and Update to Marine Birds and Mammals

Prepared for NOAA's National Marine Sanctuary Program

by the

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ABOUT THIS DOCUMENT

This document is Phase II of a biogeographic assessment completed in 2004, described below. In the spring of 2001, NOAA's National Marine Sanctuary Program (NMSP) and National Centers for Coastal Ocean Science (NCCOS) launched a project to assess biogeographic patterns of selected marine species and habitats found within and adjacent to the boundaries of three west coast National Marine Sanctuaries off north/central California: Monterey Bay, Gulf of the Farallones and Cordell Bank. Sanctuary staff were conducting a joint review to update sanctuary management plans. To support this review, the NCCOS's Biogeography Branch led a partnership effort to conduct a robust analytical assessment to define important biological areas and time periods within and adjacent to current sanctuary boundaries. The assessment was based on a synthesis of many data sets that were provided by project partners.

Phase I assessment products include a CD-ROM and website containing two reports, geographic analyses and related data and results, hundreds of maps, a description of the ecosystem components and their linkages, and future activities to be addressed in Phase II. Phase I products are available at: http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html

Phase II was initiated in the autumn of 2004 to complete the analyses of marine mammals and to update the marine bird colony information. In addition to updates to the bird and mammal chapters, an environmental settings chapter was added, containing new data and maps as well as existing maps and information from related NCCOS reports on the region. This report and related products will be available at the following site by December 2007: http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html

Results of these assessments are being used to assist the NMSP and state of California in addressing issues such as: evaluating potential modification of sanctuary and reserve boundaries, and changing management strategies or administration based on the principles of biogeography.

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EXECUTIVE SUMMARY

NOAA's National Centers for Coastal Ocean Science (NCCOS) conducts and supports research, monitoring, assessments, and technical assistance to meet NOAA's coastal stewardship and management responsibilities. In 2001 the Biogeography Branch of NCCOS partnered with NOAA's National Marine Sanctuary Program (NMSP) to conduct biogeographic assessments to support the management plan updates for the sanctuaries.

The first biogeographic assessment conducted in this partnership focused on three sanctuaries off north/central California: Cordell Bank, Gulf of the Farallones and Monterey Bay. Phase I of this assessment was conducted from 2001 to 2004, with the primary goal to identify and gather the best available data and information to characterize and identify important biological areas and time periods within the study area. The study area encompasses the three sanctuaries and extends along the coastal ocean off California from Pt. Arena to Pt. Sal (35°-39°N). This partnership project was lead by the NCCOS Biogeography Branch, but included over 90 contributors and 25 collaborating institutions. Phase I results include: 1) a report on the overall assessment that includes hundreds of maps, tables and analyses; 2) an ecological linkage report on the marine and estuarine ecosystems along the coast of north/central California, and 3) related geographic information system (GIS) data and other summary data files, which are available for viewing and download in several formats at the following website:
http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html

Phase II (this report) was initiated in the Fall of 2004 to complete the analyses of marine mammals and update the marine bird colony information. Phase II resulted in significant updates to the bird and mammal chapters, as well as adding an environmental settings chapter, which contains new and existing data and maps on the study area. Specifically, the following Phase II topics and items were either revised or developed new for Phase II:

- environmental, ecological settings – new maps on marine physiographic features, sea surface temperature and fronts, chlorophyll and productivity
- all bird colony or roost maps, including a summary of marine bird colonies
- updated at-sea data CDAS data set (1980-2003)
- all mammal maps and descriptions
- new overall density maps for eight mammal species
- new summary pinniped rookery/haulout map
- new maps on at-sea richness for cetaceans and pinnipeds
- most text in the mammal chapter
- new summary tables for mammals on population status and spatial and temporal patterns

This report and related products (report, maps, tables, GIS data) will be available on CD-ROM and at the following website in February 2007:
http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html

Results of this assessment are being used to assist the NMSP and state of California in addressing issues such as evaluating potential modification of sanctuary and reserve boundaries, and changes in management strategies or administration, based on the data and analyses of these biogeographic products.

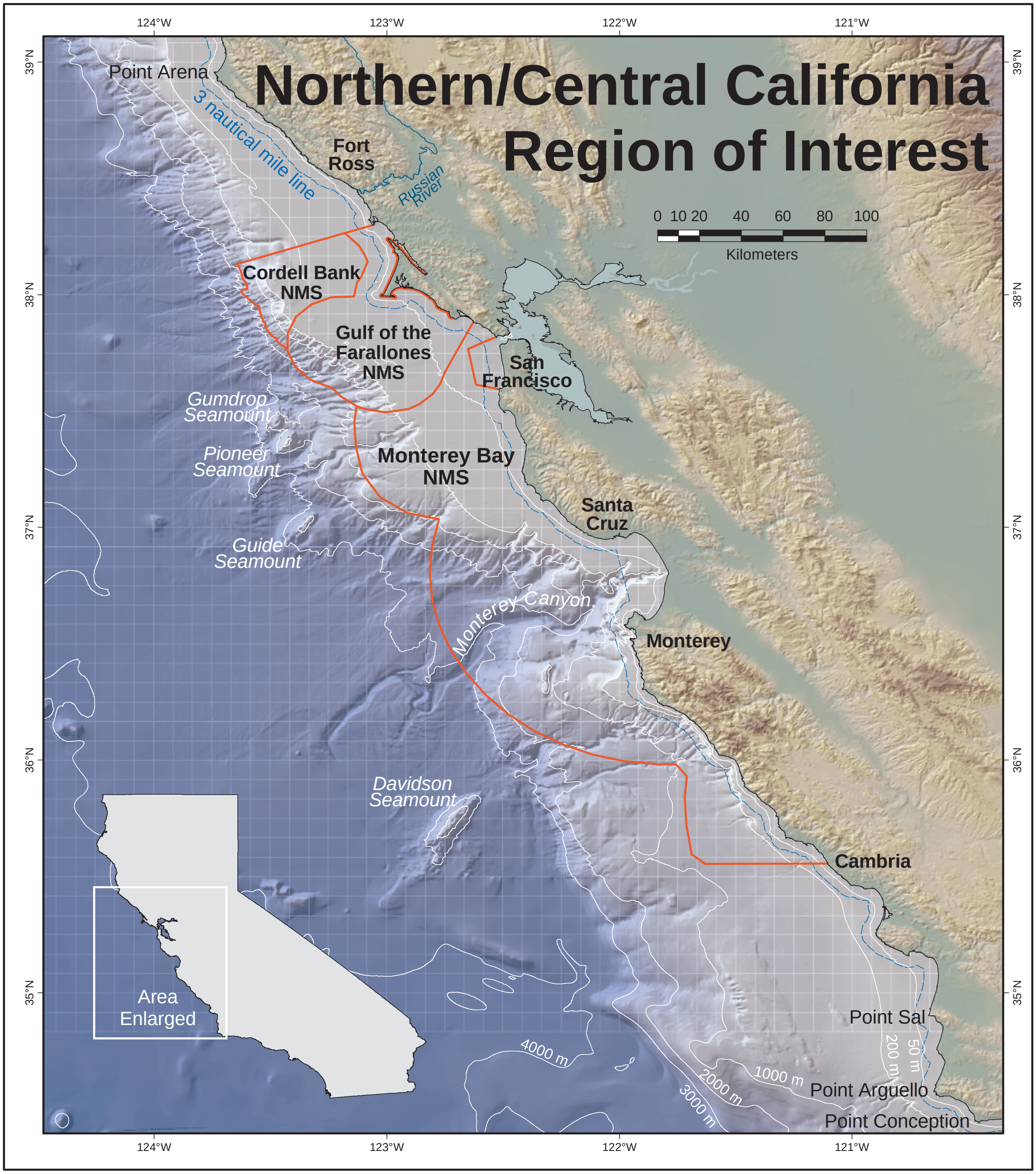

Figure 1.0 Region of interest for biogeographic assessment off north/central California

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CHAPTER 1: INTRODUCTION

1.1 PROJECT BACKGROUND

Phase I. In 2001, NOAA's National Marine Sanctuary Program partnered with the Biogeography Branch of NOAA's National Centers for Coastal Ocean Science (NCCOS) to conduct biogeographic assessments to support updates to sanctuary management plans. The first assessment conducted in this partnership focused on three sanctuaries off north/central California: Cordell Bank, Gulf of the Farallones and Monterey Bay. Phase I of this assessment was conducted from 2001 to 2004; the primary goal was to identify and gather the best available data and information to characterize and identify important biological areas and time periods within the study area and provide a suite of products for use in sanctuary management, research and other sanctuary needs.

The study area encompasses the three marine sanctuaries extending along the coastal ocean off north/central California from Point Arena to Point Sal (Figure 1.0). This partnership project was led by the Biogeography Branch, but included over 90 contributors and 25 collaborating institutions. Phase I results include: 1) a report on the overall assessment that includes hundreds of maps, tables and analyses; 2) an ecological linkage report on the marine and estuarine ecosystems along the coast of north/central California; and 3) geographic information system (GIS) and related data files, which are available for viewing and download, in several formats, at the following website:
http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html

Phase II. The goals of Phase II were to update and complete the mammal and bird analyses and products of the Phase I assessment and provide a suite of Phase II products to sanctuary staff to support management and research activities.

The overall research objectives for marine birds and mammals were to: 1) analyze updated sighting and related data and apply density corrections to mammal maps, where possible; and 2) identify, summarize and communicate summary information on the spatial and temporal patterns, key areas and time periods, and relevant life history information for marine birds and mammals of the study area.

Phase II was implemented in the Fall of 2004 with the following specific objectives:

- Update at-sea density maps for mammals to incorporate specific correction factors, such as sightability of species.
- Update colony data and maps for marine birds, sea otter and pinnipeds.
- Develop maps of marine physiographic features in the study area.
- Develop a report on the biogeographic assessment of marine birds and mammals.
- Provide a website and CD-ROM for downloading reports, maps and related data.

Phase II resulted in significant updates to the bird and mammal chapters, including new summary maps for marine mammals. An environmental settings chapter was also added, containing new and existing data and maps for the study area. Specifically, the following Phase II topics and items were either updated or developed new for Phase II:

- environmental, ecological settings – a new chapter with maps on marine physiographic features, sea surface temperature and fronts, chlorophyll and productivity
- all bird colony or roost maps, including a summary marine bird colony map (new)
- most text and tables in the bird chapter (updated)
- at-sea data CDAS data set for mammals (1980-2003) (updated)
- all mammal maps and most text of the mammal chapter (new)
- overall density maps for eight mammal species (updated)
- summary pinniped rookery/haulout map (new)
- maps of at-sea richness for cetaceans and pinnipeds (new)
- summary tables of mammal population status and summary spatial and temporal map patterns (new)

This report and related products (report, maps, tables, data) will be available in hardcopy, on CD-ROM and at the following website by December, 2007; http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html

Results of this assessment off north/central California are currently being used to assist the NMSP and the state of California in addressing issues such as: 1) evaluating potential modifications of sanctuaries and other marine protected area boundaries, and 2) changes in management strategies or administration, based on the data and analyses of these biogeographic products.

In addition to the north/central biogeographic assessment, another biogeographic assessment was completed for the Channel Islands National Marine Sanctuary in 2005. Because it is adjacent to the central California study area and is influenced by similar environmental conditions, it contains biogeographic analyses and products that are relevant to the central California study area. See the following website for more information: http://ccma.nos.noaa.gov/products/biogeography/cinms/

The Study Area. The study area extends offshore from Point Arena in the north to Point Sal in the south, and offshore to the extent of data availability. Although the assessment is focused on ocean waters, the study area was extended for the bird and mammal assessment to include seabird colonies and pinniped haulouts and rookeries when data were available. The study area includes three National Marine Sanctuaries (Cordell Bank, Gulf of the Farallones and Monterey Bay) and encompasses marine habitats along the central and northern coast of California. Together, these contiguous national marine sanctuaries include more than 650 km of coastline, from Bodega Bay, north of San Francisco, to Cambria, near San Luis Obispo, encompassing a total area of approximately 18,000 km^2. See Figures 1.1, 1.2 and 1.3 below for information on place names and selected study area features.

National Marine Sanctuaries of the Study Area. The Gulf of the Farallones National Marine Sanctuary, established in 1981, includes an area of 3,250 km^2 off the northern and central California coast; see Figure 1.1. The Gulf of the Farallones extends beyond the Sanctuary's boundaries and is one of the broadest sections of the continental shelf off the U.S. West Coast. In addition to the relatively broad shelf, the major oceanographic feature that affects this coastal region is the San Francisco Bay Plume, which, under certain conditions, extends outwards to all areas of the Gulf. Habitats within the Gulf of the Farallones National Marine Sanctuary include rocky shores, sandy beaches, estuaries, lagoons and bays, as well as the Farallon Islands and the subsurface Farallon Ridge and Escarpment. The entire stretch of the broad shelf is strongly influenced by coastal upwelling and the San Francisco Bay Plume. The upwelled waters, which support tremendous phytoplankton production, are advected offshore into the California Current (see Figure 2.11) as eddies and jets. These productive waters stimulate growth of organisms at all levels of the marine food web. In periods when upwelling is reduced, the nutrient input from the San Francisco Plume becomes important. The Farallon Islands, which are protected as a National Wildlife Refuge, are home to the largest concentration of breeding seabird species in the contiguous United States (12 species), as well as one of the richest assemblages of pinnipeds (5 species). About 163 species of marine, coastal, and estuarine birds and over 30 species of marine mammals use the Sanctuary during breeding or migration. Further, great white sharks are attracted to marine mammal colonies on the Farallon Islands, Point Año Nuevo, and Año Nuevo Island.

The Cordell Bank National Marine Sanctuary, designated in May 1989, includes an area of 1,362 km^2 off the coast of central California; see Figure 1.1. Cordell Bank is located at the edge of the continental shelf, about 80 km northwest of the Golden Gate Bridge and 33 km west of Point Reyes. The main feature of the Sanctuary is an offshore granite bank, 7 km wide and 15 km long. The rocky bank emerges from the soft sediments of the continental shelf, reaching within 37 m of the ocean's surface. The base of the Bank is over 120 m deep. The combination of oceanographic conditions and undersea topography of Cordell Bank supports a diverse and productive marine ecosystem. A persistent upwelling plume projects southward and offshore from Point Arena and Point Reyes, transporting nutrients and organisms suspended in the water column into the bank's relatively shallow waters. Insolation fuels primary productivity and eventually influences the entire food web through direct and indirect trophic linkages. This high local productivity supports abundant resident populations of invertebrates, fishes (240 species), seabirds (69 species), and marine mammals (28 species) and attracts many migratory species.

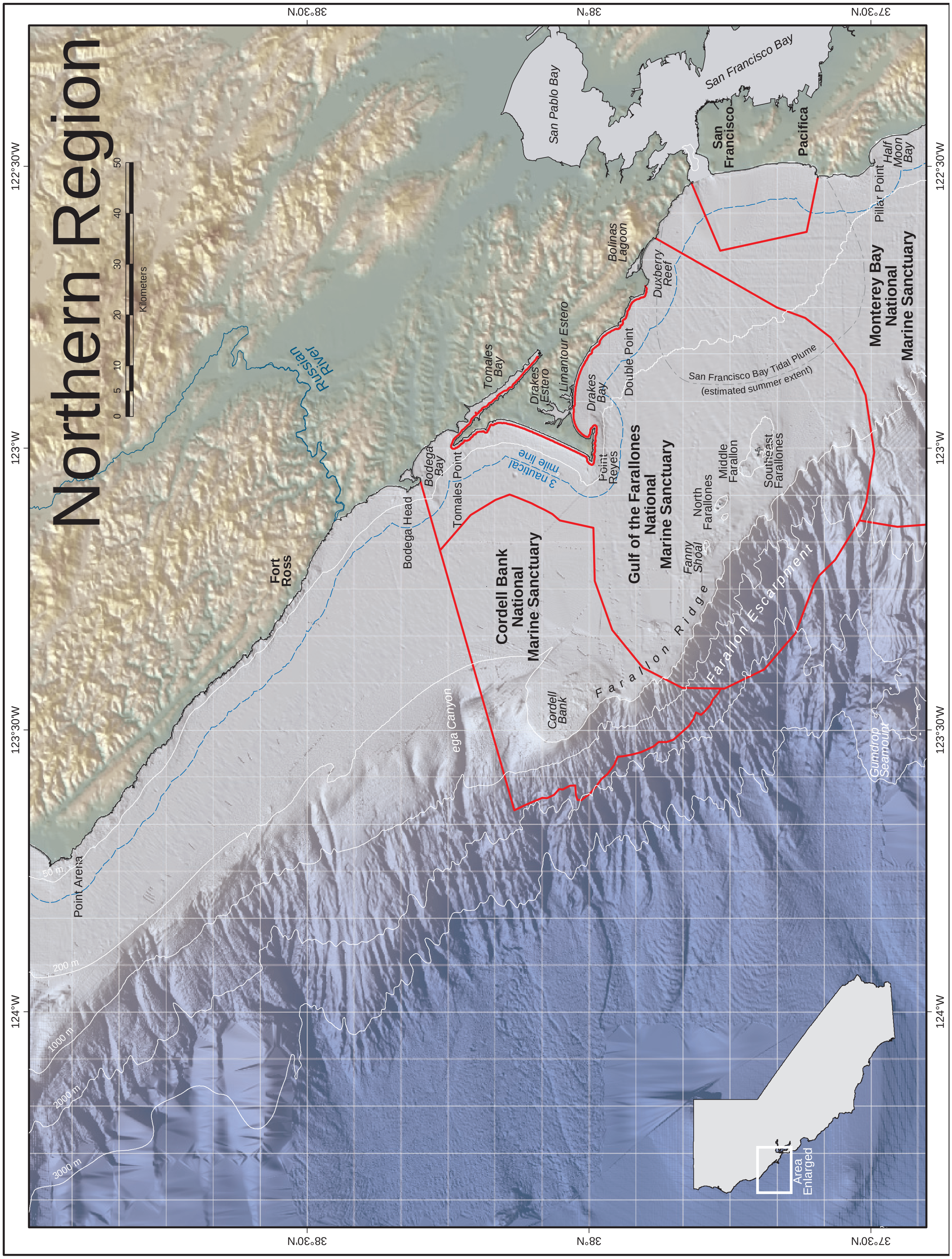

Figure 1.1. Locator map of northern region of study area.

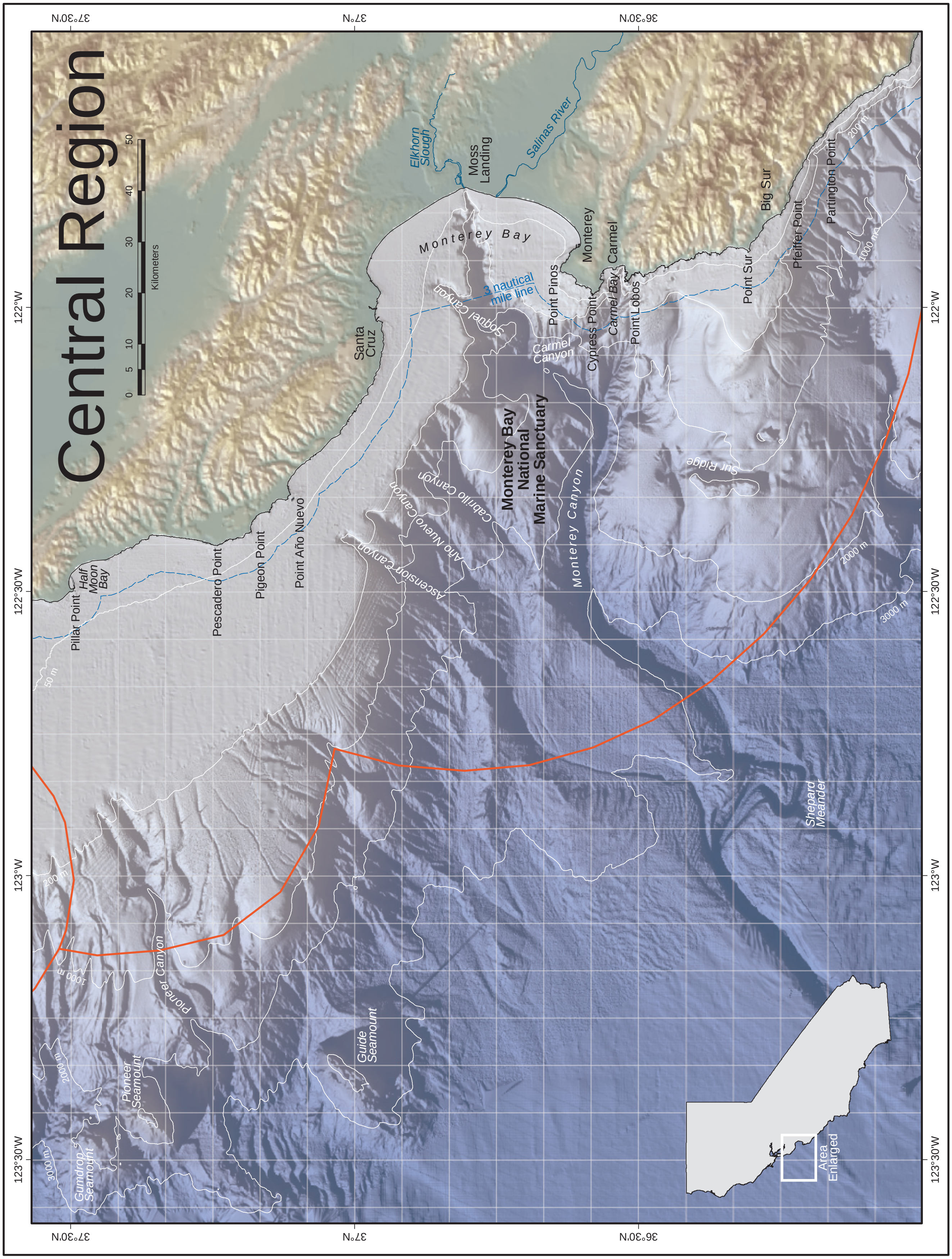

Figure 1.2. Locator map of central region of study area.

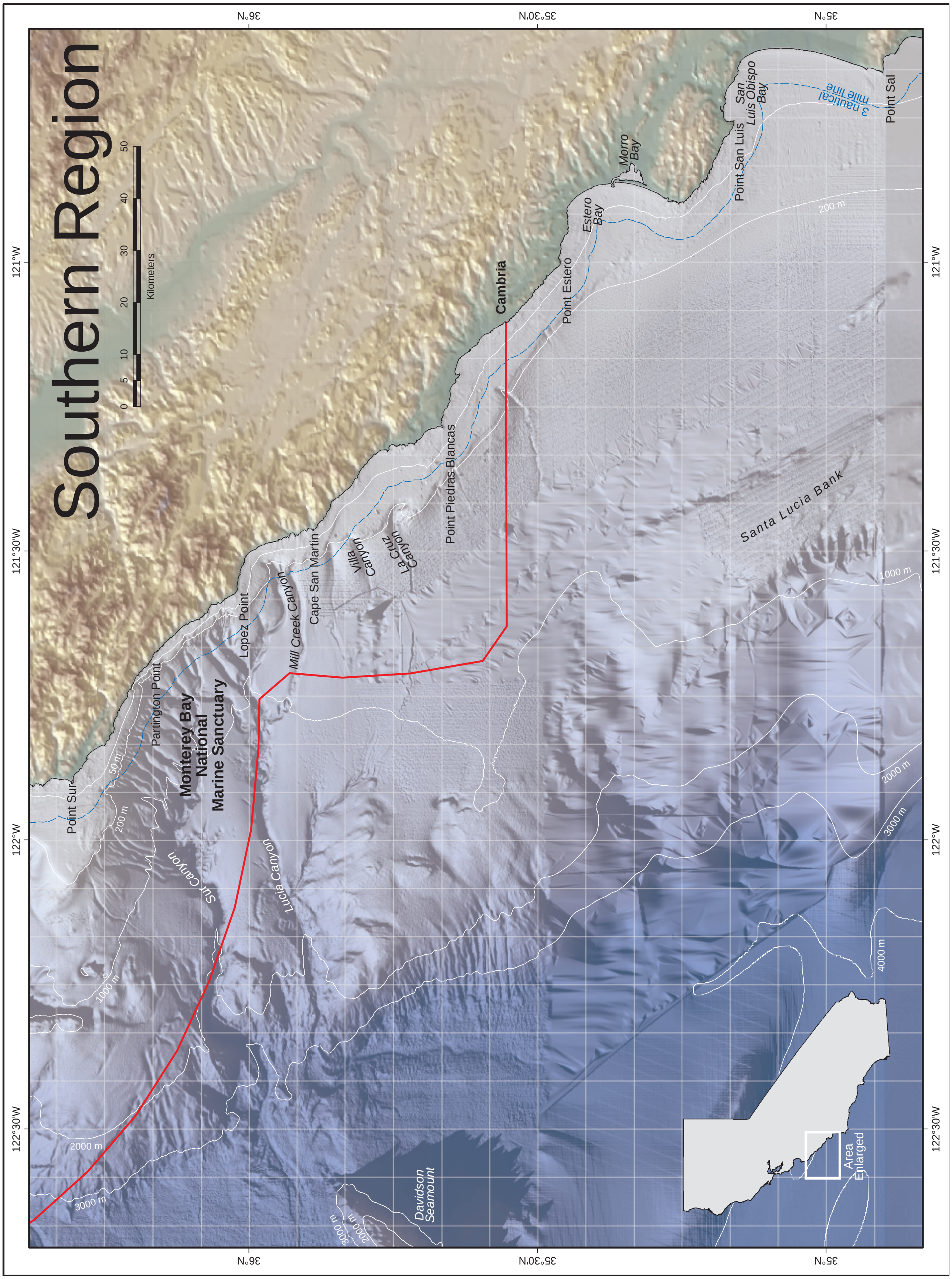

Figure 1.3. Locator map of southern region of study area.

The Monterey Bay National Marine Sanctuary, established in 1992, is one of the largest of 13 marine sanctuaries administered by the National Marine Sanctuary Program (see Figures 1.0). The Sanctuary extends from Rocky Point to Cambria Rock, encompassing nearly 450 km of shoreline and 13,780 km^2 of ocean, extending an average distance of 32 km from shore. At its deepest point, the Sanctuary reaches a depth of 3,250 m. The Sanctuary includes a variety of coastal and marine habitats, such as rugged rocky shores, lush kelp forests, and several underwater canyons, the largest of which is the Monterey Submarine Canyon. North of Partington Point and within the Gulf of the Farallones, the continental shelf is relatively wide and shallow. South of Partington Point, the Sanctuary generally protects deep ocean, owing to the consistently narrow continental shelf that extends south to Point Conception. The diverse array of habitats in the Sanctuary is home to 33 marine mammals, 94 species of seabirds, at least 345 species of fishes, and numerous invertebrates and plants.

1.2 BIOGEOGRAPHY

Biogeography is the study of the relationship of species' distribution patterns relative to the distribution patterns of their environment. An understanding of biogeographic patterns and how they are influenced by the environment enables sanctuary management decisions to be placed in a spatial context relative to the distribution of biological marine resources. Distributions of marine species are determined by climatic and oceanographic phenomena, physical tolerances and biological interactions. Each species responds to these factors in slightly different ways. Despite the physiological and ecological differences between species' response, there are many similarities in species' distributions, which can be used to define biogeographic regions, provinces and life zones (see Chapter 2).

Biogeographic assessments focus on the broader distribution of species rather than local occurrences of species and hence provide a basis for improving understanding and conservation of habitat uses within a biogeographic province. Assessments of species involves mapping reproductive, feeding and resting areas, as well as migratory routes and areas where species are harvested or have high mortality. This provides valuable information for determining essential habitat for protection. In addition to the information these assessments provide on a single species, they can provide information on community metrics, such as the distribution of species diversity and richness of biota. These assessments can be useful in identifying which species form assemblages or communities, and how population and community measures, such as species diversity and richness, vary within and across a region. These assessment results can be useful to coastal resource managers because they provide a basis for determining biota that are typical of an area and are appropriate for management of species or habitats. These assessments also highlight hot spots of density and diversity in time and space, as well as information gaps for certain areas, species and life stages.

Marine Biogeography along the West Coast. A number of biogeographic provinces occur along the California coast. There are two coastal biogeographic provinces, Oregonian and San Diegan. The Oregonian Province primarily extends from southeastern Alaska to Point Conception, and is part of the Eastern Boreal Pacific Region (Briggs, 1974, 1995). The Oregonian Province also extends southward beyond Point Conception along the outer islands of southern California, and in part reappears in upwelling areas off Baja California Mexico (Hubbs, 1949). The San Diegan Province (part of the warm-temperate California region, which also includes the Cortez Province of the Gulf of California) extends from Point Conception, California to Magdalena Bay, Baja California Sur (Briggs, 1974). However, in warm-regime years, some San Diegan species extend their ranges northward.

Offshore are two provinces of the cold temperate Oceanic Boreal Pacific Region (McGowan, 1971). The Subarctic Province extends south along the California coast to Cape Mendocino, and the Transition Zone extends south from Cape Mendocino to Magdalena Bay.

The Biogeographic Assessment Process Used in this Assessment

Species Selection. Criteria for the selection of marine bird and mammal species included: 1) species that had a mostly marine distribution in the study area, and 2) adequate survey data and information on the species was available and in a usable format for analysis. Additional considerations included abundance in the study area, Federal or state-listed endangered or threatened status, or California state species of concern.

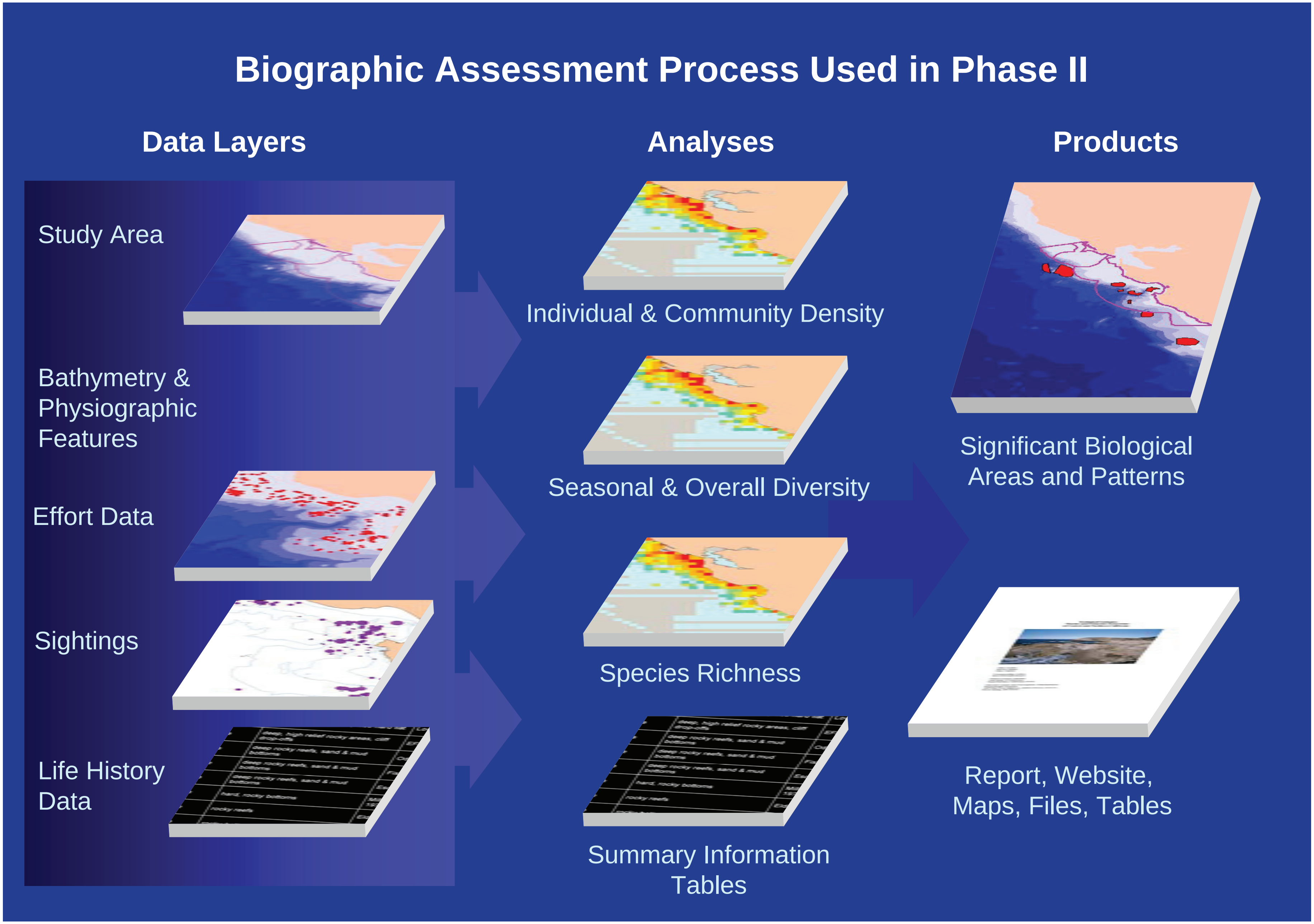

Figure 1.4. Biogeographic Assessment Process for Phase II Marine Birds and Mammals.

Data Collection, Synthesis and Analysis. Several researchers along the west coast, including Federal and state agencies, non-governmental organizations, and academia were contacted to identify available existing distributional data and literature relevant to the species selected. Once a data set was identified, its utility was evaluated through examination of its spatial extent, and quantity and quality of information provided. As this study was dependent on pre-existing data, the type and quality of information collected was extremely variable. Among the complexities of working with these inherently variable data were varying spatial and temporal coverages, as well as different methodologies employed in data collection (e.g., aerial vs. shipboard data). Combining and synthesizing these data into one spatial framework required significant processing; this is described in subsequent chapters. When differences precluded data sets from being combined and analyzed together, they were kept separate. Depending on the quantity and robustness of the data, a variety of different analyses and map products were created; for example, seasonal and year-round sea surface temperature maps, seasonal and year-round species density maps, mammal sighting and effort maps, pinniped haulout maps, and community metric maps such as richness, density, and diversity. See Figure 1.4 for an overview of the process.

Review. All analyses completed as part of the biogeographic assessment were reviewed by experts. If available, data providers, together with others familiar with the data sets, were consulted to obtain feedback on the analytical methods used and results to ensure accurate presentation of the data and interpretation of the resulting patterns.

Production, Publication and Dissemination. An important part of the assessment process is making the resulting data products and information available for the staff of the National Marine Sanctuaries and other interested users. The final report is provided in a format (PDF) that will be available on the web, along with final maps, GIS and other data tables and files; see http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html.

1.3 REPORT OUTLINE

This assessment begins with a description of the project background and biogeography of the area and the assessment process used for this project (Chapter 1). The report moves into the environmental and ecological setting of the study area in Chapter 2, where the study area is described in terms of the physical and biotic environment (e.g., climate, oceanography, habitats). Included are discussions of regional patterns of sea surface temperature, chlorophyll *a*, ocean currents, and bathymetry, and as they relate to the study area. Chapter 2 provides context for the subsequent analytical chapters and focus of this report: marine birds (Chapter 3) and marine mammals (Chapter 4). Where data were sufficient, the bird and mammal chapters include seasonal density maps by species, as well as analysis of community metrics (e.g., marine bird density and diversity, cetacean richness), and summary tables on spatial patterns, and other analysis results. The bird and mammal chapters each have an introductory section with methodology, a section of analytical map results and descriptions of the maps and species, and a chapter summary of overall results and findings, including summary tables on life history, management status, and spatial and temporal patterns.

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CHAPTER 2: ENVIRONMENTAL AND ECOLOGICAL SETTING

2.1 INTRODUCTION

The distribution and abundance of marine birds and mammals are strongly influenced by their environment. The purpose of this chapter is to provide a background on selected environmental and ecological features that influence the occurrence of marine birds and mammals off the north/central coast of California.

Most of the text in this chapter is excerpted or summarized from four NOAA reports, all developed by NOAA's National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, for NOAA's Marine Sanctuary Program off California (Airamé *et al.,* 2003; NOAA NCCOS, 2003; Stumpf *et al.,* 2005; and NOAA NCCOS, 2005). Airamé *et al.,* 2003, was developed as an ecological background for Phase I of this Biogeographic Assessment off North/Central California. NOAA NCCOS, 2003 was the Phase I report of this Assessment off North/Central California. Stumpf *et al.,* 2005 was developed for the same study area to provide information on the state and variability of selected oceanographic parameters. And NOAA NCCOS, 2005 is a biogeographic assessment developed to evaluate boundary alternatives for the Channel Islands National Marine Sanctuary off southern California. When information was not from one of the four above documents, citations were provided.

2.2 ENVIRONMENTAL SETTING

The Study Area

The area of interest extends from Point Arena, a small peninsula on an elevated coastal plain in the southern portion of Mendocino County, to Point Sal, just south of Pismo Beach and the Nipomo Dunes area. The region consists of a multitude of diverse and important ecosystems that are unique in their assemblages of marine organisms. Three national marine sanctuaries, Gulf of the Farallones, Cordell Bank, and Monterey Bay, are located in coastal and marine habitats off central and northern California, from Bodega Bay, north of San Francisco, south to Cambria, near San Luis Obispo. Together, these contiguous national marine sanctuaries include more than 650 km of coastline, and encompass a total area of approximately 18,000 km^2. Each sanctuary includes unique geological and biological features; however, all are strongly influenced by similar oceanographic processes. See Figures 2.2 - 2.5 for maps of bathymetry and selected marine physiographic features of the study area.

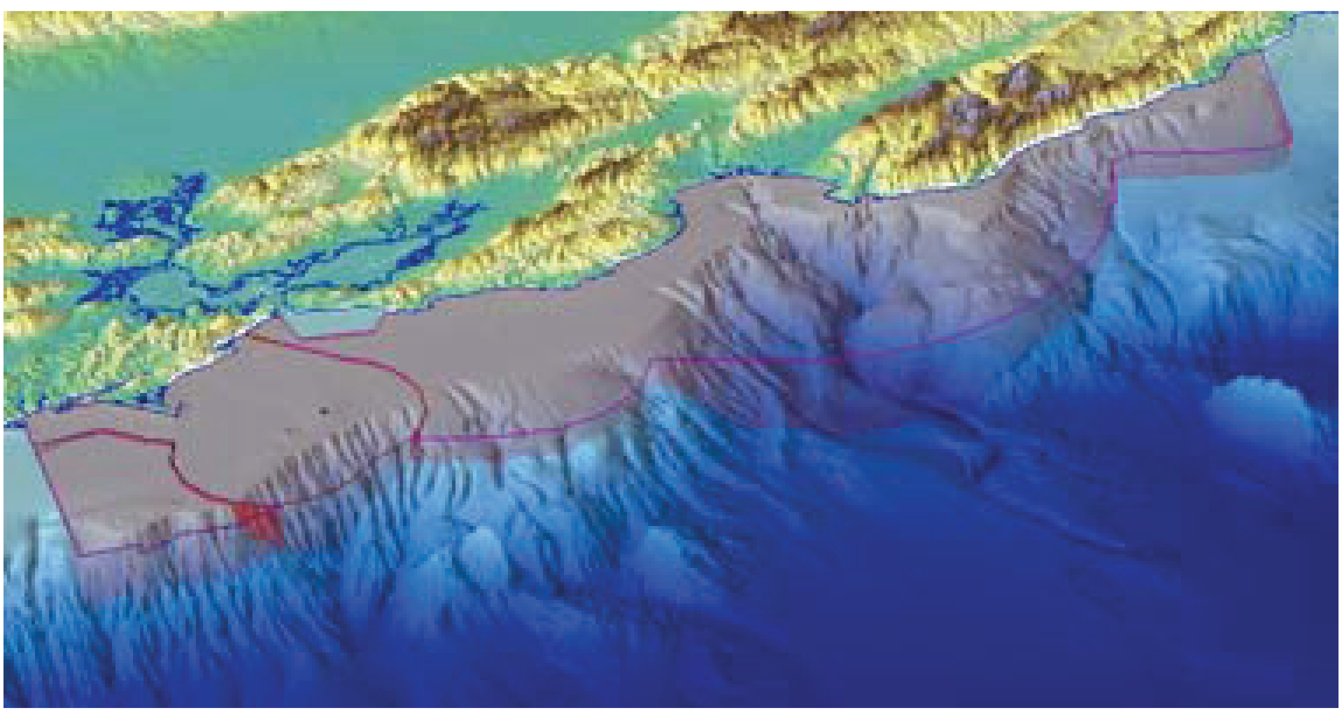


Figure 2.1. A three-dimensional view of bathymetric relief and the national marine sanctuaries off north/central California.

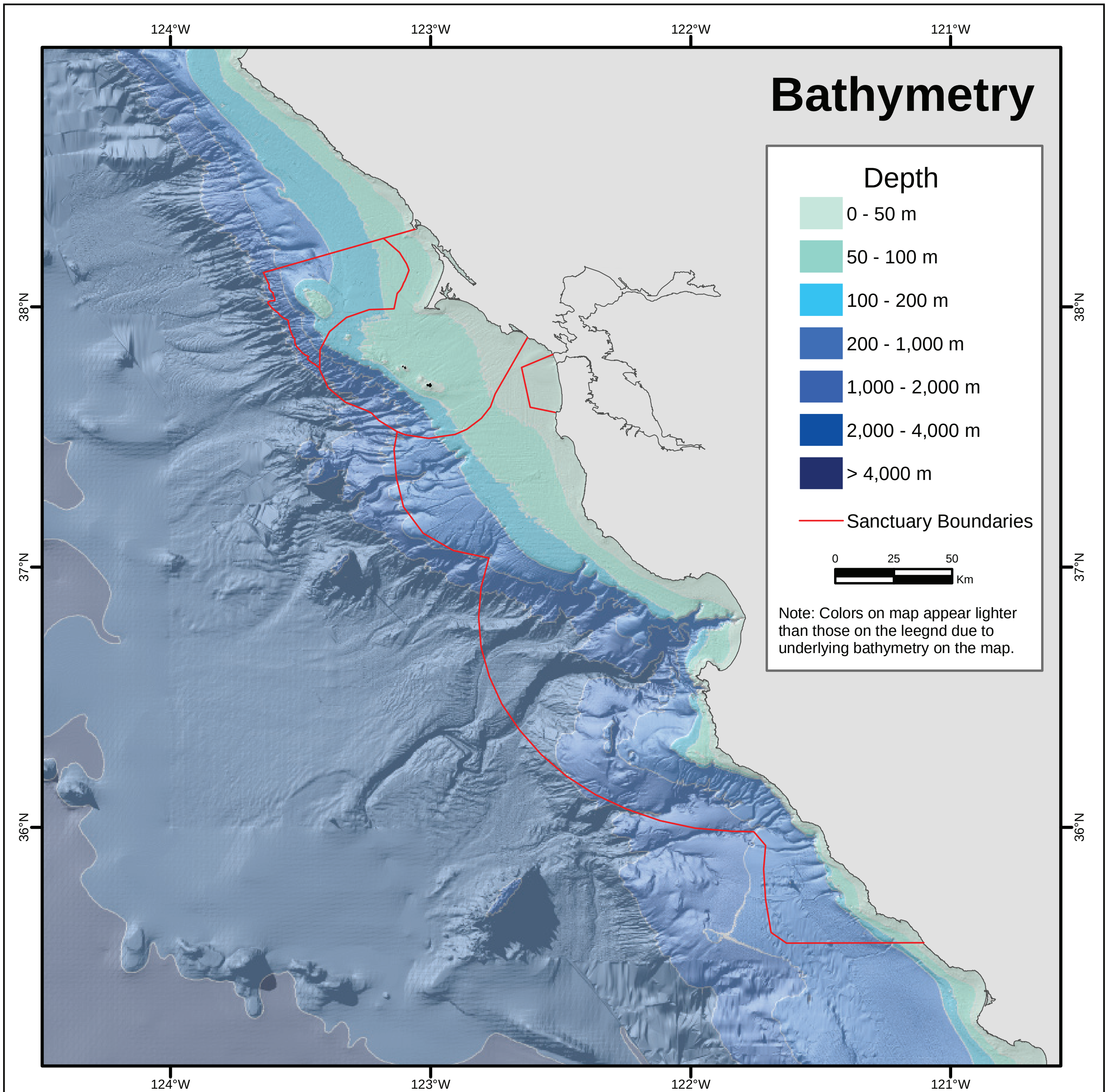
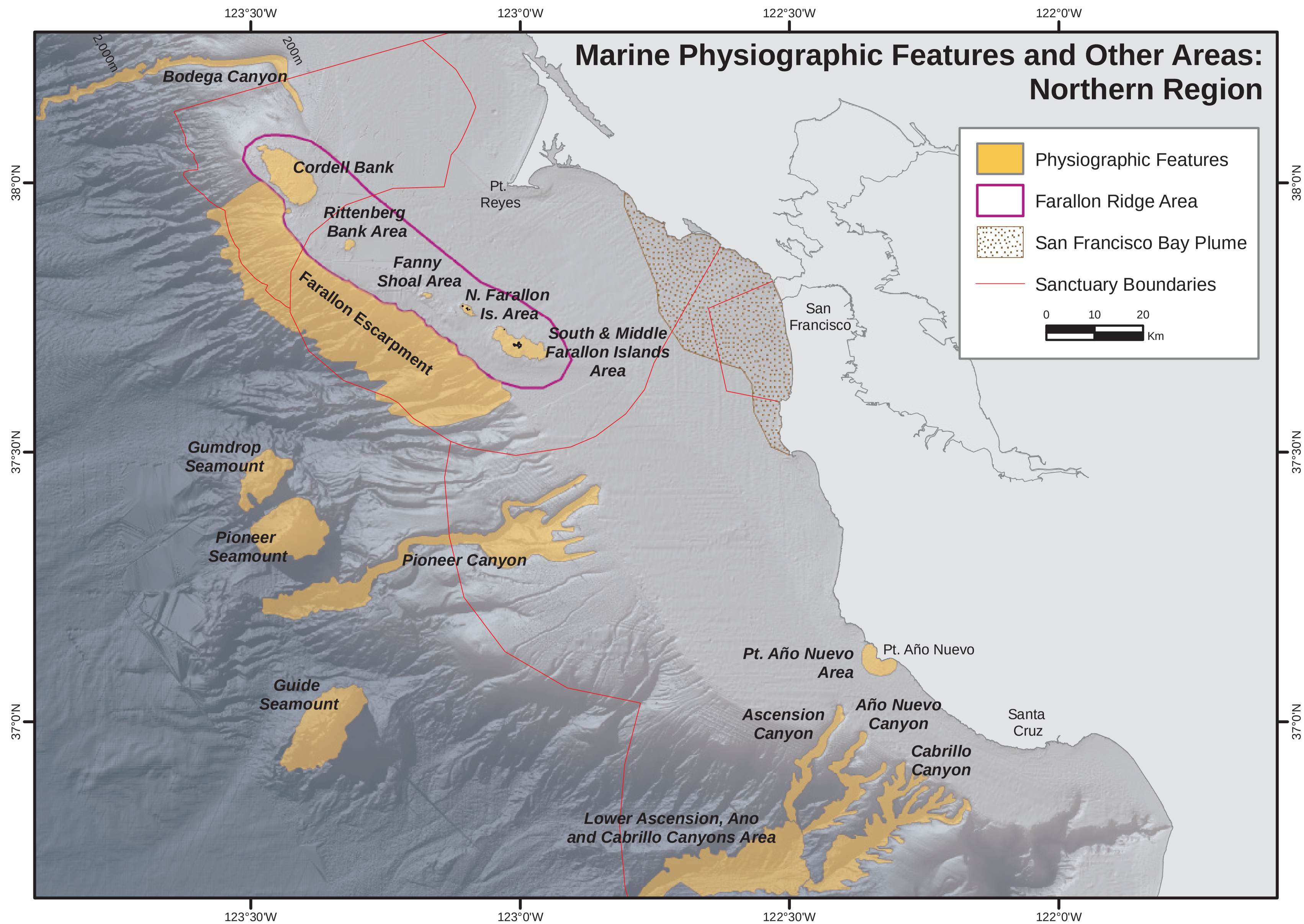


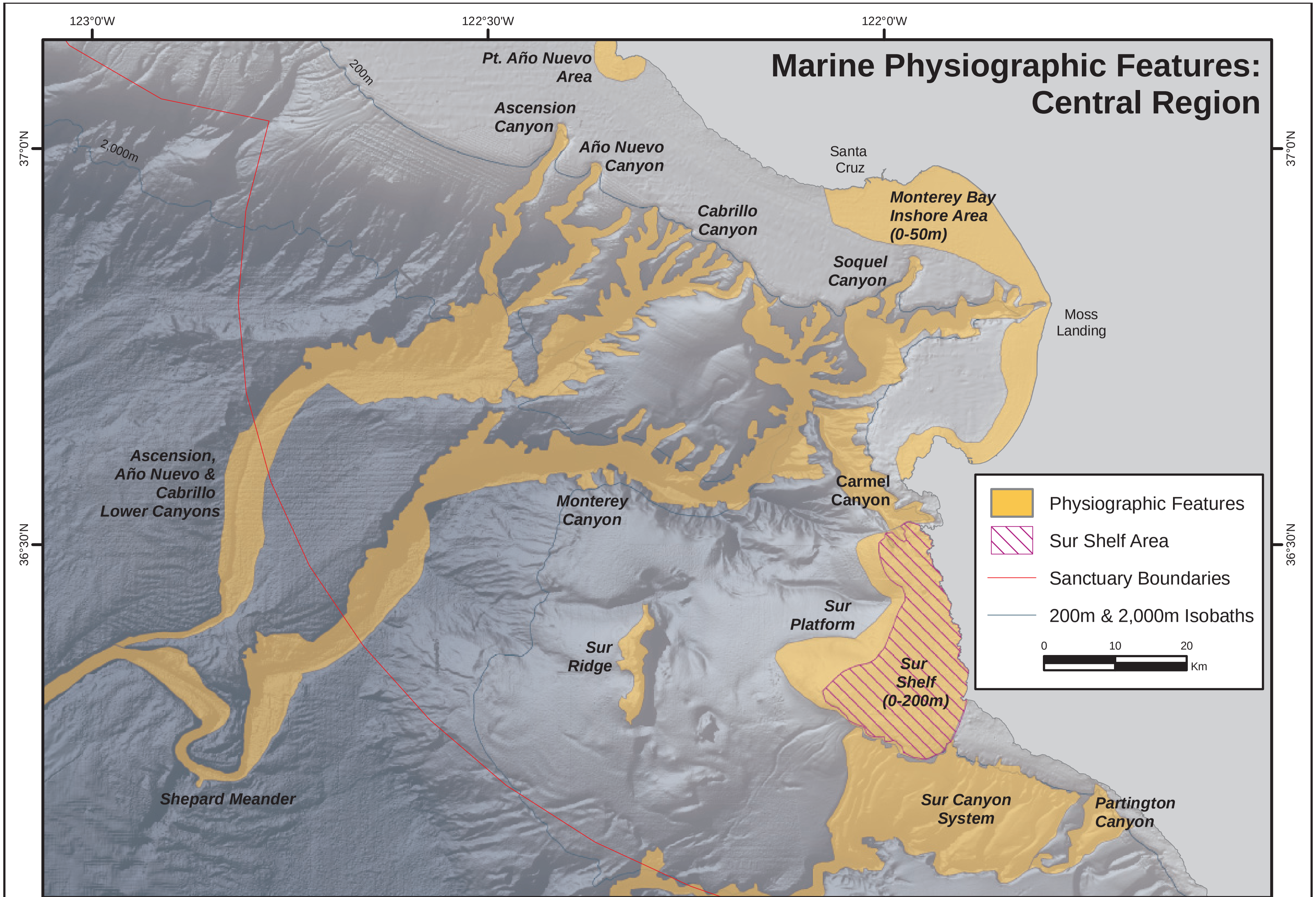
Figure 2.2. Bathymetry and depth zones of the study area.

Gulf of the Farallones National Marine Sanctuary. This marine sanctuary was established in 1981 and encompasses an area of 3,250 km^2 off the northern and central California coast. The Sanctuary extends from Bodega Head, Sonoma County in the north, to Rocky Point, Marin County in the south. Offshore, the Gulf of the Farallones National Marine Sanctuary extends farther south to waters west of San Mateo county. The Gulf of the Farallones extends beyond the Sanctuary's boundaries and is one of the broadest sections of the continental shelf along the lower U.S. West Coast. In addition to a relatively broad shelf, a second feature that affects this coastal ocean area is the San Francisco Bay Plume, which, under certain conditions, extends out to all areas of the Gulf (see Figure 2.3). Coastal upwelling is a third major feature, which supports tremendous phytoplankton production; upwelled water is advected offshore into the California Current as eddies and jets. These waters



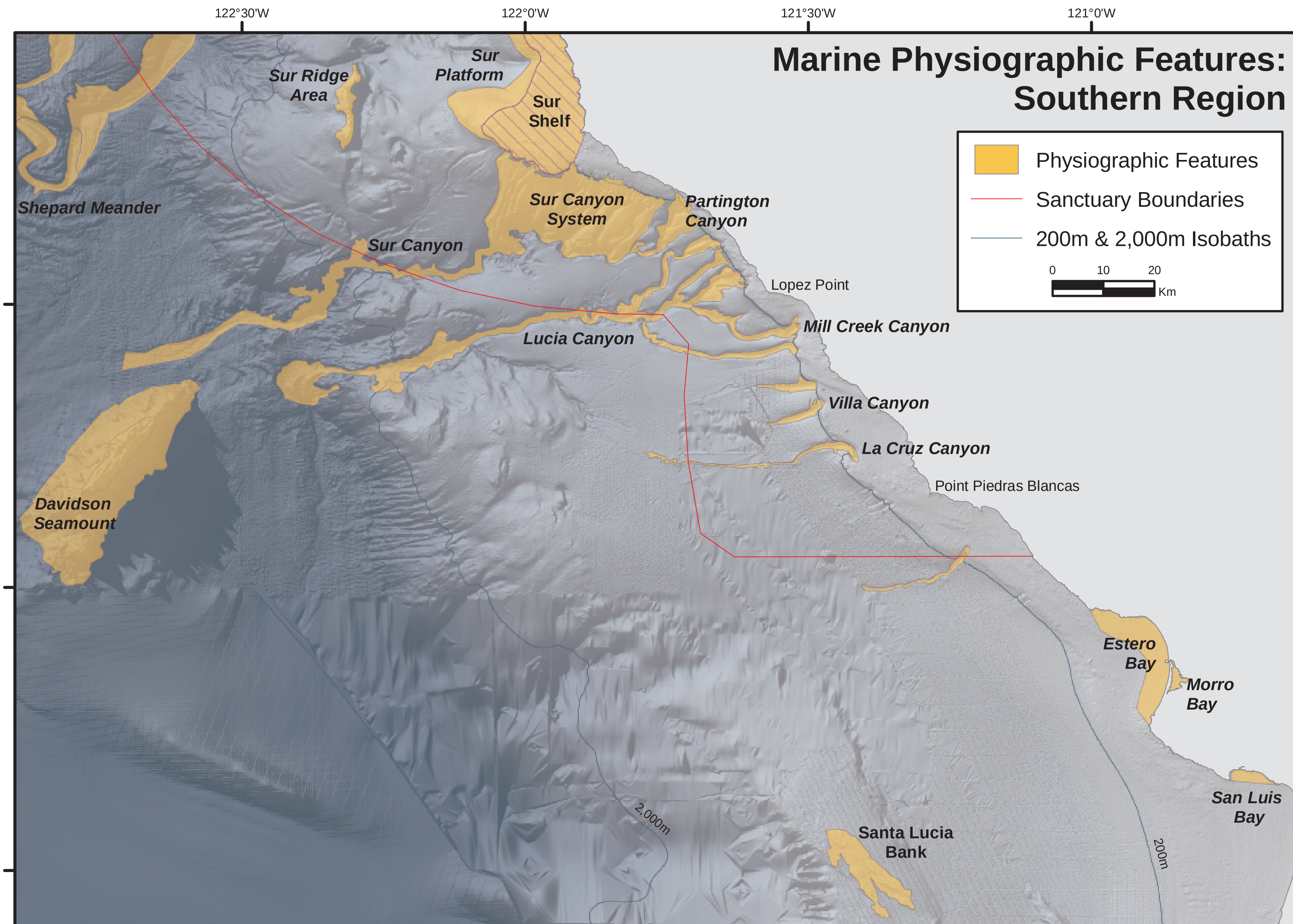
Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. These physiographic areas were developed at NOAA, based on bathymetry products from NOAA and MBARI. The areas were reviewed by staff from NOAA and MBARI.

Figure 2.3. Marine physiographic features - northern region.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. These physiographic areas were developed at NOAA based on bathymetry products from NOAA and MBARI. The areas were reviewed by staff from NOAA and MBARI.

Figure 2.4. Marine physiographic features - central region.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. These physiographic areas were developed at NOAA based on bathymetric products from NOAA and MBARI. The areas were reviewed by staff from NOAA and MBARI.

Figure 2.5. Marine physiographic features - southern region.

stimulate growth of organisms at all levels of the marine food web. In periods when upwelling is reduced, the nutrient input from the San Francisco Plume becomes relatively important. A significant upwelling plume extends south from Pt. Arena along the shelf break influencing the outer waters of the Gulf. The fourth feature of this sanctuary is the Farallon Islands group, which are protected as a National Wildlife Refuge. These islands are home to the largest concentration of breeding seabirds in the contiguous United States (12 species), as well as one of the richest assemblages of pinnipeds (5 species). About 163 species of marine, coastal, and estuarine birds and 36 species of marine mammals use the Sanctuary during breeding or migration. Additionally, white sharks are attracted to marine mammal colonies on the Farallon Islands, Point Año Nuevo, and Año Nuevo Island.

Habitats within the Gulf of the Farallones National Marine Sanctuary include rocky shores, sandy beaches, estuaries, lagoons and bays, a broad continental shelf, the Farallon Islands, the subsurface Farallon Ridge and Escarpment, and the waters overlying these features.

Cordell Bank National Marine Sanctuary. This marine sanctuary was designated in May 1989, and includes an area of 1,362 km^2 off the coast of central California. Cordell Bank is located at the edge of the continental shelf, about 80 km northwest of the Golden Gate Bridge and 33 km west of Point Reyes. The main feature of the Sanctuary is an offshore granite bank, 7 km wide and 15 km long. The rocky bank emerges from the soft sediments of the continental shelf, reaching within 37 m of the ocean's surface. The base of the Bank is over 120 m deep. The combination of oceanographic conditions and undersea topography of Cordell Bank supports a diverse and productive marine ecosystem. A persistent upwelling plume projects southward and offshore from Point Arena and Point Reyes, transporting nutrients and organisms suspended in the water column into the bank's relatively shallow waters. Insolation that reaches the shallowest depths of the Bank fuels primary productivity and eventually influences the entire food web through direct and indirect trophic linkages. This high local productivity supports abundant populations of invertebrates, fishes (240 species), seabirds (69 species), and marine mammals (28 species), and attracts many migratory species.

Monterey Bay National Marine Sanctuary. This marine sanctuary was established in 1992, and is the largest of the 13 marine sanctuaries administered by the National Marine Sanctuary Program. The Sanctuary extends from the Rocky Point to Cambria Rock, encompassing nearly 450 km of shoreline and 13,780 km^2 of ocean, extending an average distance of 32 km from shore. Waters of the Sanctuary reach a depth of 3,250 m. The Sanctuary includes a variety of coastal and marine habitats, such as rugged rocky shores, lush kelp forests, and several underwater canyons, the largest of which is the Monterey Submarine Canyon. The northern portion of the Sanctuary includes a relatively wide and shallow continental shelf that continues north into the Gulf of the Farallones and Cordell Bank. South of Monterey Bay, the Sanctuary includes primarily deep ocean, owing to the consistently narrow continental shelf. The diverse array of habitats in the Sanctuary is home to over 30 species of marine mammals, 94 species of seabirds, at least 345 species of fishes, and numerous invertebrates, and plants, including kelp.

Ocean Seasons

While certain geological and biological features are evident along particular regions of the coast, the same oceanographic processes and climatic phenomena operate throughout the study area. Over a 12-month period, the study area has three distinct oceanographic periods or seasons that vary with respect to prominence and location of ocean currents. These periods, characterized by upwelling (spring/summer), wind relaxation (fall), and winter storms (winter), are associated with different degrees of upwelling and downwelling. The timing and intensity of these "ocean seasons" vary from year to year. The amount of production in surface waters and the ability of organisms to disperse is directly impacted by these processes. In response to these seasons, the abundance and types of organisms present in a given area change throughout the year.

Most of the data mapped in this document were organized by ocean season or all available data were averaged (year-round). See Figure 2.6 for maps of average sea surface temperatures (SST) during ocean seasons along with a map of an inter-annual SST average from 1985-2005. For purposes of data analysis for marine birds and mammals, the ocean seasons were defined as follows:

Upwelling Season (March 15 - August 14, or Spring/ Summer). The upwelling season generally occurs between mid-March and mid-August. Strongest upwelling occurs during May and June. During this season, strong northwest winds, combined with the Coriolis force, move surface waters offshore and southward. Cool, nutrient-rich water from depth replaces the displaced surface water. Upwelling areas can be identified as cool sea surface temperatures in satellite images. Although the duration and intensity of upwelling is variable, episodes are commonly sustained for 7-10 days, punctuated with periods of relaxation. The upwelling-favorable winds generally subside by late July. El Niño and other warm water events may reduce the intensity by which deep waters are upwelled to the surface.

Oceanic Season (August 15 - November 14, or Fall). A period of wind relaxation generally occurs from mid-August through mid-November. During this time, winds are light and variable, and the seas can remain calm for extended periods (up to a week or two). When upwelling is not active, offshore waters move inshore and surface water is heated by sunlight and becomes warmer. When upwelling-favorable winds relax, larvae found in surface waters may be transported back to shore, where some larvae eventually settle. Periods of wind relaxation lasting approximately 2-6 days and may alternate with upwelling-favorable conditions during the spring. Periods of relaxation may persist longer during the late summer and early fall. Relaxation disappears after the onset of upwelling winds or the return of winter storms.

Davidson Current Season (November 15 - March14, or Winter). The winter storm period generally occurs between late November and mid-March. During this period, low pressure systems moving south of the Gulf of Alaska generate southerly winds off California, along with large waves. Under the influence of these processes, the northward flow of the Davidson Current is enhanced in the study area.

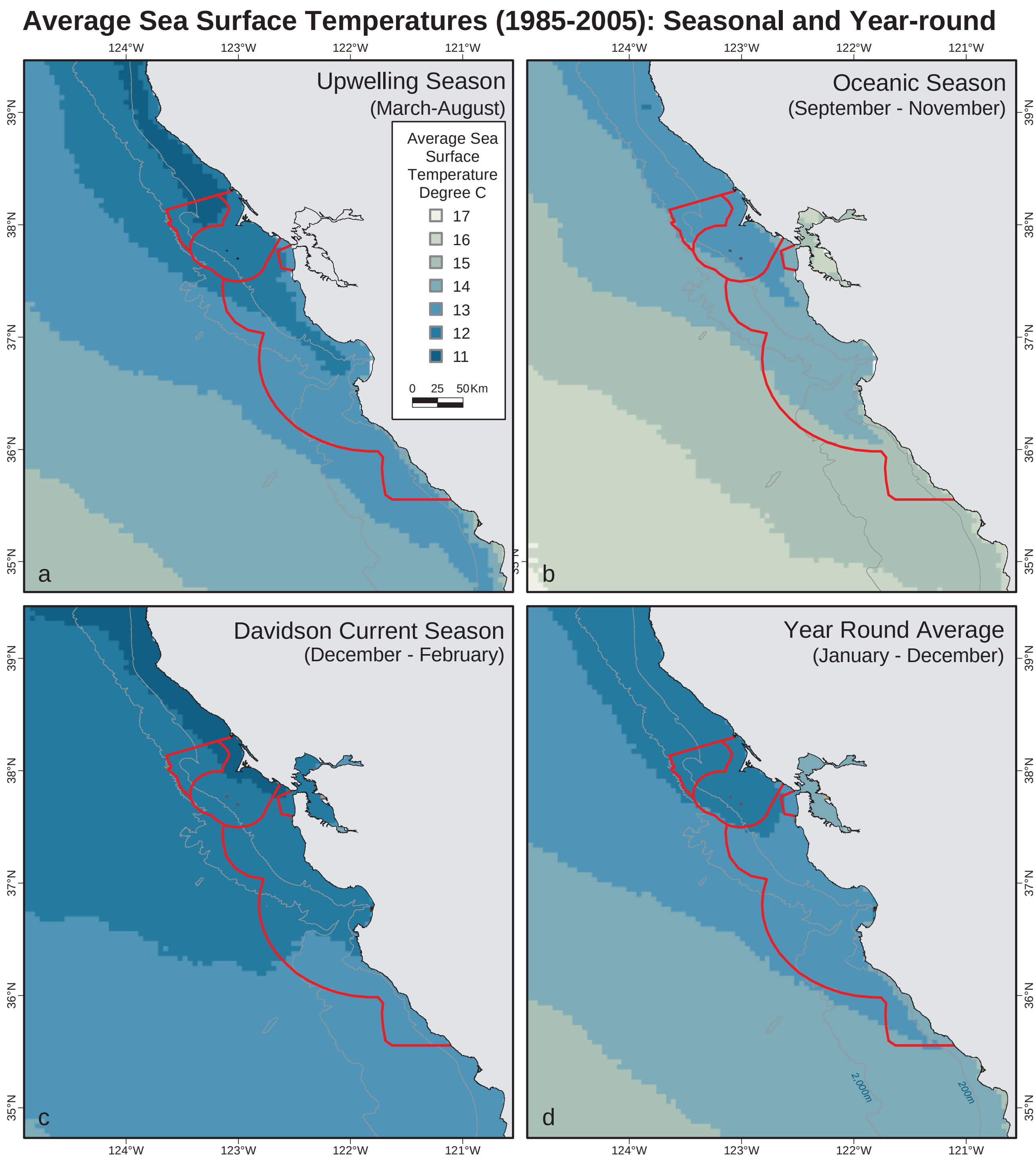
Longer-Term Cyclical Climate Perturbations

Longer-term climatic phenomena influencing the region include El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation, and global warming. The recurring ENSO pattern is one of the strongest in the ocean-atmosphere system. El Niño is defined by relaxation of the trade winds in the central and western Pacific, which can set off a chain reaction of oceanographic changes in the eastern Pacific Ocean. Off the coast of California, El Niño events are characterized by increases in ocean temperature and sea level, enhanced onshore and northward flow, and reduced coastal upwelling of deep, cold, nutrient-rich water. During this period, survivorship and reproductive success of planktivorous invertebrates and fishes decrease with plankton abundance. Marine mammals and seabirds, which depend on these organisms for food, suffer food shortages, sometimes leading to widespread starvation, but usually decreased reproductive success.

Every 20-30 years, the surface waters of the central and north Pacific Ocean (20°N and poleward) shift several degrees from the mean temperature. Such shifts in mean surface water temperature, known as the Pacific Decadal Oscillation (PDO), have been detected five times during the past century, with the most recent shift in 1976. The Pacific Decadal Oscillation impacts production in the eastern Pacific Ocean and, consequently, affects organism abundance and distribution throughout the food chain. Ocean waters off the coast of California have warmed considerably over the last 40 years. In response to these three phenomena, some species have shifted their geographic ranges northward, altering the composition of local assemblages.

El Niño Southern Oscillation (ENSO). Since 1800, there have been approximately 48 El Niño events, with a mean frequency of one event every 4.1 years. Although El Niño events occur frequently, they are difficult to predict and highly variable in intensity. Some El Niño events are relatively weak, whereas others may affect the entire Pacific Basin and other portions of the world ocean. Particularly strong El Niño events occurred during 1957-1958 and 1982-1983, and one the strongest El Niños on record occurred in 1997-1998. The opposite of El Niño is La Niña, a relatively coolwater event, and also part of ENSO. Strong La Niñas occurred in 1974-1975, 1977-79, 1985-86, and 1998-2000. See Figures 2.8, 2.9 and 2.10 for graphs and maps illustrating ENSO and its effects.

Temperature changes and other environmental variables associated with El Niño and La Niña events may directly affect the composition and structure of biological communities. El Niño events are accompanied by large reductions in plankton, fish, seabirds, and marine mammals in many up-



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Source: Varis Ransi of NOAA provided data and analysis from the Pathfinder version 5.0 Data Set, dervied from Advanced Very High Resolution Radiometer (AVHRR) satellite data, from NOAA polar-orbiting satellites, and NOAA's National Oceanographic Data Center (http://pathfinder.nodc.noaa.gov).

Figure 2.6. Average sea surface temperature (1985-2005): by ocean season and year-round average.

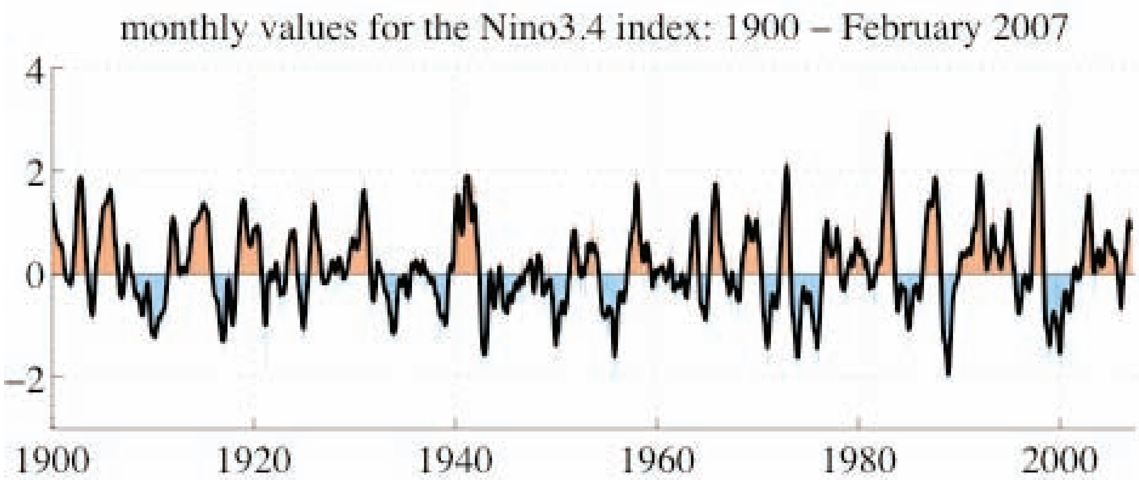


Figure 2.7. Tracking El Niño's and La Niña's in the North Pacific – red is warm and represents an El Niño, blue is cool and represents a La Niña. 1998 was a strong El Niño year. Figure provided courtesy of Nathan Mantua, University of Washington Climate Impacts Group, and Steven Hare, International Pacific Halibut Commission.

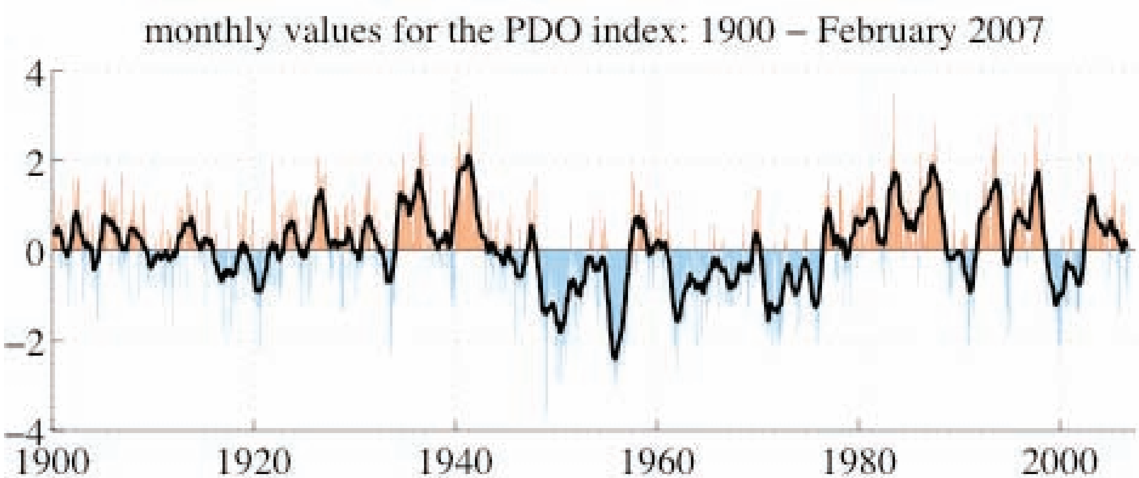


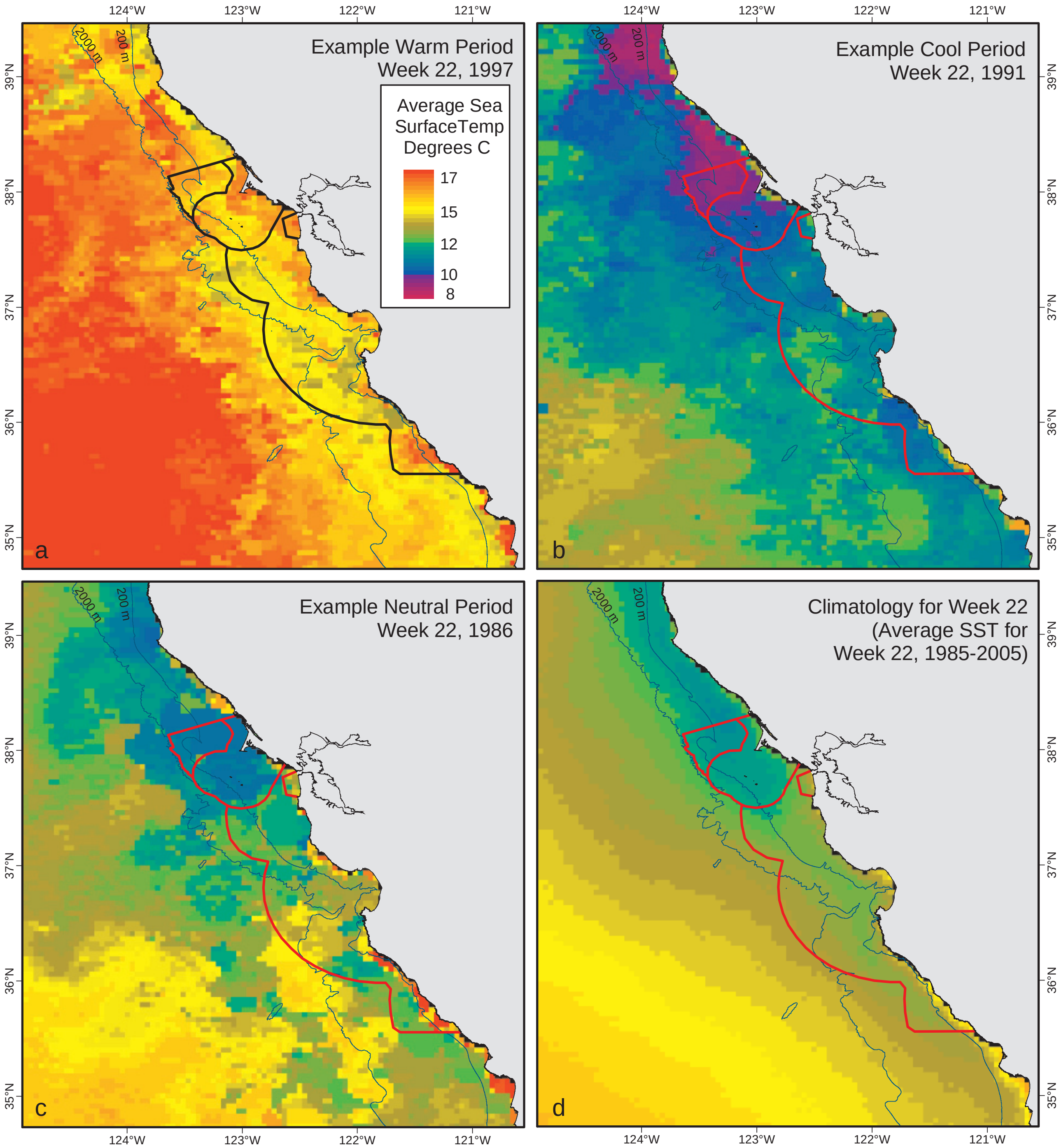
Figure 2.8. Tracking the Pacific Decadel Oscillation (PDO) Index. http://jisao.washington.edu/pdo/
A cool period occurred from 1947 to 1976, followed by a warm period from about 1977 to about 1998. Figure provided courtesy of Nathan Mantua, University of Washington Climate Impacts Group, and Steven Hare, International Pacific Halibut Commission.

welling regions of the eastern Pacific Ocean; the converse is true of La Niña. During El Niño, the thermocline that separates warm, nutrient poor surface waters from colder, nutrient rich waters below occurs much deeper than normal. As a result, when upwelling winds bring deeper water to the surface, it is still relatively warm and nutrient poor. Without the fertilizing effects of high nutrients, the blooms of phytoplankton production do not occur. For example, primary production was 5- to 20-fold lower during the 1982-1983 El Niño event than during previous years. In addition, the onset of phytoplankton blooms may be delayed several months during El Niño events. Examples of warm, cool and neutral periods of sea surface temperature affected by ENSO events are shown in Figure 2.9.

Without this flush of phytoplankton production, zooplankton biomass declines greatly. Changes in the density and abundance of zooplankton are thus secondary consequences of changes in concentrations of dissolved nutrients and biological productivity.

During El Niño events, seabirds suffer a serious reduction in sources of food, contributing to breeding failure and mortality. Species that feed locally on benthic prey (e.g., Pigeon Guillemots and Pelag-

Sea Surface Temperature: Example Warm, Cool and Neutral Periods for Week 22 and Climatology for 1985-2005



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Source: Ken Casey and Varis Ransi, both from NOAA, provided the Pathfinder Version 5.0 data set, derived from Advanced Very High Resolution Radiometer (AVHRR) data from NOAA polar-orbiting satellites, from NOAA's National Oceanographic Data Center (http://pathfinder.nodc.noaa.gov).

Figure 2.9. Sea surface temperature (1995-2005): examples of warm, cool and neutral periods for week 22 (in the upwelling season) and the 21-year average.

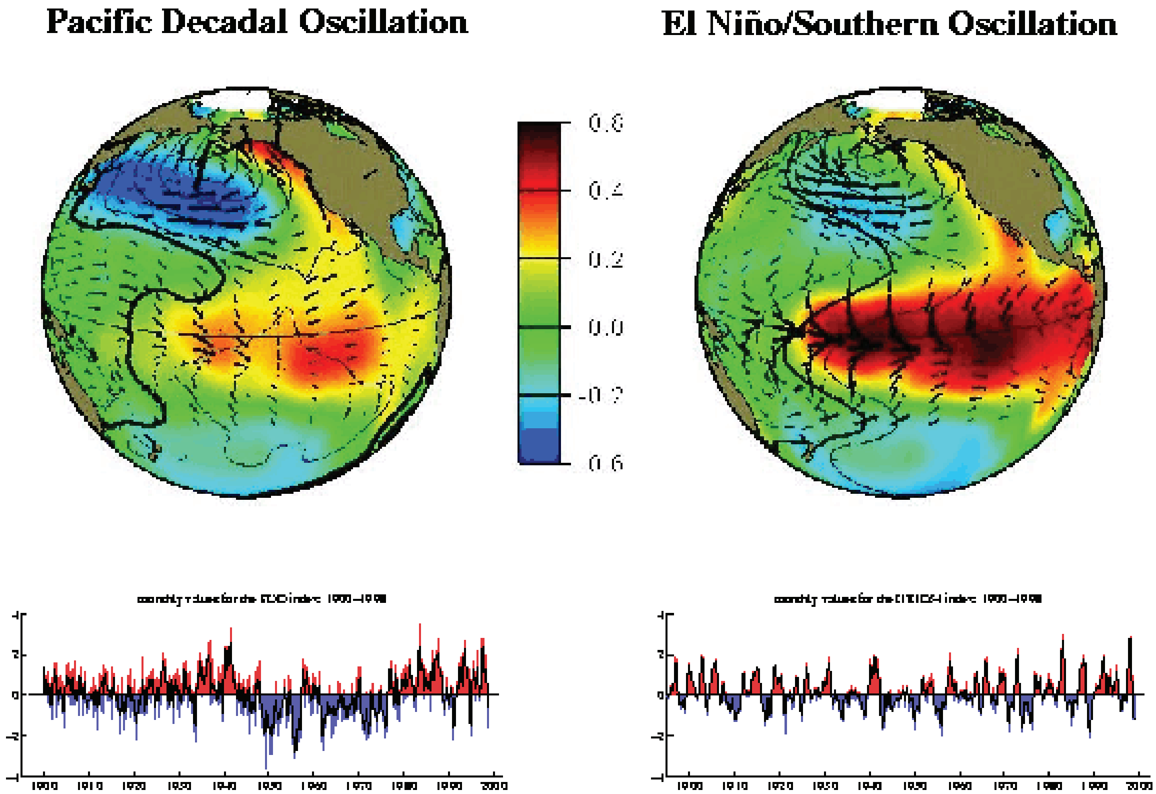


Figure 2.10. Comparing sea surface temperatures during a warm phase of the Pacific Decadel Oscillation and the El Niño Southern Oscillation. Figures provided courtesy of Nathan Mantua, University of Washington Climate Impacts Group, and Steven Hare, International Pacific Halibut Commission.

ic Cormorants) are particularly vulnerable to food shortages. For example, seabirds on the Farallon Islands delayed their reproductive effort, and mortality was higher than normal during the 1982-1983 and other recent El Niño events. Fewer chicks were fledged, and those that survived exhibited longer times to fledging and lower fledging weights.

Breeding success among seabirds at the Farallon Islands depends on multiple variables, including the strength of the California Current, the intensity of upwelling, and interannual and interdecadal fluctuations. The numbers of warm-water species (including Black-vented Shearwater, and Black and Least Storm-petrels) off southern and central California increase during periods of sea surface warming associated with El Niño events. Cool-water species (such as Sooty Shearwater) decline during periods of sea surface warming, either due to northward migration or local declines in abundance.

Pinnipeds exhibit increased mortality and reduced breeding success in central and northern California during El Niño events. However, the impacts of El Niño events on pinnipeds off central and northern California are lower than those closer to the equator, where the changes in temperature and climate are more intense. Some pinnipeds may respond to changes in food supply by moving to a more productive area, or shifting their diets to accommodate changes in prey species composition and density.

Changes have also been reported in cetacean populations off the coast of California in relation to El Niño. In 1997-98, Odontocete (e.g., dolphins and toothed whales) diversity increased as southern species moved northward off California. Rorqual whale densities declined in areas where their euphausiid prey became less abundant and increased around coastal upwelling regions where zooplankton biomass was also concentrated. These trends reversed with the 1999 La Niña conditions and the return of the euphausiids.

Humpback whales may be better able to cope with stressful environmental conditions than other rorqual whales, because they are capable of switching their primary prey between euphausiids and fish.

Cool water seabird species (e.g., Black-legged Kittiwake and Sooty Shearwater) migrate further off-

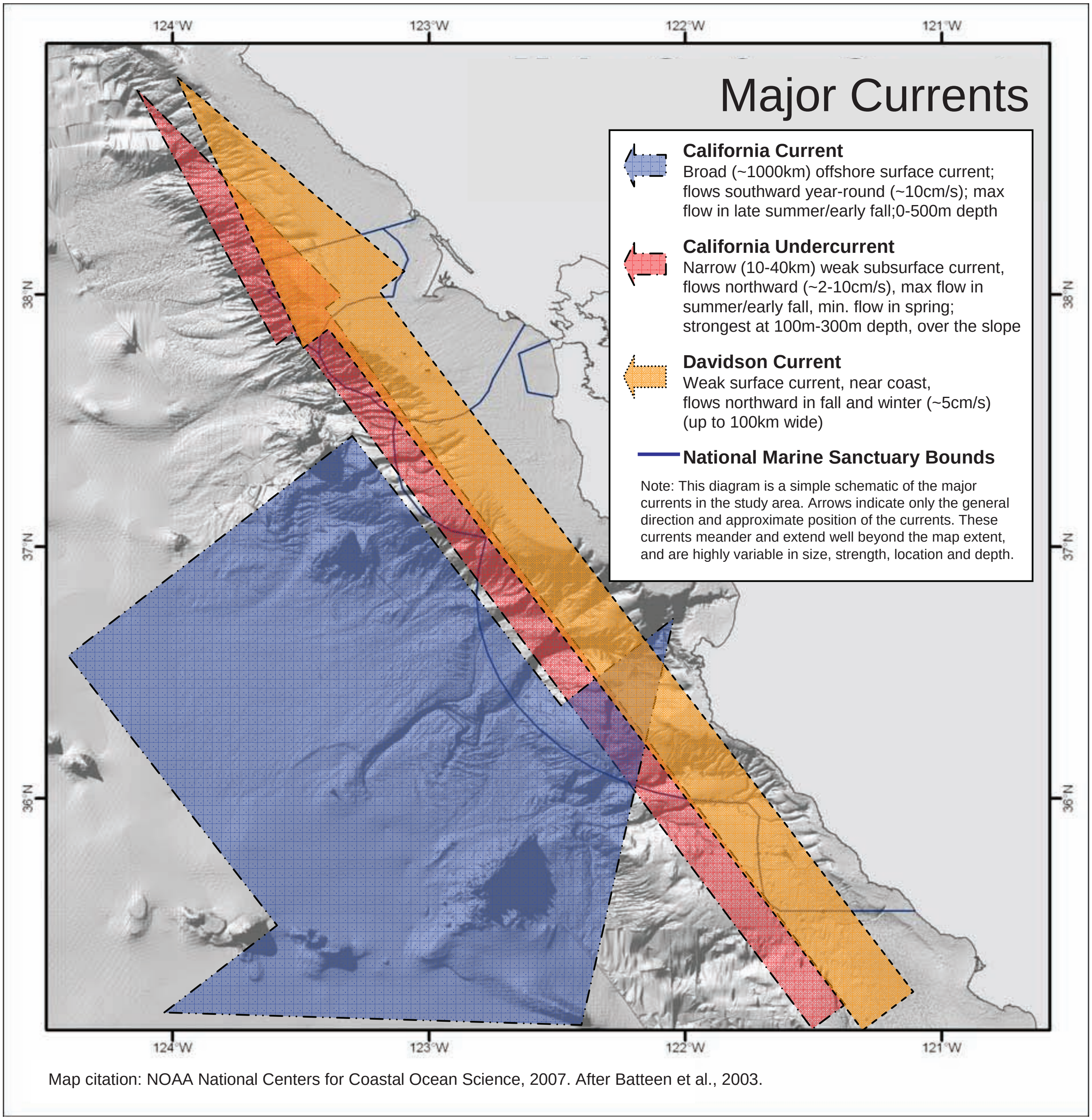


Figure 2.11. A schematic of two major surface currents and a subsurface current in the study area.

shore and north of their usual range during El Niño events. However, cool-water species return to the California coast with the onset of La Niña conditions and displace warm-water species prevalent during El Niño events.

The Pacific Decadal Oscillation. The Pacific Decadal Oscillation (PDO) is a recurring pattern of climate variability that is highly correlated with sea surface temperature in the northern California Current area; thus we often speak of the PDO as being in one of two phases, a “warm phase” or a “cool phase,” according to the sign of sea–surface temperature anomalies along the Pacific Coast of North America; see Figure 2.8 and 2.10. These phases result from winter winds in the North Pacific: winter winds blowing chiefly from the southwest result in warmer conditions in the northern California Current, and conversely, when winds blow chiefly from the north, upwelling occurs, leading to cooler conditions in the northern California Current (Citation from: http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm).

In Figures 2.8 and 2.10, a warm phase occurred from 1925 to 1946 (indicated in red), and a cool phase from 1947 to 1976 (in blue). From 1977 to about 1998, another 21-year warm phase occurred. However, since 1998 the PDO metric has been oscillating with no clear indication of warm or cool. It is not clear at this time what is driving this metric.

Numerous changes in terrestrial and marine ecosystems are associated with the PDO. Zooplankton biomass in the Gulf of Alaska and the California Current declined after a shift to warmer waters in 1976-1977. In the California Current, the biomass of macrozooplankton decreased by 70% between the mid 1970s and the early 1990s. The lowest macrozooplankton biomass of central California was recorded in 1998, when the strongest El Niño ever recorded occurred during the late stages of the warm phase of the PDO.

The changes in zooplankton abundance undoubtedly impact species that rely on zooplankton as food and their predators. The reduced supply of the euphausiid *Thysanoessa spinifera* since the mid-1970s, associated with the warm phase of the PDO, likely contributed to the decline of Cassin's Auklets and Sooty Shearwaters and some pinnipeds, including Steller sea lions and fur seals. The severe decline of sardines during the 1940s and 1950s undoubtedly affected the breeding success of certain species, including Steller sea lions, common murres, tufted puffins, and California brown pelicans. In the return of cooler waters in 1999, macrozooplankton rebounded to the long-term mean for the period of 1951-1984.

Global Warming. Ocean waters off the coast of California have warmed considerably over the last 40 years. These changes appear to be driven by a complex interaction between natural climate cycles, such as the PDO, and perhaps global increases in average temperature. Warming expands the surface layer of the ocean. As a consequence of recent warming, the sea level off California has risen an average of 0.9 (+/- 0.2) mm per year for the last 50 years. This rise in sea level is substantially lower than the average global sea level rise of 2 mm/year. Plants and animals may respond directly to increases in temperature, or indirectly to other environmental factors associated with the climate shift (e.g., altered current directions and speeds or altered nutrient dynamics). In the study area, some species appear to have shifted their geographic ranges north in response to increased water temperatures. Bottlenose dolphins moved north into Monterey Bay, and several coastal seabird species have extended their breeding ranges into California (including central California) as well. Seabird abundance within the California Current system declined by 40% from 1987 to 1994 (Veit *et al.,* 1996). The decline in overall bird abundance is driven largely by the decline of the Sooty Shearwater, a cold-water species that relies on euphausiids and small fishes. Global warming and other long-term climate variations, such as the PDO, may contribute to these biological changes.

Ocean Circulation and Currents

Circulation in the study area is dynamic and results from the interaction of wind, large-scale ocean currents, local geography, and the topography of the ocean bottom. The California Current System (CCS) forms the eastern portion of the clockwise North Pacific Subtropical Gyre; it is predominantly a wind-driven system and encompasses three major currents: the equatorward California Current, the poleward California Undercurrent and the poleward Southern California Countercurrent.

The prevailing wind system of the North Pacific Ocean is the mid-latitude Westerlies, a belt of winds that blow from west to east between 30°N and 60°N. These westerly winds create the North Pacific Current that pushes water away from Asia towards the west coast of North America. As this trans-Pacific flow converges toward the North American coastline, part of it is deflected equatorward forming the California Current, and part is deflected north to become the Alaska Coastal Current.

The California Current. The California Current has a significant effect on the study area; it is a surface current and is dominant year round, but slows generally in the late fall/winter. The Current appears as a broad, southeastern flow that transports cool, fresh, nutrient and oxygen-rich subarctic water equatorward. The California Current system extends about 3,000 km from north to south, from the Straight of Juan de Fuca (Vancouver Island) to

Baja California Sur. From east to west, the Current extends from the shelfbreak to an offshore distance of approximately 1,000 km, with strongest speeds at the surface and extending to at least 500 m in depth (Hickey, 1998), while the inshore section of the current is limited to the upper 200 m over the continental slope (Hickey, 1979). North of Point Conception, the core lies about 100-200 km from the coast, with maximum equatorward velocities of 5-10 cm/s (Chelton, 1984). South of Point Conception, the core of the California Current flows further from the coast, between 300-400 km offshore (Lynn and Simpson, 1987), with average speeds generally less than 25 cm/s (Reid and Schwatzlozse, 1962). Seasonal maxima in current speeds occurs in the summer to early fall.

The orientation of coastal peninsulas and points influences local and regional ocean circulation patterns. The California Current carries water south along the coast of central California to Point Conception, where the coastline turns east and the current continues southward and offshore.

The California Undercurrent. Underlying the California Current and the Southern California Countercurrent is a subsurface flow called the California Undercurrent, a narrow (10-40 km) poleward flow that extends the length of the coastline from Baja California to at least 50°N (Hickey, 1998). Originating in the eastern equatorial Pacific, the California Undercurrent can be characterized by a warm, saline, oxygen and nutrient-poor signature (Neander, 2001). Peak northward speeds of 30-50 cm/s usually occur in summer to early fall, being stronger at depths 100-300 m, and can be continuous over distances of more than 400 km along the continental slope (Collins *et al.,* 1996; Pierce *et al.,* 2000) or can break into separating, mesoscale jets (Cornuelle *et al.,* 2000; Barth *et al.,* 2000).

The Davidson Current. During winter, the inshore Davidson Current is observed at the surface north of Pt. Conception, when the flow of the California Current is reduced. From November through January, the northward-flowing Davidson Current is the dominant current below 100 m along the shelf break. The Davidson Current tends to be centered over the continental slope. Off San Francisco, the core of the Davidson Current is located about 800 m deep, and generally moving northwest in the study area. The return of winds from the northwest in January slows the northward surface expression of the Davidson Current.

The Southern California Countercurrent. This current draws warmer water from the south and forces the water northwest through the southern Channel Islands and the Santa Barbara Channel (Dailey *et al.,*1993). Additionally, some of the countercurrent is deflected west into the California Current south of the northern Channel Islands, resulting in a seasonal counterclockwise gyre in the Southern California Bight called the Southern California Eddy (Lynn and Simpson, 1987; Hickey, 2000). In spring, when the countercurrent is at its minimum northward flow, equatorward surface flow prevails in the Southern California Bight (Hickey, 1993). Hickey, 1979, suggested that the Southern California Countercurrent may combine with the poleward inshore Davidson Current north of Point Conception, the latter having peak flows during winter.

The ecology of the study area is closely tied to the processes of the California Current System (CCS). The CCS exhibits high biological productivity, diverse regional characteristics, and is populated with semi-stationary jets and eddies (Miller *et al.,*1999). The confluence of currents off Point Conception affects the abundance and distribution of species in the study area. Waters north of Point Conception have been classified as part of the Oregonian Province, characteristic of the coast of northern California, Oregon, and Washington. Waters south of Point Conception have been classified as the San Diegan, or Californian Province, characteristic of warm subtropical waters off southern California and Baja California, Mexico. Although many species are strongly separated by these biogeographic zones under “normal” conditions, species of the subtropical zone may occasionally extend their ranges north to central and northern California during unusually warm oceanographic events, such as El Niño or a warm phase of the PDO.

Eddies, Jets and Filaments. Ocean flows along the California coastline do not smoothly parallel the coastline. Rather, they are punctuated by eddies, jets, filaments (typically associated with points), headlands or submerged features such as seamounts. Eddies are areas of circular water flow, moving clockwise off the California coast. The formation of eddies is influenced by prominent coastal and oceanic features, such as points and seamounts.

There is a semi-permanent eddy northwest of Monterey Bay in the Gulf of the Farallones, known as the San Francisco Eddy. A second semi-permanent eddy extends out from Point Año Nuevo, and another eddy moves out from Point Arena and Point Reyes, projecting outward in the vicinity of the Farallon Islands. Eddies frequently form west and southeast of Monterey Bay and in the Bay itself. In addition, eddies may form when currents move in opposite directions on different sides of seamounts or emergent rocky features, such as at Cordell Bank. Persistent eddies may retain zooplankton or ichthyoplankton.

Jets and filaments move water rapidly offshore, for a distance of up to several hundred kilometers. These oceanographic features affect the distributions of chlorophyll and plankton. Collectively, the irregularities in coastal flows, such as eddies and jets, interact to concentrate, retain, or move production from upwelling centers to other locations.

Internal Waves. Internal waves travel below the surface and can generate complex patterns of flow over the continental shelf and slope. These waves form as marine tides and concentrate over the shelf break, particularly near irregular features such as submarine canyons. Internal waves produce turbulence, mixing, and up-canyon flow. If internal waves become unstable, they can break and form internal bores. The bores commonly travel near the bottom across the continental shelf to shore, which can generate onshore flows of bottom waters. Internal bores may move sediments or organisms across the shelf into nearshore habitats.

Ocean currents and other oceanographic features such as eddies, internal waves and internal bores, strongly influence the distribution and abundance of marine species. Although many oceanographic processes have been described in great detail, our understanding of their linkages to ecological processes is just unfolding.

Coastal Upwelling

Upwelling occurs primarily during the spring and summer along much of the California coast, and upwelling plumes expand southward from headlands. Strong coastal upwelling along central California arrests summer heating, depresses seasonal cycles of sea surface temperature (SST) within several hundred kilometers of the coast, and determines annual and semiannual phases inshore (Legaard and Thomas, 2006).

Circulation in the study area is strongly influenced by coastal upwelling, a process regulated by prevailing winds and the orientation of the coastline. In the northern hemisphere, Ekman transport causes surface water to move ~45 degrees to the right of the wind direction. Where surface water is pushed away from the coastline, deeper nutrient rich water rises to the surface creating an upwelling current. Along the north-south oriented coast of California, winds blowing from the north move surface water westward, away from the coastline, creating upwelling currents that bring colder water to the surface (San Francisco State University, 2000). North of Santa Cruz (>37°N), a strong seasonal contrast in winds results in favorable upwelling conditions in summer contrasted by downwelling during winter storms (Strub and James, 2000). From 35-37°N, modest storm activity results in monthly mean winds that remain favorable to upwelling year-round (Strub and James, 2000). In contrast, and south of the study area, upwelling is rare along the mainland coast of the Santa Barbara Channel because the headlands at Point Conception shelter the east-west oriented channel from the strong northwesterly winds that generate upwelling (Love *et al.,* 1999).

Upwelling is closely associated with coastal morphology and tends to occur off points along the eastern boundary of the North Pacific Ocean. Point Conception is the southernmost major upwelling center on the west coast of the United States, and marks a transition zone between cool surface waters to the north and warm waters to the south (Love *et al.,* 1999). Pt. Diablo, Oregon, is the northernmost point that generates an upwelling plume and eddy.

Major upwelling centers in the study area (i.e., those that generate plumes and eddies) are located near Points Arena, Reyes, Año Nuevo, and Sur; areas of upwelling tend to occur south of these locations. Particularly strong upwelling also occurs in the area between Point Arena and Point Reyes. Coastal mountains concentrate and intensify winds in this region, increasing the offshore movement of water. Off Pt. Reyes, upwelling brings cool, nutrient-rich water to the surface, moving it offshore and southward across the Gulf of the Farallones. Cool waters may accumulate off central California as well, especially near Point Año Nuevo and Point Sur. These waters and associated nutrients can then be transported to Monterey Bay via surface currents.

Phytoplankton, which support the complex web of marine life, thrive on nutrients in upwelled waters. Chlorophyll abundance is also associated with fronts, eddies and regions of upwelling. Upwelled waters in some regions of the world are high in nutrients, but do not stimulate large blooms of phytoplankton because other micronutrients, such as iron, can limit productivity. In the central coast region of California, iron is commonly resuspended from bottom sediments into the cold bottom water that is ultimately brought to the surface by upwelling. Figure 2.12 highlights seasonal changes and year-round averages of chlorophyll-*a*, a key component of overall productivity in the study area.

Oceanic Fronts

Patterns in sea surface temperature (SST) influence the distribution of marine species and habitats, particularly in areas of persistent SST fronts. The convergence of currents, the boundaries of adjacent water masses and the process of upwelling result in dynamic biological and physical convergence zones, or fronts, which influence the abundance and distribution of many organisms, including pelagic juvenile fishes, plankton, seabirds and marine mammals. Fronts are often identifiable by dramatic shifts in the sea surface temperature. Since fronts are areas of convergence, biota are often concentrated either passively, in the case of plankton, or actively, as in the case of nekton seeking to feed more efficiently on the plankton. Large shifts in SST, and consequently frontal boundaries, affect the spatial and temporal distribution of organisms. Off central California, ocean fronts become especially evident during upwelling periods, when waters of different properties are brought together. The edges of an upwelling plume or eddy, for instance, form a front with adjacent water. As upwelling increases in the summer, the ocean fronts move offshore. In the fall, ocean fronts begin to decrease and there are relatively few in the winter (December-February). Figure 2.13 shows seasonal and year-round estimates of offshore sea surface temperature fronts.

2.3 MARINE BIOGEOGRAPHIC SETTING

There are two coastal oceanic biogeographic provinces along the California coast: Oregonian and San Diegan. The Oregonian Province extends primarily from southeastern Alaska to Point Conception and is part of the Eastern Boreal Pacific Region (Briggs, 1974, 1995). The Oregonian Province extends southward beyond Point Conception along the outer islands of southern California, and in part reappears in upwelling areas off Baja California (Hubbs, 1949).

The San Diegan Province (part of the warm-temperate California region, which also includes the Cortez Province of the Gulf of California) extends from Point Conception, California to Magdalena Bay, Baja California Sur, Mexico (Briggs, 1974). However, in warm-water years, some San Diegan species extend their ranges northward.

Coastal biogeographic provinces differ in their distribution with depth, with the Oregonian Province extending further south with each successive benthic life zone (Allen, 2006). For example, sometimes submergence occurs, with species that occur in shallow depth zones in central and northern California occurring in deeper life zones in southern California (Hubbs, 1949; Allen, 2006a and b).

Offshore, only one of two oceanic provinces of the cold-temperate, Ocean Boreal Pacific Region occurs in the study area (McGowan, 1971). The Subarctic Province extends south along the California coast to Cape Mendocino, just north of the study area, and the Transition Zone extends south from Cape Mendocino through the study area, to Magdalena Bay.

2.4 ECOLOGICAL SETTING: SELECTED MARINE HABITATS USED BY MARINE BIRDS AND MAMMALS IN THE STUDY AREA

Below are discussions adapted from Airamé *et al.,* 2003 of three major marine habitats occupied by different assemblages of the marine birds and mammals of the study area:

- neritic and epipelagic ocean waters
- submarine canyons and waters above
- offshore islands and adjacent waters

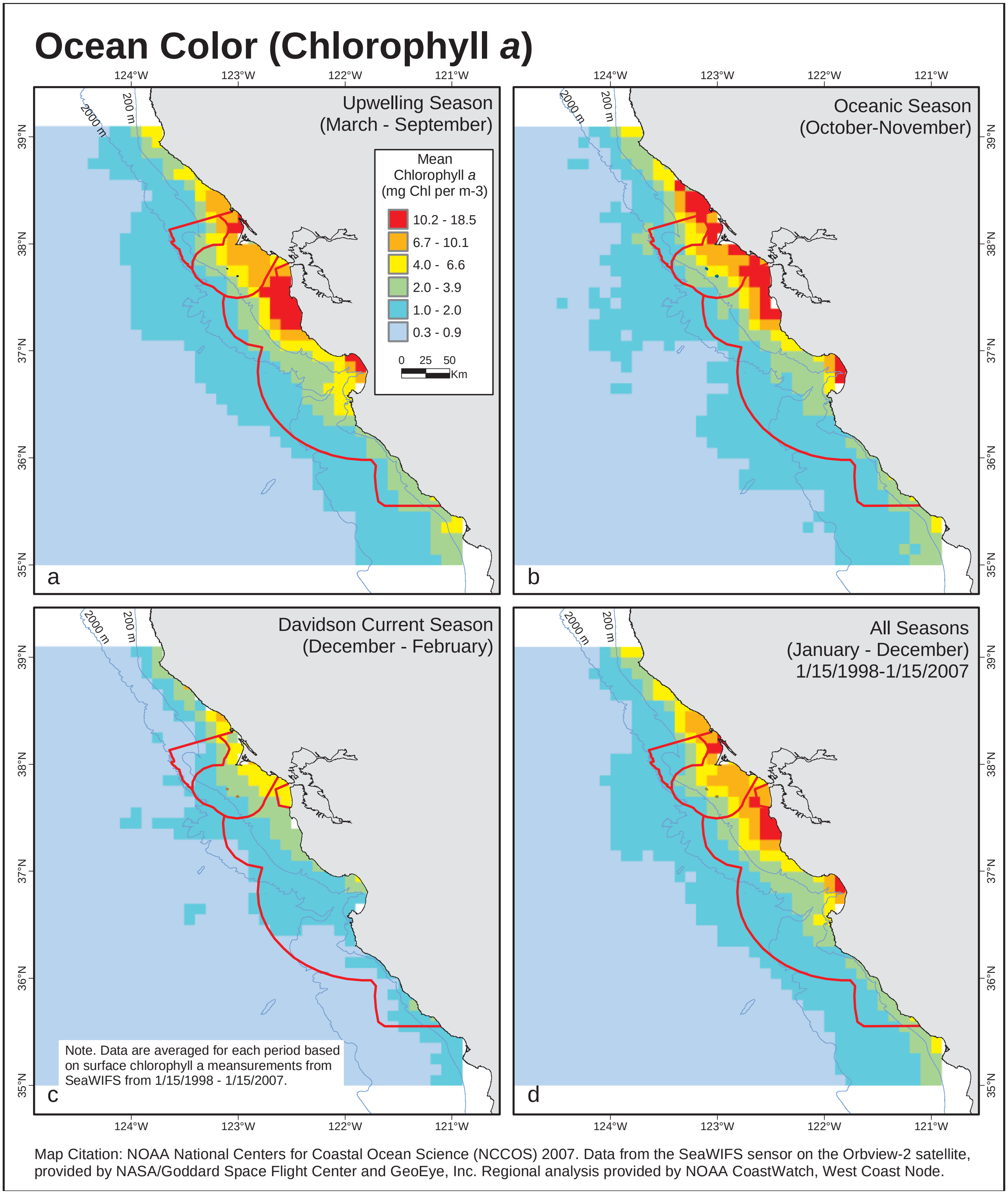


Figure 2.12. Ocean color (chlorophyll *a*), by ocean season and year-round.

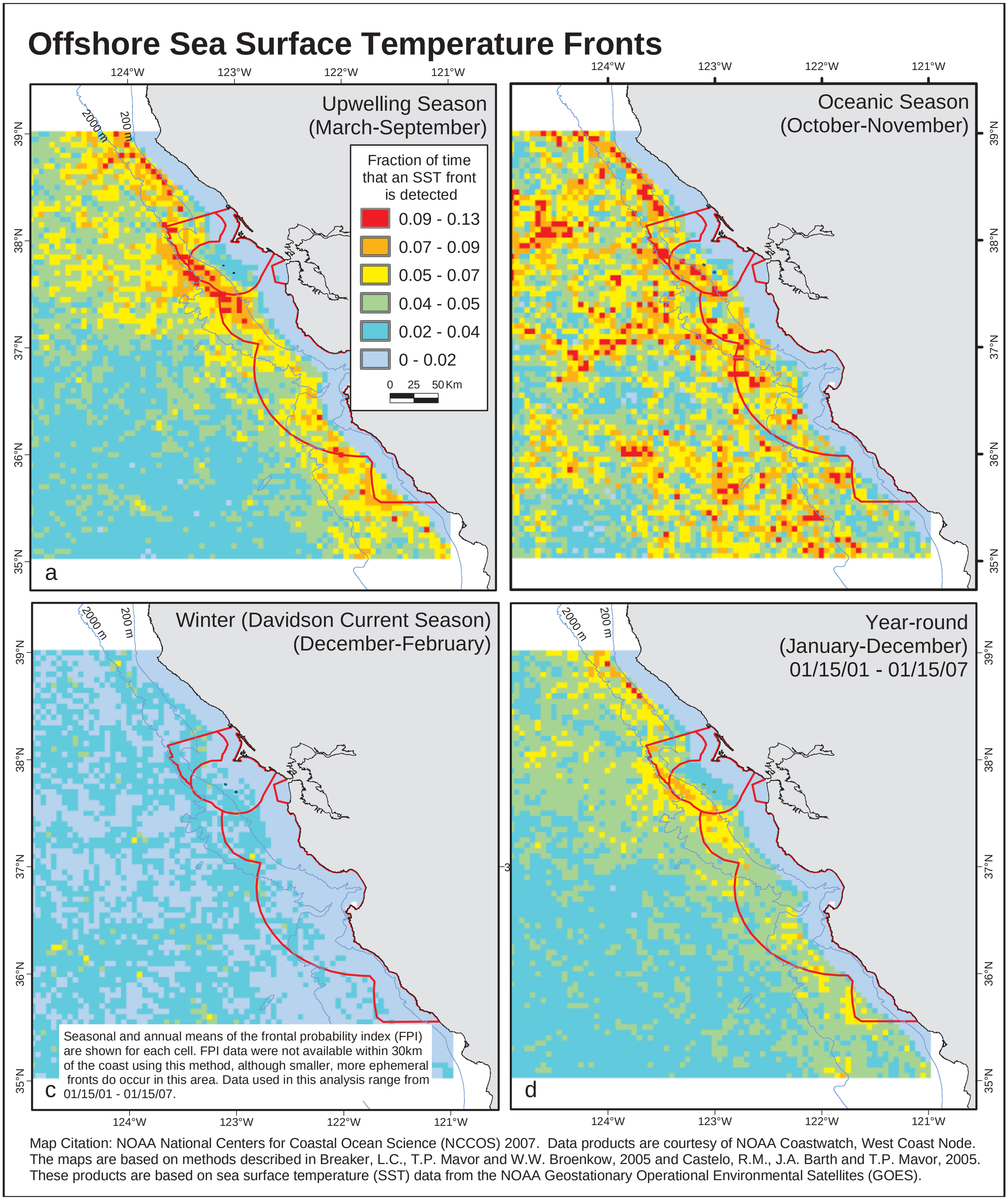


Figure 2.13. Offshore sea surface temperature fronts, by ocean season and year-round.

Other habitats that marine birds and mammals use include sandy beaches, lagoons and estuaries, sandy beaches, rocky intertidal, kelp forests, and coastal old growth forests. Descriptions of these habitats are not included here, but they can be found in Airamé *et al.,* 2003.

Neritic and Epipelagic Habitats

The vast majority of the three marine sanctuaries consist of open ocean habitats. These waters are classified into two primary zones, neritic (waters over the shelf, 0-200 m) and oceanic (waters beyond the shelf, from the surface to 200 m depth).

Several pelagic and benthic life zones occur in this region (Allen and Smith, 1988). Pelagic life zones consist of the Neritic Zone (water column over shelf to 200 m isobath) and three oceanic zones (over slope and basins): Epipelagic Zone (surface to 200 m); Mesopelagic Zone (200-1,000 m); and Bathypelagic Zone (1,000-4,000 m). Benthic life zones (Allen, 2006a and b) include Intertidal, Inner Shelf (0-30 m), Middle Shelf (30-100 m), Outer Shelf (100-200 m), Mesobenthal (Upper) Slope (200-500 m), and Bathybenthal Slope (500-1,000 m). A separate Estuarine Zone consists of both water-column and benthic species (Hedgpeth, 1957). Bathymetry of the study area is shown on Figure 2.2.

Both the neritic and epipelagic zones receive high levels of light and are subjected to seasonal variations in temperature and salinity. The neritic, epi-, and mesopelagic zones support a diverse and complex food web of plankton, invertebrates, fishes, birds and mammals. The bathypelagic zones are characterized by reduced or no light, cold temperature, and high pressure. Organisms that live under these conditions require specialized characteristics for hunting and locating mates.

Ecological Linkages in Neritic and Epipelagic Communities**.** Most marine food webs are supported almost entirely by phytoplankton, the primary food for protozoans, zooplankton, bivalves, and larval fishes, such as anchovies and sardines. In general, the highest phytoplankton biomass occurs in surface waters near the shore. The maximum phytoplankton production occurs during the spring and summer upwelling season, when the nutrient content of surfaces waters is relatively high (see oceanographic seasons). During upwelling, coastal plumes and jets may displace waters, nutrients, and phytoplankton production offshore. Throughout the year, phytoplankton are important. Microzooplankton depend on phytoplankton production for food, and in turn, contribute to the food supply of macrozooplankton. Zooplankton production varies with physical factors, including oceanographic conditions, temperature, currents, and eddies, and biological factors, including biomass of the adult stock and the reproductive effort for the year. Large populations of zooplankton are associated with high productivity in upwelling centers along the central coast of California. Zooplankton abundance decreases from north to south and from inshore to offshore with changes in temperature and nutrient availability. Zooplankton biomass in the California Current is highest in late spring, summer, and early fall.

Crustacean larvae, including euphausiids and copepods, are dominant groups in the epipelagic zone. Two species of euphausiids, *Euphausia pacifica* and *Thysanoessa spinifera*, are abundant in the epi- and mesopelagic zones. Euphausiids often are concentrated near Cordell Bank, the Farallon Islands and in Monterey Bay, due to high local productivity and oceanographic and geologic characteristics (see offshore island habitats, below). Copepods are found in a variety of marine habitats, including open water, sea floor sediments, tidal flats, and deep-sea trenches (see neritic and epipelagic communities).

Gelatinous zooplankton, including Hydromedusae, Siphonophora, Scyphomedusae, Ctenophora, Heteropoda, Pteropoda, Thaliacea, and Appendicularia, are abundant in the neritic and epi- and mesopelagic zones. Gelatinous zooplankton play a significant role in processing and transporting nutrients throughout the oceans. Pteropods, salps, and appendicularians are filter-feeders; they collect, concentrate, and transport particulate organic matter using mucous sheets, nets, strands, and filters.

Numerous fish species of the continental shelf and slope and submarine canyons have pelagic larvae and juvenile stages, which are important seabird and marine mammal prey. The duration of the pelagic larval and juvenile stages of many fish species is typically several weeks to months, but may be more than one year. After the pelagic phase, juveniles of many species settle into shallow waters near the coast and move into deeper waters as they grow.

Spatial and temporal distribution of plankton affects the distributions of planktivorous fishes, marine mammals, and seabirds. In particular, marine mammals and seabirds aggregate in regions with extremely high plankton density, such as Cordell Bank, the Gulf of the Farallones, parts of Monterey Submarine Canyon, and certain areas around the Channel Islands.

Squid are an important food source for numerous fishes, seabirds (including one of the most abundant pelagic seabirds, sooty shearwater), and marine mammals (including sea lions, seals, dolphins, orcas (killer whales), and sperm whales). The most important forage or prey species of squid along the California coast are *Loligo spp*., which concentrate in relatively shallow waters over the shelf, especially in Monterey Bay. Also, a large squid that initially invaded from waters to the south, *Dosidicus gigas*, is increasingly altering food webs owing to intense predation on fish, especially along the shelfbreak and outer shelf. Other squid live in deeper waters where they consume euphausiids and copepods, and a variety of other crustaceans, gastropods, and polychaete worms. Spawning squid, including *Loligo spp*., tend to congregate in protected bays, usually over sandy bottoms with rocky outcroppings.

The composition of fish species in the neritic and epipelagic zone varies throughout the year with migration and spawning, and from year to year with environmental fluctuations and predation pressure from fisheries. A small number of migratory species dominate the fisheries of central and northern California, including northern anchovy (*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), Pacific hake (*Merluccius productus*), and jack mackerel (*Trachurus symmetricus*). These species spawn in the Southern California Bight (where upwelling, and hence offshore transport, is at a minimum) and subsequently migrate into waters off northern California, Oregon, and Washington. During warm water conditions, the center of spawning may shift northward and continue longer. Northern anchovy and Pacific sardine can spawn throughout the year, but the peak in sardine spawning occurs in April and May. Pacific hake spawn in the winter whereas jack mackerel spawn between March and June. These fish are an important linkage in the marine food web, supporting a wide variety of higher-level predators, including: humans; other fishes; seabirds such as pelicans, gulls, and cormorants; and marine mammals, such as seals and sea lions, dolphins and porpoises, and sperm and humpback whales.

Sharks are predators of marine birds and mammals in the study area. Numerous sharks, including the blue shark (*Prionace glauca*), common thresher shark (*Alopias vulpinus*), mako shark (*Isurus oxyrhinchus*), basking shark (*Cetorhinus maximus*), and spiny dogfish (*Squalus acanthias*), are common residents of the neritic and epipelagic environment. Occasionally, the bigeye thresher shark (*Alopias superciliosus*), salmon shark (*Lamna ditropis*), and soupfin shark (*Galeorhinus galeus*) are present in small numbers. The white shark (*Carcharodon carcharias*) hunts in shallow open waters, often in the vicinity of Point Reyes, the Farallon Islands, and Año Nuevo Island where pinnipeds aggregate to molt and mate.

Concentrations of pelagic invertebrates and fishes attract seabirds to the open ocean over the continental shelf. Over 80 species of migrant seabirds and shorebirds, including Pacific and Red-throated Loons, California Brown Pelican, Red-necked, Western, and Clark's Grebes, Black-footed Albatross, Pink-footed, Sooty, Buller's, and Black-vented Shearwaters, Herring and Glaucous-winged Gulls, and White-winged and Surf Scoters, are regular visitors to waters around the Farallon Islands.

The most important types of prey for many seabirds are euphausiids, squid, juvenile rockfish, subadult sardine, and anchovy. Sooty shearwaters (*Puffinis griseus*), which are among the most numerous seabirds in the study area, migrate to the North Pacific during their non-breeding season to forage on fish, squid, and euphausiids. Shortbelly rockfish, anchovy, and sardine are among the primary foods of Common Murres (*Uria aalge*), Brandt's Cormorants (*Phalacrocorax penicillatus*), and Rhinoceros Auklet chicks (*Cerorhinca monocerata*). Murres and other seabirds feed principally on euphausiids in the spring, before juvenile fish and anchovies are available. Adult Rhinoceros Auklets consume sablefish and juvenile lingcod found in deep waters far offshore. California Brown Pelicans (*Pelecanus occidentalis californicus*) feed primarily on northern anchovy, Pacific Sardine, and Pacific Mackerel. Cassin's Auklets (*Ptychoramphus aleuticus*) depend on euphausiids and copepods as their primary food supply. Rhinoceros Auklets and Ashy Storm-Petrels (*Oceanodroma homochroa*) frequent waters of the continental slope, where they feed on epipelagic invertebrates, including euphausiids and oceanic squid. And fishes, including lanternfishes and Pacific saury.

Although pinnipeds use sandy beaches, mudflats, and rocky shores for resting and breeding, they forage in neritic, epipelagic, and mesopelagic waters, especially of the continental slope. California sea lions (*Zalophus californianus*) and Steller sea lions (*Eumetopias jubatus*) forage over the entire continental shelf and slope on a variety of invertebrates and pelagic fishes. Northern elephant seals (*Mirounga angustirostris*) feed on or near the bottom along the slope and deeper waters, where they hunt for fishes and invertebrates, including squid, octopus, hagfish, ratfish, hake, and rockfish. Female and juvenile elephant seals remain off the coasts of California and Oregon, whereas males travel as far northwest as the Aleutian Islands and the Gulf of Alaska. During their nonbreeding season, northern fur seals (*Callorhinus ursinus*) are the most abundant pinnipeds over the continental slope off California, where they hunt sablefish, rockfish, anchovy, squid, crabs, and various other types of prey. Most of these seals are from the Pribilof Islands, with a small number of seals from the Channel and Farallon Islands. Harbor seals, which are found primarily in coastal habitats, occasionally travel 300-500 km to find food. Generally, they feed on coastal species such as anchovy, jacksmelt, and herring.

Dolphins and porpoises are residents of neritic and oceanic (or pelagic) waters, with occurrence patterns stratified by ocean depth. Common dolphins (*Delphinus spp.*) are the most abundant cetaceans off California, but most occur far seaward of sanctuary boundaries. The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) is the second most abundant cetacean off California, with its greatest concentrations off central California. Pacific white-sided dolphin, northern right whale dolphin (*Lissodelphis borealis*), and Risso's dolphin (*Grampus griseus*) are found primarily in pelagic waters of the slope and beyond. They move north into Oregon and Washington as water temperature increases in the late spring and summer. Bottlenose dolphins (*Tursiops truncatus*) include a coastal population that is generally found within one km of the shore as well as an offshore population. Only the coastal form is found in the three marine sanctuaries. Harbor porpoises (*Phocoena phocoena*) are found in coastal waters in depths generally less than 100 m. The vast majority of the central California population is concentrated in the Gulf of the Farallones. Dall's porpoise (*Phocoenoides dalli*) occurs in both offshore neritic and pelagic waters. Similarly, orca (or killer whale, *Orcinus orca*) occur in both neritic and pelagic waters from California to Alaska. Orcas eat a variety of different types of prey, including fish, squid, seals, sea lions, seabirds, dolphins, porpoises, and occasionally large whales.

Sperm whales (*Physeter macrocephalus*) frequent waters of the continental slope and in the vicinity of seamounts where subsurface topography is steep. They subsist on fish and squid, are found year-round off California, but are most abundant in the spring and fall. Although the northeastern Pacific population of sperm whales is increasing under international and federal protection, this species continues to be listed as federally endangered.

Large baleen whales, including blue, gray, humpback, and fin whales, either migrate through the waters of coastal California, or move into the area to feed during the summer and fall. Baleen whales depend on concentrations of euphausiids for food. Large numbers of blue and humpback whales feed on euphausiids, anchovies, and sardines in the vicinity of Cordell Bank, the Farallon Islands, and Monterey and Bodega Canyons. Blue and humpback whales migrate south to mate and give birth in protected warm waters off Mexico and Central America during the winter and spring. Gray whales (*Eschrichtius robustus*), the most commonly observed cetacean off central California during the winter and early spring, migrate annually from their feeding grounds in the Arctic Ocean and Bering Sea to their calving grounds in Baja California. Fin whales (*Balaenoptera physalus*) feed on euphausiids and schooling fish off southern and central California throughout the year.

<u>Ecological Linkages of Neritic and Epipelagic Communities with Other Ecosystem Components</u>. Phytoplankton, which is commonly found in neritic and epipelagic waters, is the primary source of production in the oceans. Although phytoplankton grows in surface waters, they are transported to other habitats by ocean currents, other organisms, and gravity.

Phytoplankton blooms, including toxic blooms, have increased in frequency and distribution worldwide since 1980. Frequency of blooms may be increasing with nutrient enrichment from agricultural and urban storm runoff, and sewage effluent. Several phytoplankton species produce toxins that may impact other organisms. Toxic phytoplankton become dominant when warm waters are carried closer to shore during relaxation events. Toxic algal blooms are common in the Gulf of the Farallones between August and October. Toxins produced by the dinoflagellate *Alexandrianum catenell*a are primarily responsible for paralytic shellfish poisoning in California. The diatom *Pseudonitzschia australis* produces the neurotoxin domoic acid, which has contributed to deaths of seabirds and marine mammals that consumed tainted fish.

Zooplankton and small, schooling fishes comprise the principal trophic linkage between primary and higher-level production. Euphausiids, especially *Euphausia pacifica* and *Thysanoessa spinifera*, directly support a variety of neritic and pelagic predators, including various fishes (anchovy, squid, salmon, hake, blue sharks), seabirds (Sooty Shearwaters, Cassin’s Auklets, Common Murres), and baleen whales (blue, humpback, gray, and fin). Euphausiids are a common source of food that may be the primary reason for aggregation of midwater species, such as the market squid, Pacific hake, plainfin midshipman, Pacific herring, juvenile rockfishes, Pacific butterfish, and speckled and Pacific sanddabs. The lowest macrozooplankton biomass of central California was recorded in 1998. In 1999, macrozooplankton abundance rebounded to values near the long-term mean.

Numerous species that depend on zooplankton as a primary food source may be affected by the persistent low zooplankton biomass since the mid-1970s. Sooty Shearwaters, which consume euphausiids in the North Pacific during their non-breeding season, exhibited a dramatic decline in abundance in the waters of the California Current. Changes in the abundance of euphausiids also may have contributed to the decline of planktivorous Cassin’s Auklets.

The decline in productivity of the California Current System may be associated with long-term variation in climate. Populations of some species, including Pacific sardine and northern anchovy, vary widely with climate fluctuations.

Human activities in the epipelagic and neritic habitats, including recreational and commercial fishing and boating, may affect nontargeted species, including turtles, seabirds, and marine mammals. Seabirds, particularly albatross, are frequently caught on hooks set out on long-lines of commercial fisheries. In trawl fisheries, seabirds may be attracted to the catch and become tangled in nets as they are gathered. Industrial fishing has had profound effects on ocean food webs worldwide including the California Current. Unusually high mortality of Common Murres from November 1997 to March 1998 was associated with spilled oil from submerged vessels, changes in food availability during El Niño, and an increase in set gillnet fishing in southern Monterey Bay. Marine mammals, including common and Pacific white-sided dolphins, and harbor porpoise, can become tangled, injured, or killed in gear from set and drift gillnet, and purse-seine fisheries. Restrictions on these fisheries have reduced the rate of entanglement, but some animals are injured or killed each year during routine fishing operations. Marine mammals also may be injured or killed by collision with ships.

Hunting of large whales during the last two centuries contributed to dramatic declines of many whale species. Some species are recovering under international protection. Gray whales, which recovered completely from very low populations, were removed from the Endangered Species List in 1994. Since protection, blue whales in the eastern North Pacific have increased from a very small population, which was nearly entirely depleted off California, to approximately 2,000 individuals. The population of humpback whales in the North Pacific has increased to over 6,000 individuals from a low of 1,200 in 1966. Fin whales were hunted to near extinction during the last century but under protection, the fin whale stock off California/Oregon and Washington has increased to approximately 2,541 individuals. All three species are currently listed as endangered, as their numbers now are still estimated to be far below historical levels.

Hunting of pinnipeds for meat, oil and fur contributed to the decline of many species. The population of northern elephant seals was reduced to less than 100 individuals on Isla de Guadalupe off the coast of Mexico. Since protection, the world population of northern elephant seals has increased to over 84,000 individuals and likely has reached its pre-exploitation biomass. Elephant seals are, by far, the most abundant breeding pinniped species in the marine sanctuaries. Harbor seals were greatly reduced to a few hundred individuals by commercial hunting. Under state and federal protection, the harbor seal population has increased to approximately 28,000 individuals in California, a large portion of which occur in the marine sanctuaries. California sea lions were reduced to low populations by hunting, but have increased at a rate of about 5% per year to over 200,000 individuals. This species, too, is likely near to pre-exploitation biomass. In contrast, the Steller sea lion population has declined over the last 30 years due to: reduction in sardine populations and other coastal fish stocks from over fishing; entanglement in fishing gear; deliberate shooting to protect salmon and herring fisheries; and perhaps interference of reproductive capabilities owing to chemical pollution. The Steller sea lion is listed as a Federally threatened species.

Submarine Canyon Communities

The continental shelf off central California is highly dissected by numerous submarine canyons. Submarine canyons are submerged v-shaped valleys that begin on the continental shelf, extend down the slope, and end on the abyssal plain. They were formed by river erosion when sea levels were approximately 200 m lower, during the Last Glacial Maximum and previous glacial periods. A variety of habitats are found in submarine canyons, including vertical cliffs, ledges, talus slopes, cobble and boulder fields, and soft mud. Canyon walls are often steep and rocky whereas canyon bottoms tend to slope gently and accumulate finer sediments, such as silt and mud. Submarine canyons form during erosion of rapidly flowing currents that carry heavy sediment loads, known as turbidity currents. When turbidity currents reach the base of the continental slope, they slow and deposit their sediment loads in broad submarine fans. Figures 2.3-2.5 show selected submarine canyons and other marine physiographic features in the study area.

Unique Submarine Canyons. Pioneer Canyon bisects the continental slope just south of the Farallon Islands. Pioneer Canyon consists of two smaller canyons that merge near the shelf break to form the main valley of the canyon.

The Ascension Canyon system, west of Point Año Nuevo, includes three major canyons: Ascension, Año Nuevo, and Cabrillo. Near their heads, the canyon walls are steep and v-shaped. The main channel of Ascension Canyon is relatively straight and narrow (<0.5 km). Sediment slides influence the shapes of the head and the northwestern wall of Ascension Canyon.

The Monterey Canyon system, located within Monterey Bay and offshore, includes three major canyons: Soquel, Monterey, and Carmel. In addition to these canyons, the Monterey Canyon system includes several prominent meanders: Gooseneck, Monterey, and San Gregorio.

Soquel Canyon is located on the continental shelf just south of Santa Cruz. The canyon extends about 10 km southwest where it intersects the larger Monterey Canyon at a depth of about 1,000 m.

The head of Monterey Canyon is located near Moss Landing. The upper part of the canyon is relatively narrow (~250 m wide) and the canyon walls are quite steep (10-35°). Although sediment slides occur on both walls of the canyon, slumping and sliding are more prevalent on the north wall. The Monterey Canyon cuts steeply into the continental shelf, reaching depths of 1,300 m in the outer bay. The canyon floor continues to widen as it meanders across the continental shelf, reaching a width of over 3.5 km in some places. From the edge of the continental shelf, the Monterey Canyon slopes down to the abyssal plain to a depth of 3,200 m. On the deep sea floor, the canyon expands out across a broad submarine fan, extending over 160 km wide.

Carmel Canyon is formed by the confluence of three canyon heads, two in Carmel Bay and one along an active fault zone southwest of Carmel Bay. The canyon intersects Monterey Canyon approximately 30 km from its head at a depth of about 1,970 m. Sur Canyon is located approximately 60 km south of Monterey Canyon. Several heads of Sur Canyon originate on the Sur Platform. The canyon extends to the west for more than 50 km where it reaches the abyssal plain just northeast of the Davidson Seamount. The steep north side of the

Sur Canyon is particularly susceptible to slumping and sediment flows.

Lucia Canyon slopes to the west across the narrow continental shelf just south of Sur Canyon. The incline of the canyon is relatively gentle on the upper continental slope, but becomes steeper toward the bottom. The steep canyon walls are heavily scarred with landslides along the lower continental slope.

Ecological Linkages of Submarine Canyons and Other Marine Ecosystems. Cool, nutrient-rich waters accumulate at upwelling regions such as Point Año Nuevo and Point Sur. These waters and associated nutrients can then be transported, in this example, to Monterey Bay via surface currents. The south side of the Monterey Canyon is particularly productive due to the combination of currents moving southward and the canyon structure. As organisms (such as euphausiids) migrate up the water column to feed, they may be transported southward on the California Current and trapped in relatively shallow waters over the continental shelf just south of deep canyons. These concentrations of organisms attract a variety of predators, including fishes, birds, and marine mammals. Blue and fin whales often, at least seasonally, feed on dense swarms of euphausiids near the Monterey Canyon.

Offshore Island Communities

The islands off California's coast are unique habitats that provide breeding and resting sites for migrating seabirds and marine mammals. Together, the Farallon Islands, Año Nuevo Island, and the rocks off Point Reyes, support interconnected populations of breeding seabirds and pinnipeds. In addition, California's islands support numerous rare, endemic species that evolved as a consequence of their isolation and adaptation to conditions on islands. Historically, islands have been strongly influenced by hunting for animals and their eggs, which resulted in the near extinction of northern elephant seals, northern fur seals, Common Murres, Cassin's Auklets, and Tufted Puffins from the California coast. Today, the Farallon Islands are protected by the Farallon National Wildlife Refuge, Año Nuevo Island is a state reserve, and Pt. Reyes is protected within the Pt. Reyes National Seashore.

The Farallon Islands, located approximately 50 km west of San Francisco, are the only major offshore islands in central and northern California (see Figures 2.3 and 2.14). The five Farallon Islands are part of a granite ridge that rises from the seafloor. Southeast Farallon and West End islands together cover just over 35 hectares. Southeast Farallon Island is the largest and the only one of the Farallon Islands to have been occupied by humans. Middle Farallon Island is about 4 km to the northwest, and the North Farallon Islands are a group of three rocks located 8 km farther to the northwest. The Farallon Islands are located at the edge of the continental shelf and south of the largest upwelling center along the California coast. The high marine productivity of this region attract a diverse assemblage of invertebrates, fishes, seabirds, and marine mammals.

A number of coastal rocks also occur within the marine sanctuaries. The largest, Año Nuevo Island, is located off Point Año Nuevo and south of Half Moon Bay and Pigeon Point (see Figure 2.3). This small, rocky islet is approximately 400 m long and 260 m wide. Higher parts of the island are covered with sand and vegetation. Año Nuevo Island was a part of the mainland just a few hundred years ago.

Other important coastal rocks in the study area include Bird Rock near Tomales Point, Double Point and Point Resistance rocks just south of Point Reyes, Devil's Slide rock near Pacifica, a rock off Point Lobos, and Hurricane rocks off Big Sur. Morro Rock is substantial, but since it is connected to the mainland at low tide, it is not an important marine bird roosting or breeding site.

Ecological Linkages of Offshore Islands with Other Ecosystem Components. The Farallon Islands are the most important area for nesting seabirds off the California coast. Seabirds also nest on coastal rocks and islands, but no other site is used by all 12 of the bird species that breed on the Farallon Islands. Over 300,000 adult birds nest on the islands in May during the height of the breeding season. Twelve species of seabirds, including Common Murre, Cassin's and Rhinoceros Auklets, Pigeon Guillemot, Tufted Puffin, Western Gull, Double-crested, Brandt's and Pelagic Cormorants, Ashy and Leach's Storm-petrels, and Black Oystercatcher, breed on the Farallon Islands; (Peregrine Falcons, which perhaps once bred there, are present for the fall-spring period). Smaller colonies of most of these species also breed at Point Reyes and Año Nuevo Island. Other than these locations, breeding

Figure 2.14. Aerial view of South Farallon Islands.

sites for the majority of these species are few along the coast of California south of Humboldt County.

Murres and auklets are the most abundant of the breeding seabirds on the Farallon Islands. Common Murres (*Uria aalge*) form dense breeding colonies (>100,000 individuals) on cliffs. Murres also breed along the Marin County coast in Point Reyes National Seashore at sites including Devil's Slide Rock, Castle Rock, Hurricane Point, Point Reyes, Double Point, and Point Resistance. Cassin's Auklets (*Ptychoramphus aleuticus*), the second most abundant species on the Farallon Islands, nest there in burrows on marine terraces and talus slopes; it also breeds on Año Nuevo Island. Several thousand pigeon guillemots (*Cepphus columba*) breed at the Farallon Islands. Smaller populations are found at other locations along the California coast (Año Nuevo Island, Partington Ridge, Grayhound Rock, Point Reyes National Seashore, and cliffs along San Mateo and San Francisco counties). Tufted Puffins (*Fratercula cirrhata*) breed on the Farallon Islands each year; and a few pairs have attempted to breed at Point Reyes. After the breeding season, auklets and murres leave breeding sites and disperse along the coast.

Although several gull species may be observed around the Farallon Islands, only one species breeds there. Western gulls (*Larus occidentalis*) nest on the lower slopes and flat areas of Southeast Farallon Island, Año Nuevo Island, and other locations along the central California coast, including Cape San Martin, Elkhorn Slough, and Morro Rock.

Three cormorant species breed on the Farallon Islands. Brandt's Cormorants (*Phalacrocorax penicillatus*) nest in scattered colonies on lower elevation flat areas of the Farallones, as well as at Año Nuevo Island, and Point Reyes. Pelagic Cormorants (*Phalacrocorax pelagicus*) nest on narrow cliff edges of the Farallon Islands, Point Reyes, and other locations along the California coast, including Bodega Head, Devil's Slide Rock (south of San Francisco), and Año Nuevo Island. Double-crested Cormorants (*Phalacrocorax auritus*) breed on the Farallon Islands and throughout the San Francisco Bay region, especially on the larger bridges over the inner bay. Unlike most other species that breed on the Farallon Islands, double-crested cormorants forage primarily in estuaries, lagoons, and bays, and pelagic cormorants forage primarily in intertidal areas.

The Farallon Islands support breeding populations of two storm-petrel species. Ashy Storm-Petrel (*Oceanodroma homochroa*) and Leach's Storm-Petrel (*Oceanodroma leucorhoa*) nest in burrows and crevices, deep beneath the surface of talus slopes, under boulders and in rock walls on Southeast Farallon Island. Most of the remainder of the California populations of these species nest on the Channel Islands, although small numbers breed on a few coastal rocks of the Pt. Reyes National Seashore. Storm-Petrels feed on epipelagic invertebrates and fish, with the ashy storm-petrel frequenting waters of the continental slope and the Leach's Storm-Petrel those waters farther to the west.

Large breeding populations of pinnipeds are found on offshore islands of central and northern California. Pinnipeds haul out on shore to rest or breed. Northern elephant seals breed at Point Año Nuevo Island and the adjacent mainland, Point Piedras Blancas, Big Sur Beach, Point Reyes, and the Farallon Islands. A small breeding population of northern fur seals is found on the Farallon Islands. Although the California sea lion is the most widely distributed pinniped off central and northern California, this species breeds mainly on offshore islands in Mexico and southern California. A few California sea lion pups have been born on Año Nuevo and the Farallon Islands. Steller sea lions once bred in great numbers on the Farallon Islands, Año Nuevo Island, and the Channel Islands, but breeding populations have declined steeply and the southernmost breeding site is now Año Nuevo Island.

The waters around the Farallon Islands are important to pinnipeds during the non-breeding season. During the winter, the Steller sea lions haul-out at Point Reyes and on the rocky islands off the Sonoma coast. Cordell Bank is a primary feeding area for this species, possibly because of the abundance of rockfish and sardines around the bank. The Gulf of the Farallones contains a significant portion of the California population of harbor seals.

The Farallon and Año Nuevo islands, Point Reyes, and the rocks and coasts near Point Reyes comprise a demographic unit characterized by extensive interchange of individuals among the resident species. Among banded or marked individuals that have been seen at all or two of the three locations are: white sharks, Brandt's Cormorants, Black Oystercatchers, Western Gulls, Rhinoceros Auklets, Steller sea lions, and northern elephant seals.

Aside from this triangle of breeding sites, there is no other major breeding site for marine birds or mammals along the coast to the north until Cape Mendocino, and only a few to the south until the Channel Islands. Other seabirds that nest within or adjacent to the marine sanctuaries are Caspian and Forster's Terns and Marbled Murrelet. The waters from Point San Pedro to northern Monterey Bay are particularly important to Marbled Murrelet, which is listed as threatened. Small numbers of five marine bird species breed on the rocks off Big Sur. A small rock off Pacifica, just south of San Francisco, supports small numbers of murres and cormorants.

Seabirds provide organic material and nutrients to habitats they use for breeding and feeding. Seabirds deposit excreta, feathers, eggshells, and carcasses in habitats they use. This nutrient input may increase plant productivity as well as alter composition of flora communities in areas around seabird colonies.

Many bird species occurring on offshore islands in California have declined during the last 150 years due to a variety of factors, including: depletion of food owing to overfishing, exposure to toxic materials, egg collecting, disturbance, habitat destruction, effects of fishing gear, environmental changes, and increased predation. Some of these impacts were reduced when: 1) Southeast Farallon Island became a National Wildlife Refuge in 1969; 2) the Gulf of the Farallones National Marine Sanctuary was established in 1981; and 3) when the Channel Islands National Marine Sanctuary was established in 1980. Under protection, many marine bird and mammal populations have increased or recovered.

Offshore islands are an important component of the marine ecosystem off north/central California, providing breeding and resting habitat for thousands of birds and mammals.

2.5 CHAPTER SUMMARY

Many factors influence the distribution and abundance of marine birds and mammals of the study area, and much remains unknown about the dominant environmental drivers (e.g., climate, temperature) that influence species distributions and the habitats and ecosystems they occupy; this chapter was included to offer environmental and ecological context for the following chapters on marine bird and mammal distributions.

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CHAPTER 3: BIOGEOGRAPHY OF MARINE BIRDS

3.1 INTRODUCTION

The overall goal of this assessment on marine birds off north/central California was to identify, collect and analyze the best available data and information on the spatial and temporal patterns of marine birds in the study area, and provide a report with maps, tables and related products for the National Marine Sanctuaries Program. A chapter on marine birds in the Phase I biogeographic assessment was completed in 2003 (NOAA NCCOS, 2003; also http://ccma.nos.noaa.gov/products/biogeography/canms_cd/welcome.html). The following chapter includes additional work and revisions completed for Phase II of this work, and includes updates to bird colony maps, map discussions, data tables and chapter text.

Background

The marine study area off north/central California occurs within the California Current system (CCS), one of the most productive ocean systems in the world (Glantz and Thompson, 1981). The CCS includes a southward-flowing surface current (the California Current), a northward flowing undercurrent (the Davidson Current or California Undercurrent), and various eddies and upwelling jets that run perpendicular to the coast. Such complexity, along with shallow- and deep-water habitats, steep topography, coastal lagoons, steep cliffs, and islands for breeding, brings a rich fauna of marine birds to central California, as evidenced by the species abundance and richness described herein. In addition to a populous assemblage of breeding birds, the assemblage of seasonal residents and migrants is even more robust, as central California is the destination for many marine bird species from elsewhere in the Pacific seeking productive feeding areas and acceptable habitat in which to spend their non-breeding periods. Unlike many organisms, marine birds have tremendous mobility and the fact that many seek this region to find food is evidence of the region's trophic richness. Some visiting species come from the Southern Hemisphere and others from the North, in appropriate seasons, dependent on their breeding phenology. All combine with breeding species to make a diverse, seasonally changing community. Fortunately for the purpose of management of the central California National Marine Sanctuaries, the marine avifauna of the study area has been one of the most thoroughly surveyed in the world.

3.2 DATA AND ANALSES

Overview of the Map Development and Analysis Process

More than one method was used in the at-sea surveys and because of this, careful consideration and correction was required to merge, analyze and map the data sets in a meaningful and scientifically acceptable way. The major steps of the management and compilation of data for the bird analyses were as follows: select species and study area; identify and collect survey sets; make the necessary corrections so that different data sets were compatible with one another; convert the data into common comparable units; organize the data into 5' latitude by 5' longitude cells; and calculate effort and density for each marine bird species. Seasonal density maps were created for 40 species. Overall density, biomass density, and diversity maps (across species) were also created using combined distribution and abundance data for 76 bird species. The Phase I bird chapter was reviewed by experts in 2002 (see list of reviewers at end of this section) and finalized in 2003; the Phase II chapter was reviewed via email in the summer of 2007. In accord with comments, revisions were made and the bird chapter was completed.

Table 3.1. Marine bird species used in the analyses, organized by map treatment & family.*

Common Name	Scientific Name	Order/Family/SubFamily
Species mapped separately & used in summary diversity & density analyses (n=31; 124 maps)		
Pacific Loon	*Gavia pacifica*	Gaviiformes/Gaviiadae
Laysan Albatross	*Phoebastria immutabilis*	Procellariiformes/Diomedeidae
Black-footed Albatross	*Phoebastria nigripes*	Procellariiformes/Diomedeidae
Northern Fulmar	*Fulmarus glacialis*	Procellariiformes/Procellariidae
Pink-footed Shearwater	*Puffinus creatopus*	Procellariiformes/Procellariidae
Buller's Shearwater	*Puffinus bulleri*	Procellariiformes/Procellariidae
Sooty Shearwater	*Puffinus griseus*	Procellariiformes/Procellariidae
Black-vented Shearwater	*Puffinus opisthomelas*	Procellariiformes/Procellariidae
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	Procellariiformes/Hydrobatidae
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	Procellariiformes/Hydrobatidae
Ashy Storm-Petrel	*Oceanodroma homochroa*	Procellariiformes/Hydrobatidae
Black Storm-Petrel	*Oceanodroma melania*	Procellariiformes/Hydrobatidae
California Brown Pelican	*Pelecanus occidentalis californicus*	Pelecaniformes/Pelecanidae
Brandt's Cormorant	*Phalacrocorax penicillatus*	Pelecaniformes/Phalacrocoracidae
Double-crested Cormorant	*Phalacrocorax auritus*	Pelecaniformes/Phalacrocoracidae
Pelagic Cormorant	*Phalacrocorax pelagicus*	Pelecaniformes/Phalacrocoracidae
Red-necked Phalarope	*Phalaropus lobatus*	Charadriiformes/Scolopacidae
Red Phalarope	*Phalaropus fulicarius*	Charadriiformes/Scolopacidae
Heermann's Gull	*Larus heermanni*	Charadriiformes/Laridae/Larinae
Western Gull	*Larus occidentalis*	Charadriiformes/Laridae/Larinae
Glaucous-winged Gull	*Larus glaucescens*	Charadriiformes/Laridae/Larinae
Sabine's Gull	*Xema sabini*	Charadriiformes/Laridae/Larinae
California Gull	*Larus californicus*	Charadriiformes/Laridae/Larinae
Black-legged Kittiwake	*Rissa tridactyla*	Charadriiformes/Laridae/Larinae
Arctic Tern	*Sterna paradisaea*	Charadriiformes/Laridae/Sterninae
Common Murre	*Uria aalge*	Charadriiformes/Alcidae
Pigeon Guillemot	*Cepphus columba*	Charadriiformes/Alcidae
Cassin's Auklet	*Ptychoramphus aleuticus*	Charadriiformes/Alcidae
Rhinoceros Auklet	*Cerorhinca monocerata*	Charadriiformes/Alcidae
Tufted Puffin	*Fratercula cirrhata*	Charadriiformes/Alcidae
Marbled Murrelet	*Brachyramphus marmoratus*	Charadriiformes/Alcidae
Species mapped with related species & used in diversity & density analyses (n=9 , 16 maps)		
Western Grebe	*Aechmophorus occidentalis*	Podicipediformes/Podicipedidae
Clark's Grebe	*Aechmophorus clarkii*	Podicipediformes/Podicipedidae
Black Scoter	*Melanitta nigra*	Anseriformes/Anatidae
Surf Scoter	*Melanitta perspicillata*	Anseriformes/Anatidae
White-winged Scoter	*Melanitta fusca*	Anseriformes/Anatidae
Caspian Tern	*Sterna caspia*	Charadriiformes/Laridae/Sterninae
Elegant Tern	*Sterna elegans*	Charadriiformes/Laridae/Sterninae
Xantus's Murrelet	*Synthliboramphus hypoleucus*	Charadriiformes/Alcidae
Craveri's Murrelet	*Synthliboramphus craveri*	Charadriiformes/Alcidae

Table 3.1. continued. Marine bird species used in the analyses, organized by map treatment and family*.

Common Name	Scientific Name	Order/Family/SubFamily
Species in the CDAS data used only in the diversity & density analyses and maps (n=37)		
Red-throated Loon	*Gavia stellata*	Gaviiformes/Gaviidae
Common Loon	*Gavia immer*	Gaviiformes/Gaviidae
Horned Grebe	*Podiceps auritus*	Podicipediformes/Podicipedidae
Red-necked Grebe	*Podiceps grisegena*	Podicipediformes/Podicipedidae
Eared Grebe	*Podiceps nigricollis*	Podicipediformes/Podicipedidae
Murphy's Petrel	*Pterodroma ultima*	Procellariiformes/Procellariidae
Cook's Petrel	*Pterodroma cookii*	Procellariiformes/Procellariidae
Parkinson's Petrel	*Procellaria parkinsoni*	Procellariiformes/Procellariidae
Flesh-footed Shearwater	*Puffinus carneipes*	Procellariiformes/Procellariidae
Short-tailed Shearwater	*Puffinus tenuirostris*	Procellariiformes/Procellariidae
Manx Shearwater	*Puffinus puffinus*	Procellariiformes/Procellariidae
Townsend's Shearwater	*Puffinus auricularis*	Procellariiformes/Procellariidae
Wilson's Storm-Petrel	*Oceanites oceanicus*	Procellariiformes/Hydrobatidae
Wedge-rumped Storm-Petrel	*Oceanodroma tethys*	Procellariiformes/Hydrobatidae
Markham's Storm-Petrel	*Oceanodroma markhami*	Procellariiformes/Hydrobatidae
Least Storm-Petrel	*Oceanodroma microsoma*	Procellariiformes/Hydrobatidae
Red-billed Tropicbird	*Phaethon aethereus*	Pelecaniformes/Phaethonidae
Brown Booby	*Sula leucogaster*	Pelecaniformes/Phaethonidae
White Pelican	*Pelecanus erythrorynchos*	Pelecaniformes/Pelecanidae
South Polar Skua	*Stercorarius maccormicki*	Charadriiformes/Laridae/Stercorariinae
Pomarine Jaeger	*Stercorarius pomarinus*	Charadriiformes/Laridae/Stercorariinae
Parasitic Jaeger	*Stercorarius parasiticus*	Charadriiformes/Laridae/Stercorariinae
Long-tailed Jaeger	*Stercorarius longicaudus*	Charadriiformes/Laridae/Stercorariinae
Bonaparte's Gull	*Larus philadelphia*	Charadriiformes/Laridae/Larinae
Mew Gull	*Larus canus*	Charadriiformes/Laridae/Larinae
Ring-billed Gull	*Larus delawarensis*	Charadriiformes/Laridae/Larinae
California Gull	*Larus californicus*	Charadriiformes/Laridae/Larinae
Thayer's Gull	*Larus thayeri*	Charadriiformes/Laridae/Larinae
Glaucous Gull	*Larus hyperboreus*	Charadriiformes/Laridae/Larinae
Red-legged Kittiwake	*Rissa brevirostris*	Charadriiformes/Laridae/Larinae
Royal Tern	*Sterna maxima*	Charadriiformes/Laridae/Sterninae
Common Tern	*Sterna hirundo*	Charadriiformes/Laridae/Sterninae
Forster's Tern	*Sterna forsteri*	Charadriiformes/Laridae/Sterninae
Thick-billed Murre	*Uria lomvia*	Charadriiformes/Alcidae
Parakeet Auklet	*Aethia psittacula*	Charadriiformes/Alcidae
Ancient Murrelet	*Synthliboramphus antiquus*	Charadriiformes/Alcidae
Horned Puffin	*Fratercula corniculata*	Charadriiformes/Alcidae

*Note: This table is not in phylogenetic order.

Species Selected for Analysis

Selection criteria for bird species included in this assessment were: 1) those that had a mostly marine distribution in the study area; and 2) adequate ocean survey data were available and were in a usable format. If possible, a species was included if it was: a) abundant in the study area; b) a Federal or State-listed endangered or threatened species; or c) a California state species of concern. The study area for the Geographic Information System (GIS) assessment was seaward of the beach and did not include the coast or estuaries, so few shorebirds and waterfowl were included. The exception is in the mapping of breeding colonies, which included San Francisco Bay. Because the marine distributions of locally breeding bird species are affected by colony (and roost) location, information was included on the location and size of breeding and roosting sites, when available and appropriate.

Table 3.1 is a list of marine bird species selected for this assessment. Data for 40 species were either mapped separately or as groups if they generally co-occurred (e.g., scoters). Even if not mapped individually, all species that occurred in the study area were used to develop summary community metric maps on diversity and density. Over 200 maps on individual bird species and community metrics were created for this marine bird assessment.

The Literature and Survey Data Used in this Assessment

The Literature. Several reports provided background information on the occurrence patterns of marine birds in the region. The general composition and distribution of the marine avifauna has been described by Ainley, (1976) and Briggs *et al.,* (1983, 1987a, b), with an historical perspective provided by Ainley and Lewis, (1974). Ainley and DeSante, (1980), and Pyle and Henderson, (1991), provide a fine-scale look at species' seasonal presence and migratory periods, as viewed from the Farallon Islands; Ainley *et al.,* (1995a, c); Veit *et al.,* (1997); and Oedekoven *et al.,* (2001), provide an interannual view of variability in spatial occurrence for selected species. The last four references, as well as Ainley *et al.,* (1994); Spear and Ainley, (1999); and Ainley and Divoky, (2001), investigated long-term temporal trends in populations. Information on habitat preferences of marine birds and how these are affected by ocean climate variability are provided for selected species in Ainley and Boekel-


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heide, (1990); Oedekoven *et al.,* (2001), and in a GIS analysis by Allen, (1994). The food-web relationships of marine birds in this region are also remarkably well described by Balz and Morejohn, (1977); Ainley and Sanger, (1979); Briggs *et al.,* (1984); Briggs and Chu, (1987); Chu, (1984); Ainley and Boekelheide, (1990); Ainley *et al.,* (1996a, b); and Sydeman *et al.,* (1997). The breeding biology, including interannual variability in productivity and relationship to food-web variation, is also very well described (Ainley and Boekelheide, 1990; Ainley *et al.,* 1995b). Studies of habitat preferences, including effects thereon of ocean climate variability, is provided for select species in Ainley and Boekelheide, (1990) and Oedekoven *et al.,* (2001), with a GIS analysis also by Allen, (1994). See the end of this section for a complete list of references used.

Most of the above reports considered marine bird patterns over periods of less than 10 years. In this study, the spatial and temporal patterns of marine birds were examined using data gathered over two decades (1980-2001), an opportunity rarely enjoyed in the study of marine birds and mammals. This time period, however, did not capture the complete spectrum of variability because most of these data were collected during what is known as a "warm phase" of the Pacific Decadal Oscillation (PDO) (http://jisao.washington.edu/pdo/) (Hare and Mantua, 2000; Mantua and Hare, 2002). During that period (approximately 1977 to 1998), coincident with warming ocean temperatures, zooplankton volumes declined (Roemich and McGowan, 1995) and the fish fauna changed dramatically: sardine abundance increased while anchovy, herring, and demersal fishes declined. These changes were also affected by industrial fishing,

Table 3.2. A summary of at-sea data sets in the CDAS Central California data set (1980-2001) used in the marine bird analyses.

Data Set & Platform Type	Principal Investigator	Platform & Height	Ocean Habitat Covered	Years	Ocean Seasons/ Months Sampled	Total Transect Width	Total Sightings	Total Individuals
NMFS Midwater Trawl Juvenile Rockfish Assessment: Ship Surveys	Ainley	David Starr Jordan, 10 m	Surface survey of shelf and slope to 3,000 m	1985-2001	Mainly the upwelling season (March-August)	300 m	52,134	427,302
San Francisco Deep Ocean Disposal Site (SF-DODS) Ship Surveys	Ainley	Point Sur, 8 m	Surface survey of shelf and slope to 3,000 m	1996-2000	Year-round; all three ocean seasons	300 m	17,055	82,649
NMFS/SWFSC (Southwest Fisheries Science Center) ORCA WALE Ship Survey	Ballance	MacArthur, 11 m	Surface survey of the shelf, slope & deep ocean beyond	2001	Mainly the oceanic season (~August-November)	200-300 m, depending on species & conditions	823	1,917
EPOCS Shipboard Surveys	Ainley	Surveyor, 12 m, Discoverer, Oceanographer, 15 m	Surface survey of the deep ocean	1984-1994	Year-round; all three ocean seasons	300-600 m	450	843
MMS Low Altitude Aerial Surveys	Briggs	Pembroke, 62 m	Surface survey of the shelf, slope & deep ocean beyond	1980-1983	Year-round; all three ocean seasons	50 m	39,486	145,499
CA Dept. of Fish & Game, Office of Spill Prevention and Response (OSPR), Low Altitude Aerial Surveys	Bonnell, Tyler	Partenavia, 62 m	Surface survey of shelf and slope	1994-1998, 2001	Year-round; all three ocean seasons	50 m	17,368	289,159
CA Seabird Ecology Low-Altitude Aerial Surveys	Briggs	Partenavia, 62 m	Surface survey of shelf and slope	1985	Mainly the upwelling season (March and May)	50 m	2,439	9,307
MMS Santa Barbara Channel Low Altitude Aerial Surveys	Bonnell	Partenavia, 62 m	Surface survey of shelf and slope	1995-1997	Year-round; all three ocean seasons	50 m	1,830	8,310

Note: See chapter text for additional detail on the individual data sets in the CDAS central CA data set (1980-2001).

especially for herring and some demersal species, that occurred at a level perhaps inappropriate to the warm-water phase of the PDO. In response, the avifauna changed, showing major declines in key "cool-water" species such as Sooty Shearwaters (Ainley *et al.,* 1994; Veit *et al.,* 1997; Spear and Ainley, 1999), Common Murres and Cassin's Auklets (Ainley *et al.,* 1995b; Ainley and Divoky, 2001; Oedekoven *et al.,* 2001; Ainley and Lewis, 1974). Some warm-water species have appeared in small numbers during recent years, some only for brief periods (Ainley, 1976; Schwing *et al.,* 1997). Other species (e.g., Hawaiian Petrel, Black Skimmer) have shown signs of staying (Ainley and Divoky, 2001). Features of the coastal ocean environment off California (e.g., water temperature, winds, upwelling, fronts, food availability) are highly variable, and at different time and space scales. This makes it difficult to describe the relative distribution and abundance of marine avian species in the region, unless specific, shorter time periods are identified. It is likely the species' habitat usage did not change. However, we do know that certain species, such as murres and auklets, occupied the ocean progressively closer to shore as the warming period persisted (Oedekoven *et al.,* 2001).

In 1999, the ocean waters off central California appeared to be shifting to cooler sea surface temperatures and it was thought perhaps a cool PDO phase had started (Bograd *et al.,* 2000; Schwing *et al.,* 2000). However, since 2003, ocean surface temperatures have returned to a relatively warm state, and the status of the PDO is not clear. Certainly, the results from this study indicate that some visiting species changed their occurrence patterns, if only for a few years, much like some did in response to warm events (Ainley *et al.,* 1994). For example, sightings of black-legged kittiwake appeared to expand from mostly slope waters in 1997/1998 to include shelf waters, as the waters cooled in 1999/2000 (see Figure 3.47).

Survey Data. The rationale for collecting the data used in this summary was based on: 1) the interests of individual researchers to study spatial and temporal patterns of marine birds; 2) Federal government efforts to assess potential biological impacts of oil development; and 3) state government efforts to respond to oil spills, of which there had previously been several major ones in the study area. Nevertheless, these objectives broadly overlap the needs of sanctuary resource management.

Survey Methods at Sea. Both ship and air surveys used strip transects, with transect width depending on the platform used. Earlier aerial survey data were collected at sea using methods described by Briggs *et al.,* (1983, 1987b); more recent data were collected using updated technologies for determining the position of the survey trackline, including the use of Global Positioning System (GPS) and data logging software. Ship-based surveys were conducted using the flux-corrected techniques described in Spear *et al.,* (2004).

In Table 3.2 and below are descriptions of the at-sea surveys used in this assessment. The data sets were combined in a system called MMS-CDAS (The Marine Mammal and Seabird Computer Database Analysis System, MMS 2001, version 2.1), developed and maintained by the R.G. Ford Consulting Co. For the bird assessment, data from eight survey efforts were combined, and are now known as the CDAS central California data set (1980-2001). The results and products from this data set were published in 2003 in Phase I of this assessment, and updates are included in this chapter. Aggregating the individual data sets into one spatial framework provided more information over a larger area and time period. Figures 3.1, 3.2 and 3.3 show the spatial extent of the individual data sets and Table 3.2 provides a summary of survey effort in those data sets.

The ship and aerial strip-transect data used in CDAS were collected from 1980-2001 and occurred along the U.S. west coast from Washington through California. This study used data only from the study area, which extends from the coast between Point Arena and Point Sal, and offshore to the extent of data availability. Estuaries were not part of the survey area, although colony data from estuaries were included when available.

1. NMFS Rockfish Assessment Cruises. Seabird and marine mammal data were collected 1985-2001 (except 1995-1996) by D.G. Ainley, L.B. Spear and helpers (initially PRBO, and subsequently H.T. Harvey and Associates) from the flying bridge on the *NOAA research vessel David Starr Jordan* (8 m ASL). These cruises are conducted by the National Marine Fisheries Service (NMFS) -Tiburon (now Santa Cruz) Laboratories. Most cruises were done in May and June for purposes of assessing rockfish year-class strength, but included are a few cruises at other times of the year on this vessel. During the first few years, three sweeps of the study area (Bodega Bay to Cypress Point) occurred from late May into mid-June. The cruise dates were then advanced to be mostly in May, a change that led to bird observers participating only in the later sweep(s) in order to maintain consistency in timing within the data set relative to avian phenology. Cruises started and ended usually from a port in San Francisco Bay area. Except for ship costs, the seabird surveys were funded by participating individuals.

The ship followed a series of transects from shore to about the 2,000 m - 4,000 m isobaths, same tracks every cruise, spaced about 15' latitude apart. In the early years, when time was made available, bird observers directed the ship to transit waters farther offshore or well within the Gulf of the Farallones (sometimes avoided by NMFS owing to ship traffic that precluded fish sampling). At all times that the ship was underway during daylight, at least two (and sometimes three) observers counted all birds and pinnipeds seen within 300 m of one forequarter of the vessel (one with least glare) and all cetaceans within 800 m. Only when visibility was <300 m or winds >30 kts were counts not conducted.

Counts were continuous but broken into 15 minute bins. See Figure 3.1a.

2. The San Francisco Deep Ocean Disposal Site (SF-DODS) Cruises. These cruises were conducted by H.T. Harvey and Associates personnel (Ainley and Spear, 1996-2000) on board R/V *Pt. Sur*, beginning and ending at Moss Landing. The protocol was similar to that described for the Rockfish Assessment Cruises (see above), with extensive overlap in personnel, except that counts were made from within the wheelhouse (6 m ASL). Three cruises were done per year, one in each of the oceanographic seasons. After a transit to/from Moss Landing, a series of transects were conducted to cross the SF Deep Ocean Disposal Site, extending 15 nm in all directions. After this effort was completed a circuit of the Gulf of the Farallones was completed for comparison of inshore versus offshore avifauna. Included are a series of data collected from tug boats pulling barges from SF Bay to the SF-DODS. Protocols were the same, except that height above sea level was about 4 m and the survey strip width was 200 m for birds and pinnipeds and 400 m for cetaceans. The work was funded by the U.S. Army Corps of Engineers investigating the San Francisco Bay deep ocean (dredged materials) disposal site. See Figure 3.1b.


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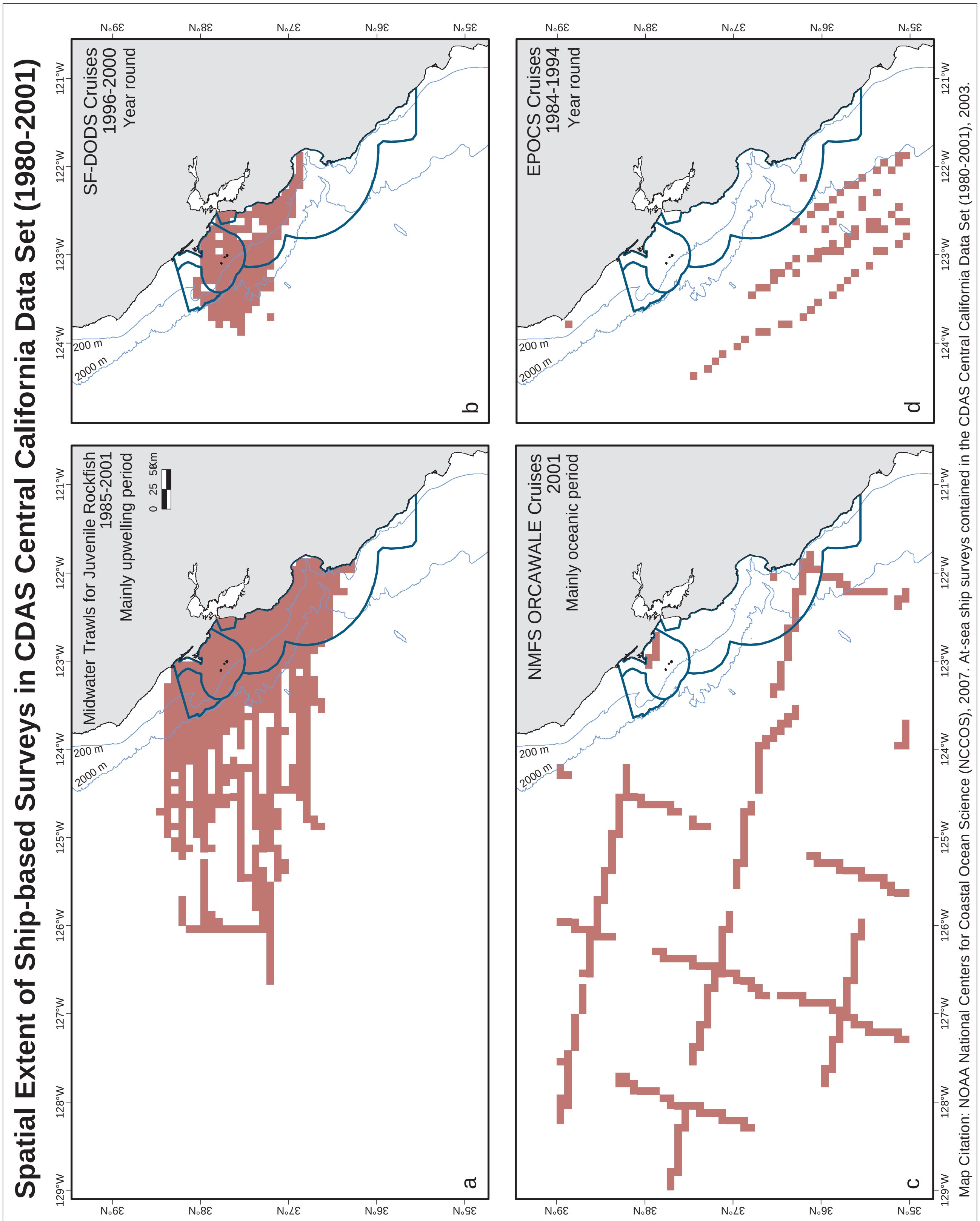
3. The NOAA ORCAWALE Cruise. This cruise was conducted in 2001 on the NOAA/NMFS/SWFSC cruise to assess stock size of cetaceans. The vessel was the NOAA ship MacArthur. Data collection protocols used for birds were similar to those described for the NMFS Rockfish Assessment Cruises. See Figure 3.1c.

4. EPOCS Transit Cruises. These cruises were conducted 1984-1994 on NOAA vessels transiting from Seattle to the eastern tropical Pacific in order to service oceanographic buoys stationed along the Equator (Equatorial Pacific Ocean Climate Study). Protocol was largely the same as that described for the Rockfish Assessment Cruises (below), including extensive overlap in personnel. The exception was that the flying bridge was higher (12-15 m ASL) during EPOCS and, therefore, survey width was wider depending on vessel height (400-600 m for birds and pinnipeds; 800 m for cetaceans). These cruises were largely in waters well beyond the continental shelf. See Figure 3.1d.

5. Minerals Management Service (MMS) Effort: Marine Mammal and Seabird Surveys off Central and Northern California. These surveys included both high-altitude aerial surveys (for cetaceans) and low-altitude aerial surveys (for birds and mammals). The principal investigator for this study was Thomas P. Dohl of the Center for Marine Studies, University of California, Santa Cruz. Michael L. Bonnell headed the pinniped portion of the study and Kenneth T. Briggs headed the bird portion. Funding was provided by POCS-MMS, Contract Number: 14-12-0001-29090. The time period of this study was February 1980 through June 1983, and surveyed shelf, slope, and pelagic (offshore) waters to a distance of 60 nm from Point Conception to the California-Oregon boundary. Surveys were flown twice-monthly at two different altitudes (200 ft (60 m) and about 750-1,000 ft ASL) along approximately 40 east-west transect lines extending an average of 60 nm offshore. The transects sampled on a given survey were selected randomly from a set of 92 predetermined lines spaced at 5' latitude intervals. Sightings of seabirds were recorded only on low-altitude surveys, and only on the shaded side of the aircraft within a strip transect 50 m wide. Navigation was by Loran and VLF-Omega. See Figure 3.2a.

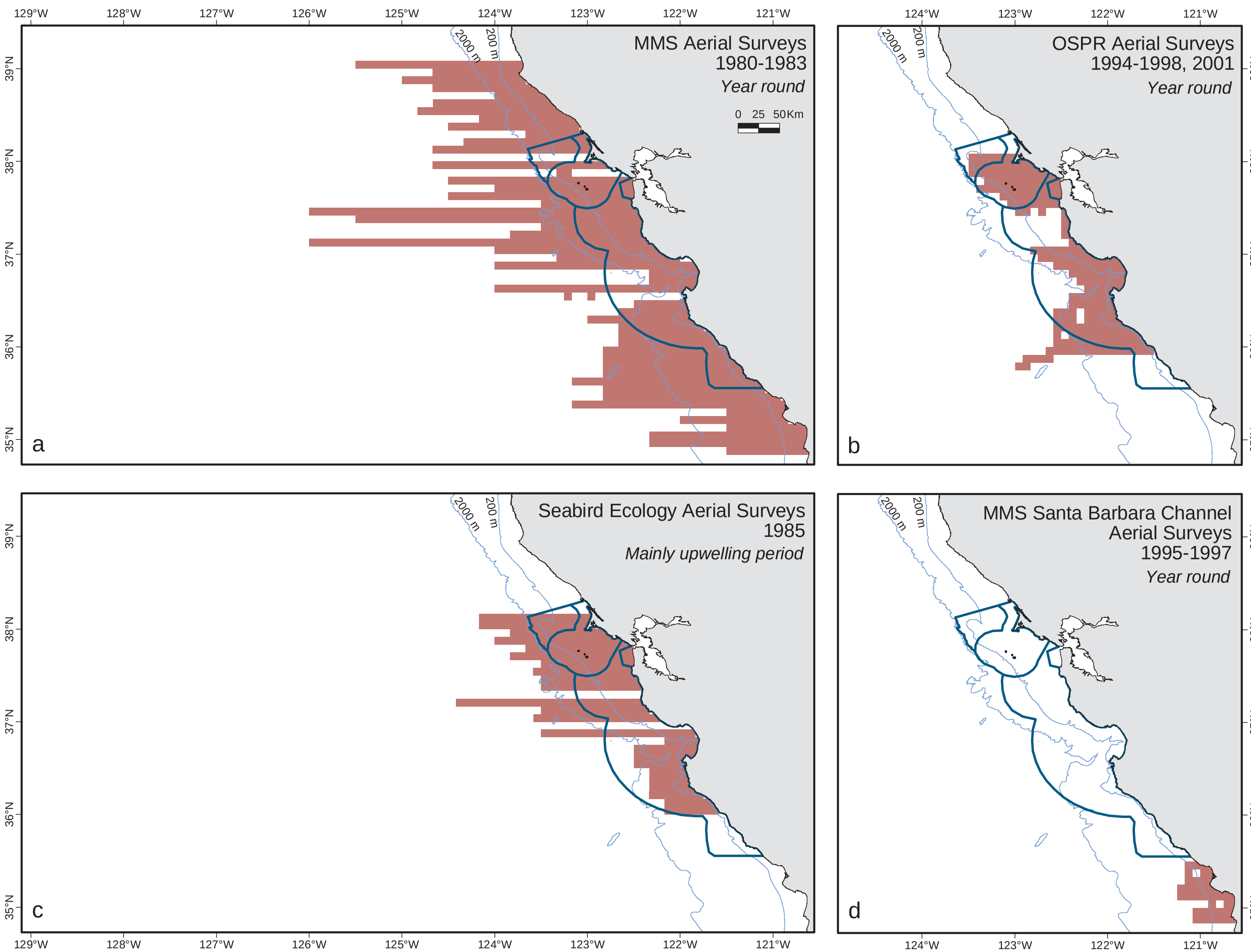
6 and 7. The OSPR Aerial Surveys and the MMS Santa Barbara Channel Aerial Surveys. These surveys were conducted as part of a program to maintain readiness for oil spill response. Aerial surveys were conducted frequently throughout the year to ensure that trained and experienced aerial observers were available in the event of an oil spill in California offshore waters. The principal investigators for this work were Michael L. Bonnell (from 1994 to 1998) and W. Breck Tyler (beginning in 2001), from the Institute of Marine Sciences, University



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS), 2007. At-sea ship surveys contained in the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.1. Spatial extent of ship-based surveys in the CDAS central California data set (1980-2001) used in the marine bird analysis.

Spatial Extent of Aerial Surveys in CDAS Central California Data Set (1980-2001)



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS), 2007. At-sea aerial surveys conained in the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.2. Spatial extent of aerial at-sea surveys in in the CDAS central California data set (1980-2001) used in the marine bird analysis.

of California, Santa Cruz. The funding agencies are the California Department of Fish and Game (CDFG), Office of Spill Prevention and Response (OSPR) (Contract Number: FG7407-OS). Credit for this study is shared with OSPR by the MMS, Pacific OCS Region. The areas of these studies pertinent to the present effort included offshore areas in the Gulf of the Farallones and Monterey Bay, San Francisco Bay.

The aircraft used was a Partenavia PN68 Observer provided by the Department of Air Services, CDFG, flown at an altitude of 200' (60 m) above ground level and at a typical air speed of 90 knots. Two observers searched a corridor of 50 m on each side of the aircraft. Species, numbers, behavior and other information was described on hand-held tape recorders for later transcription and computer entry. Date, time, and position of the aircraft were recorded directly into the data-logging computer with time, latitude and longitude provided by a GPS. Only data recorded by experienced observers are included in this data set. See Figures 3.2b and d.

8. The California Seabird Ecology Study Aerial Surveys. These aerial surveys were conducted as part of a smaller follow-on study to the above MMS effort. The principal investigator was Kenneth T. Briggs of the Institute of Marine Sciences, University of California, Santa Cruz. Portions of this work were done by D. G. Ainley and L. B. Spear at Point Reyes Bird Observatory, Stinson Beach, CA. The funding agency was POCS-MMS (Contract Number: 14-12-001-30183). The period of study was 1984 - 1987, and the area pertinent to the present synthesis focused on the Gulf of the Farallones.
Field studies were conducted from Monterey Bay to about Bodega Head. Data collection protocols for aerial surveys were identical with those used for the MMS Surveys (above). Four aerial surveys were conducted in the spring and summer of 1985. See Figure 3.2c.

Data Synthesis

Summarizing Transect Data into Grid Cells. The above data sets required a significant amount of processing and correction in order to make them compatible for synthesis and analysis. Because wind speed affects detection of some marine bird and mammal species, data collected when wind speed exceeded 25 knots were excluded. From the digitized survey data, the distributions of effort and of species were allocated into 5' latitude by 5' longitude cells. All aerial data were continuous; each ship-based data set was converted separately into a continuous transect format 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 speed were used to compute the end position of each 2-4 km continuous transect. From this, a midpoint of the transect was determined. As times of observations were not available, the position of

Table 3.3. Summary of combined data set effort by ocean season for the marine bird analysis.

Ocean Season	Ocean Season Time Period	Number of Months	Years of At-Sea Data	Kilometers of Trackline Surveyed	% of Total Trackline Surveyed	Number of Visits	Number of 5' Cells Sampled	% of Total Cells Sampled
Upwelling	15 Mar-14 Aug	5	1980-1982, 1985-2001	64,177	48%	11,050	1,335	58%
Oceanic	15 Aug-14 Nov	3	1980-1982, 1991, 1994-2001	29,263	22%	4,171	1,130	49%
Davidson Current	15 Nov-14 Mar	4	1980-1986, 1991-2001	40,265	30%	5,878	1,593	69%
TOTAL	1 Jan – 31 Dec	12	1980-2001	133,705	100%	21,099	2,294	100%

Note. The number of 5' cells sampled is not a straight sum; it refers to the number of unique cells surveyed.

the 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 bird 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

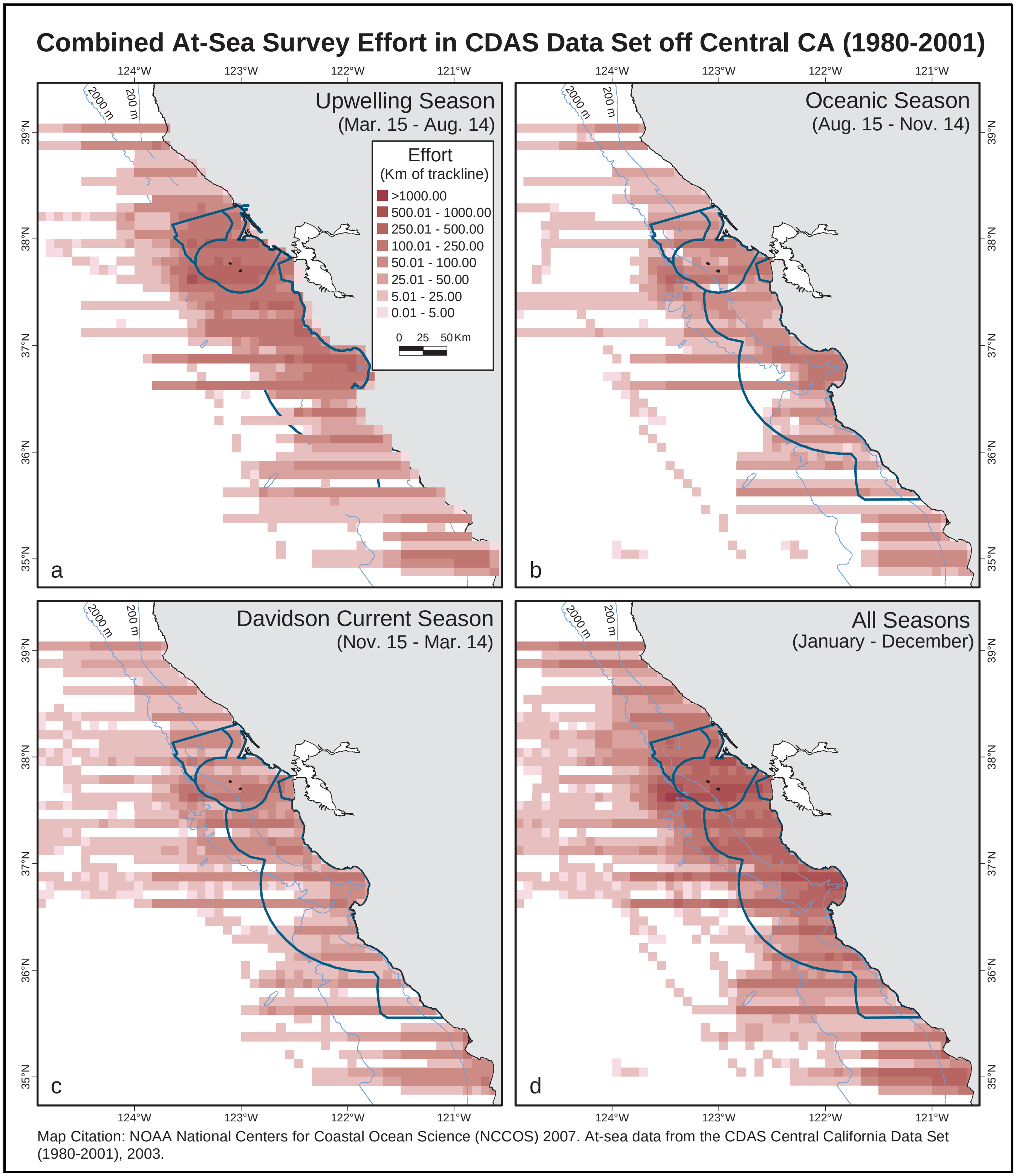


Figure 3.3. Total at-sea survey effort (shipboard and aerial) used for the marine bird analysis, CDAS data (1980-2001), 2003.

interpolated along the cruise track according to the time of each observation. The marine bird survey data from the ORCAWALE cruise were recorded continuously using automatic recording software and were processed like the aerial survey data.

Data Analysis

A variety of analytical methods were used to develop the analytical products for this study. Below are brief descriptions of the methods used in this assessment.

Effort. In these analyses it was important to know survey effort, whether or not birds were seen. Otherwise, true densities would be impossible to calculate, and it would not be possible to combine survey methods that used different survey strip widths or traveled at different speeds (thus covering different proportions of the ocean). The utility of aerial surveys is that they can provide a synoptic snapshot. However, owing to fast speed, species identifications were not as accurate (certain similar species were combined), very small species were sometimes missed, and no environmental data could be collected. Ship surveys could not provide a synoptic picture like aerial surveys.

The combined at-sea survey effort for birds included 133,705 km of trackline, involving 128,886 observations of 973,318 birds in the analyzed data set. Survey effort in CDAS is summarized by ocean season in Table 3.3 and Figure 3.3.

Organizing Data into Ocean Seasons. The effort and species data were organized and mapped into three distinct ocean seasons (Bolin and Abott, 1963): Upwelling, Oceanic, and Davidson Current, because ocean conditions differ distinctly among them and these seasons significantly influence the distribution and abundance of marine biotic patterns of the California Current (Ainley, 1976; Briggs *et al.,* 1987). As there is significant interannual variation in the actual initiation and termination of these ocean seasons, the following dates were used to define 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.

These ocean seasons were used to organize the data by the broad-scale oceanographic conditions that influence the distribution and abundance of marine species in the study area. Because the time periods used for the ocean seasons are of different lengths and because survey effort also varies geographically and by season, the bird density estimates of the various cells in the seasonal maps do not have identical variances. Density values are unbiased estimates, but the degree of certainty varies from cell to cell and from season to season. Combining data in this way allows the broad seasonal geographic patterns to be displayed.

Although the total at-sea data span the years from 1980 to 2001, data are not available for all seasons and all cells in all years. For the Upwelling Season, data were from 1980-1982 and 1985-2001. For the Oceanic Season, data were from 1980-1982, 1991, and 1994-2001. For the Davidson Current Season, data were from 1991-2001.

Estimating Density. To provide occurrence patterns of marine birds in the study area, density maps were developed using the CDAS central California data set (1980-2001), 2003. Densities (animals per square kilometer) were calculated by dividing the number of animals seen by the amount of area 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, which varied from 50 m for most aerial surveys to 300 m for most ship-based surveys; see Tables 3.2 and 3.3. Density estimates were calculated using the formula 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 survey area as a weighting factor.

Bird density was estimated using the standard formula:

$$D = n / (l \times w)$$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where D is density (birds per km^2), 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 strip.

Estimates of density were calculated using 5' latitude x 5' longitude cells. If blocks included results from multiple investigators or years, data were combined by using the area-weighted average from all sources. The density within a block was calculated as:

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

where k different studies are combined to calculate the density within a 5' block.

For density maps, if a cell was censused in other years or the same year by another survey, densities in the cells were averaged and weighted according to effort.

Seasonal Density Maps for Individual Species. Seasonal density maps were generated for 40 marine bird species. These maps were then analyzed and reviewed to characterize the spatial and seasonal density pattern of each species in the data set.

Seasonal High Use Areas for Individual Species. The purpose of the seasonal high use maps is to provide one map for each species (or group of species) that summarizes the species' spatial and temporal use patterns of the study area. To do this, seasonal density data from CDAS were binned into 10' latitude by 10' longitude cells for each species or species group. A seasonal high use index was developed, and it is based on the top 20% of sampled cells for a species within a given season. The index is therefore sensitive to cells that were not sampled in any one of the three seasons, causing a downward bias in the index. Use of a 10-minute block size greatly reduced the magnitude of this bias. Non-zero cells were then ranked and those in the top 20% were selected and defined as seasonal high use areas. Cells were then mapped with colors corresponding to the number of seasons of high use. Cells in which there was effort but birds were not observed, and cells where sightings occurred but were not high use areas, were also mapped with two additional colors.

Breeding Colonies and Roost Sites. The best available breeding colony data were mostly from Carter *et al.,* (1992), with updates from, Capitolo *et al.,* (2006); McChesney, unpubl. data; and others. Colonies were mapped for each species for which colony information was available, usually on the same map as the "seasonal high use" information. A map was also made of all marine bird colonies in the study area. In support of this Phase II product, a report and data set on selected colony counts for Common Murres, Brandt's Cormorant and Double-crested Cormorant was completed (Capitolo *et al.,* 2006), and information from that report is contained in this assessment. A general nesting area (rather than specific breeding locations) was provided for the Marbled Murrelet.

Roost sites for endangered California Brown Pelicans were provided by the California Department of Fish and Game, Office of Spill Prevention and Response (CDFG/OSPR), but the information is dated; these data are currently being updated.

A Tabular Summary of Spatial and Temporal Patterns of Birds at Sea. This analysis was done to provide a simple tabular summary (Table 3.5) of spatial and temporal associations of marine bird species with selected oceanographic and physiographic features of the study area. This table was developed through a visual inspection of the bird density maps. Density maps for 44 species were inspected to identify: 1) areas or physiographic features that exhibited relatively high or moderate densities; and 2) ocean seasons with relatively high or moderate densities. Using the two highest density categories, each species was "scored" over relatively large features (e.g., shelf, slope), as well as smaller, more discrete physiographic features (e.g., Monterey Canyon). Maps of selected physiographic features are included in the environmental settings chapter.

Summary/Community Metric Maps of Overall Density, Biomass and Diversity. Overall marine bird density was mapped for each season and for all seasons combined, using CDAS data for 76 marine bird species. Densities of all species in a cell were then converted to biomass by multiplying density for each species by its average body mass (from Dunning, 1993), and then summing for all species detected in that cell; see Appendix 2 for table of body masses used. Biomass was then mapped in a manner similar to the individual species' density maps.

The Shannon Index (Shannon and Weaver, 1949) was used to estimate species diversity in the study area.

$$H' = -\sum_{i=1}^{S}\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right]$$

The Shannon Index was selected as the diversity metric because it is widely used and accepted in community ecology, and because it incorporates both evenness and richness. For a given number of species (e.g., richness value), the diversity index has its greatest value when the proportion of each species is the same. Given two completely diverse or even communities, the one with the higher number of species has a greater diversity value. The Shannon Index has three desirable properties for a diversity index, noted below. Most diversity indices do not take these three qualities into account. For more information on diversity indices, see Pielou, 1975(7-18).

1. The diversity index is greatest when all species in the community are equally represented in numbers (e.g., evenness). Or, for a given number of species (e.g., richness), the diversity index should have its greatest value when the proportion of each species is the same.

2. Given two completely diverse or even communities, the one with the higher number of species has a greater diversity value.

3. The last property is difficult to summarize: this property takes into account the hierarchical nature, or "representativeness" in the biological classification of each species when estimating diversity.

In this analysis, diversity was calculated for each season and all seasons combined. All 76 marine bird species that had been recorded in the CDAS data set were included. To standardize for the variable effort among cells and variable strip width for species, density was used for each species in each cell as the basis for calculating the diversity index value. This mostly eliminates the effects of variable survey effort on the calculation of evenness. However, the estimated diversity for areas with lower sampling effort should be interpreted with caution; areas that are not well sampled may actually have higher diversities than estimated. Generally, the more survey effort there is for an area, the more likely there will be more species sighted and the area will have a higher diversity.

Species diversity is influenced by a wide variety of factors, including the actual, true diversity of species, with our perception of this affected by: the survey methods; the observer's skill; the amount of survey effort per area; the environmental conditions during the surveys; the combined survey data and its spatial and temporal coverage; and the diversity index used. Affecting the true diversity are factors such as: the temporal and spatial scales of food availability, season and migration patterns of species, and disturbance from human-caused factors. In any one location, the estimated diversity may range significantly based on any one of these factors. While this CDAS data set from 1980-2001 has several spatial and temporal gaps, it does combine a robust array of data from different sources and time periods, and thus might provide a better basis for diversity than any one of the individual data sets.

<u>Evaluating Variation in Species Abundance at Sea</u>. In order to evaluate factors that affect the abundance of marine birds in the study area, a regression model was developed (Seber, 1977; Kleinbaum *et al.,* 1988), with marine bird density as the dependent variable. Independent variables that could be addressed in the limited time frame included: ocean season, year, ocean depth, distance to nearest breeding colony, distance to shelf break (estimated to the 200 m isobath), distance to deep ocean (estimated to the 2,000 m isobath), latitude, periods of short-term ocean climate anomalies (e.g., El Niño or La Niña events), and latitude. The data used for the multiple regression analyses was a subset of the CDAS central California data set;

the regression data set included cell-based density data from 1985 – 2001 (6,641 cell samples, all with effort ≥ 0.24 km^2 per cell). To control for differences in survey effort among cells, regression analyses were weighted by km^2 of ocean area surveyed (effort) per cell. After deletion of cells with effort <0.25 km^2, these values ranged from 0.25 km^2 to 17.71 km^2.

Response to Variation in Marine Climate. Short-term ocean climate anomalies in this report are often referred to as ENSO (El Niño/Southern Oscillation), and generally pertain to the climatic events that cause significant interannual changes in thermocline depth and water temperature in the study area. Results from ENSO include: a warm-water period (often known as El Niño), a cold-water period (often known as La Niña), and a neutral period, when the water is neither unusually warm nor cold (Ainley *et al.,* 1995b and references therein). The official ENSO events and time periods tracked by NOAA characterize most closely regions to the far south and well outside of the study area, and thus the official NOAA ENSO periods do not accurately reflect the timing of the ENSO-related events that occur off north/central California. In part, there are lags in the progression of ENSO across the Pacific and the marine climate of the central and northern California Current region is also affected by variation in atmospheric pressure centers in the Gulf of Alaska.

Table 3.4. Assignment of warm, cold and neutral periods, based on surface water temperature off Central California.

Year	Davidson Current Season (11/15-3/14)	Upwelling Season (3/15-8/14)	Oceanic Season (8/15-11/14)
1975	Cold	Cold	Cold
1976	Cold	Cold	Warm
1977	Warm	Cold	Neutral
1978	Warm	Warm	Cold
1979	Cold	Neutral	Neutral
1980	Warm	Neutral	Cold
1981	Warm	Cold	Cold
1982	Neutral	Neutral	Neutral
1983	Warm	Warm	Warm
1984	Warm	Neutral	Neutral
1985	Cold	Warm	Cold
1986	Neutral	Neutral	Neutral
1987	Warm	Warm	Warm
1988	Neutral	Neutral	Cold
1989	Cold	Neutral	Neutral
1990	Cold	Cold	Neutral
1991	Cold	Cold	Neutral
1992	Warm	Warm	Warm
1993	Warm	Warm	Warm
1994	Warm	Neutral	Cold
1995	Neutral	Warm	Neutral
1996	Warm	Neutral	Cold
1997	Neutral	Neutral	Warm
1998	Warm	Warm	Cold
1999	Cold	Cold	Cold
2000	Cold	Cold	Cold
2001	Cold	Cold	-

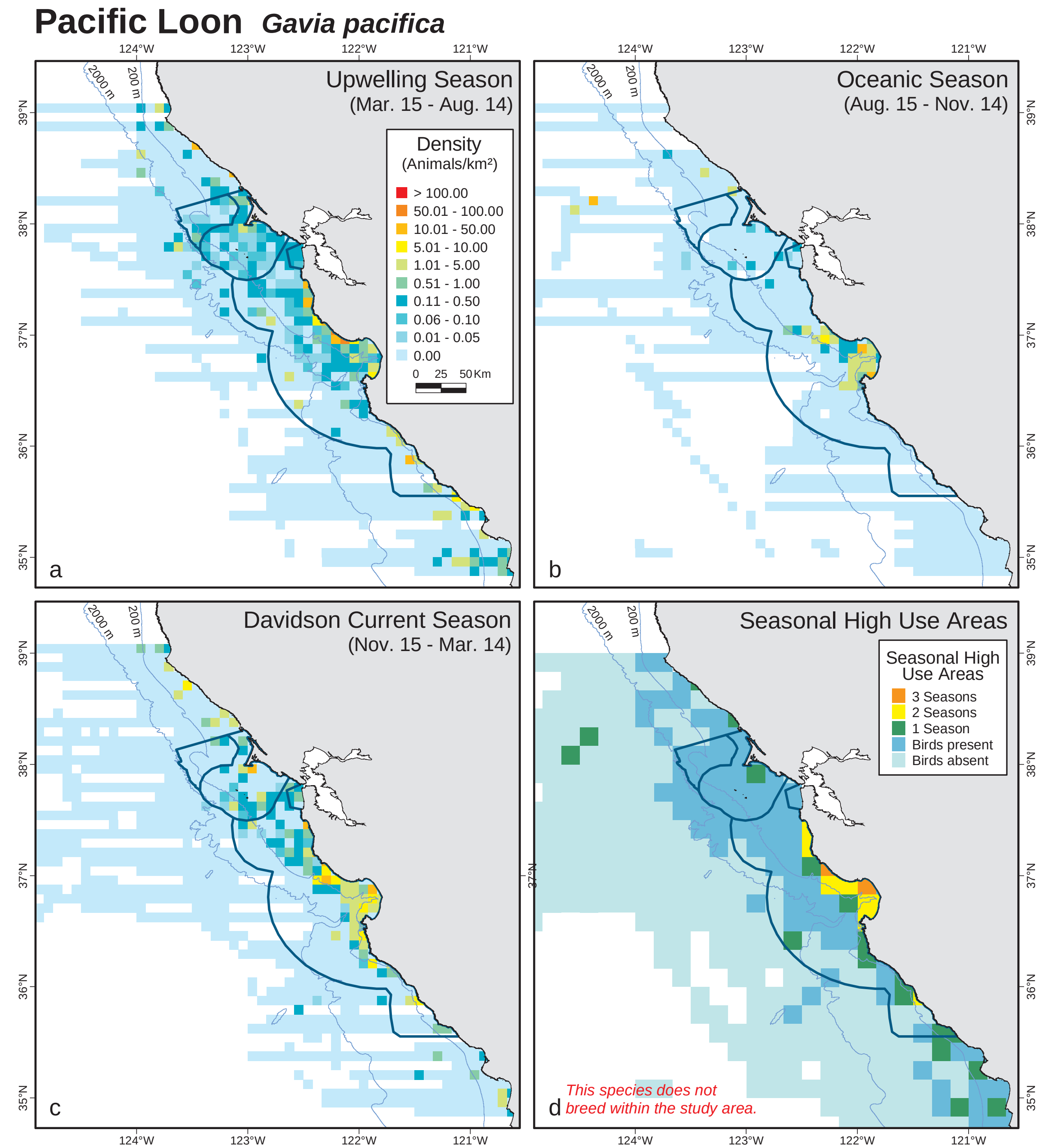
Note: Period of analysis ended in 2001.

To determine the time periods and effects of interannual climate anomalies on marine birds as evidenced in the study area (i.e., warm-water, cold-water and neutral periods), two sea-surface temperature data sets for central California were analyzed: daily temperatures taken as part of a Scripps Institution of Oceanography program at Southeast Farallon Island and the NOAA Coast Watch data off central California. Both data sets ranged from 1975-2001. Table 3.4 indicates the periods of unusual weather (warm water, cool water, and neutral) as determined from these data. Warm- and cold-periods had temperatures that were one standard deviation above or below, respectively, of the mean value for the study period.

Also affecting the marine climate are factors that operate on a decadal scale, such as the Pacific Decadal Oscillation (PDO; Mantua and Hare, 2002). In the PDO, the ocean-atmosphere oscillates between two states, a cool and warm phase (or regime). A shift in state apparently occurred in 1976, from cool to warm, and shifted again in the winter of 1998/1999, from warm to cool. The cool period (post 1999) however, inexplicably lasted only a few years before shifting back to a warm period. At this time (2007), no clear PDO phase has emerged. Other shorter-term variations, as noted above (e.g., ENSO), occur within these longer phases or regimes.

3.3 ANALYTICAL PRODUCTS

Analytical maps products include seasonal density and high-use area maps for 40 marine bird species. In addition, nine summary/community metric maps on marine birds are included, along with data tables that summarize various attributes of marine bird life history, management and distribution.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.4. Pacific Loon: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Pacific Loon (*Gavia pacifica*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Pacific Loons were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Pacific Loon is the most marine of the five loon species that occur in the north/central California study area, where it is common; in the CDAS data set (1980-2001), there were 1,172 sightings of 4,191 individuals. The other loon species, including the Common Loon (a California State "Species of Special Concern"), had 166 individuals observed in surveys in CDAS, mostly in bays and estuaries. Midway in the study period (1980s) the Arctic Loon species was "split" into: Arctic Loon (Asian form, *G. arctica*) and Pacific loon (w. North American form, *G. pacifica*). From that time, any Arctic loons seen in the study area, would be considered vagrants; only rarely has one ever been detected because they must be held in the hand to assess such characteristics as the color of the sheen to their plumage.

A multiple regression analysis of nine independent variables explained 10.6% of the variation in cell density of the Pacific Loon. The three most important variables were: season (most abundant during Davidson Current Season and least during Oceanic Season), distance to land (most abundant close to shore), and latitude (more abundant in the south); see Table 3.8. The average ocean depth where Pacific loons occurred was deep, 300 ± 29 m, and average distance from land was 13 ± 0.9 km from land. Pacific Loons within the study area occurred most often in the inshore waters of Monterey Bay, although they do occur throughout the nearshore waters of the study area. This is especially the case during the Davidson Current Season. The Farallon Escarpment was also important for migrants, for both the Upwelling and Davidson Current seasons. Thus, the marine sanctuary boundaries generally encompass the majority of the species "high use" habitat in the study area. Also, the species occurred in the study area in all three seasons. North and south of the sanctuaries, Pacific Loons were sporadic in occurrence, owing to the narrow continental shelf in those areas. Abundance of this species has remained stable between 1985 and 2002.

Pacific Loon is a deep diver that presumably feeds mainly on fish; no study of it's foraging in marine waters of the West Coast has ever been conducted. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

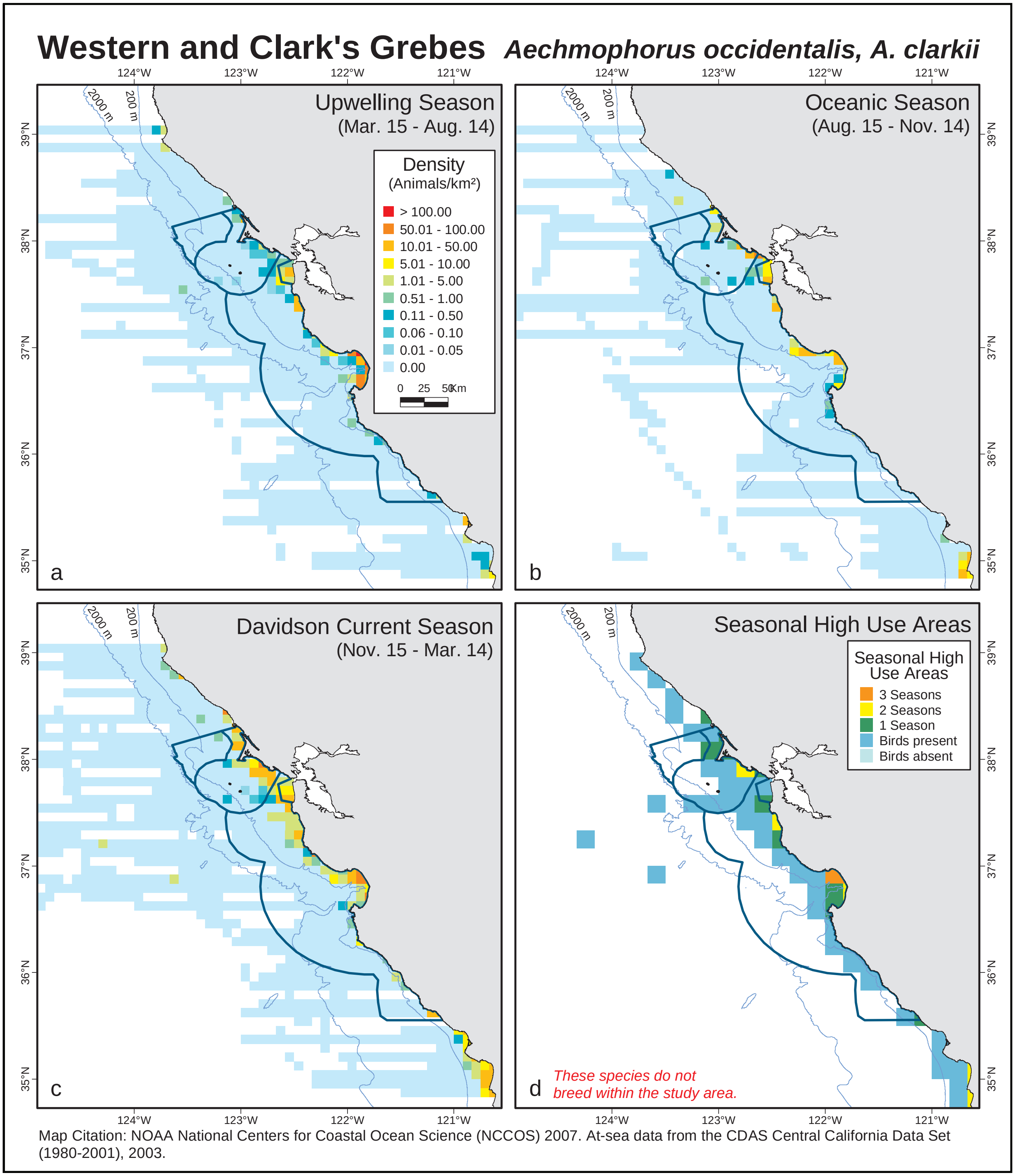


Figure 3.5. Western and Clark's Grebes: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the combined at-sea densities (birds/km^2) of Western Grebe (*Aechmophorus occidentalis*) and Clark's Grebe (*A. clarkii*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Western or Clark's grebes were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

Individuals of Western and Clark's grebes are separable by plumage, but share the same ecological niche; they are abundant in the nearshore waters of the study area. Surveys in CDAS tallied 2,511 sightings of 13,526 individuals. During most oil spills in this region, these species have been near the top of the list, by number, of oiled birds. These birds breed inland at freshwater lakes and marshes (e.g., Clear Lake, Lake County; reservoirs in Santa Clara County).

A multiple regression model of nine independent variables explained 15.5% of variation in cell density; most important variables were season, and an inverse relationship with distance to land and to depth; see Table 3.8. These results reflect the large number of grebes occurring primarily during the Oceanic Season, in shallow waters (mean depth 42 ± 11 m), and within a few kilometers of shore (mean distance to land 7.4 ± 1 km). Moderate numbers are present during the Upwelling and Davidson Current seasons. During the latter, these grebes expanded farther offshore to the middle continental shelf (mean depth of occurrence 79 ± 24 m), mainly in association with the San Francisco Bay tidal plume.

Inshore waters of the Gulf of the Farallones (tidal plume area), Monterey Bay, and Estero/San Luis Obispo bays had particularly high concentrations of these birds. North and south of National Marine Sanctuary boundaries in the study area, these species were observed mostly at isolated river mouths. Therefore, the sanctuary boundaries encompass the majority of the species' habitat in the study area, except for the 'sanctuary exclusion area', off San Francisco and Pacifica, which contained many grebes. The broad continental shelf off central California is ideal for these grebes, which capture prey by diving; it is likely they are capable of exploiting most of the water column lying over the shelf, in spite of their inshore occurrence. Abundance of this species-pair remained stable between 1985 and 2002.

These grebes feed mainly on fish, such as surf-perch, anchovy, smelt and herring, which are also abundant in these shallow, nearshore waters. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

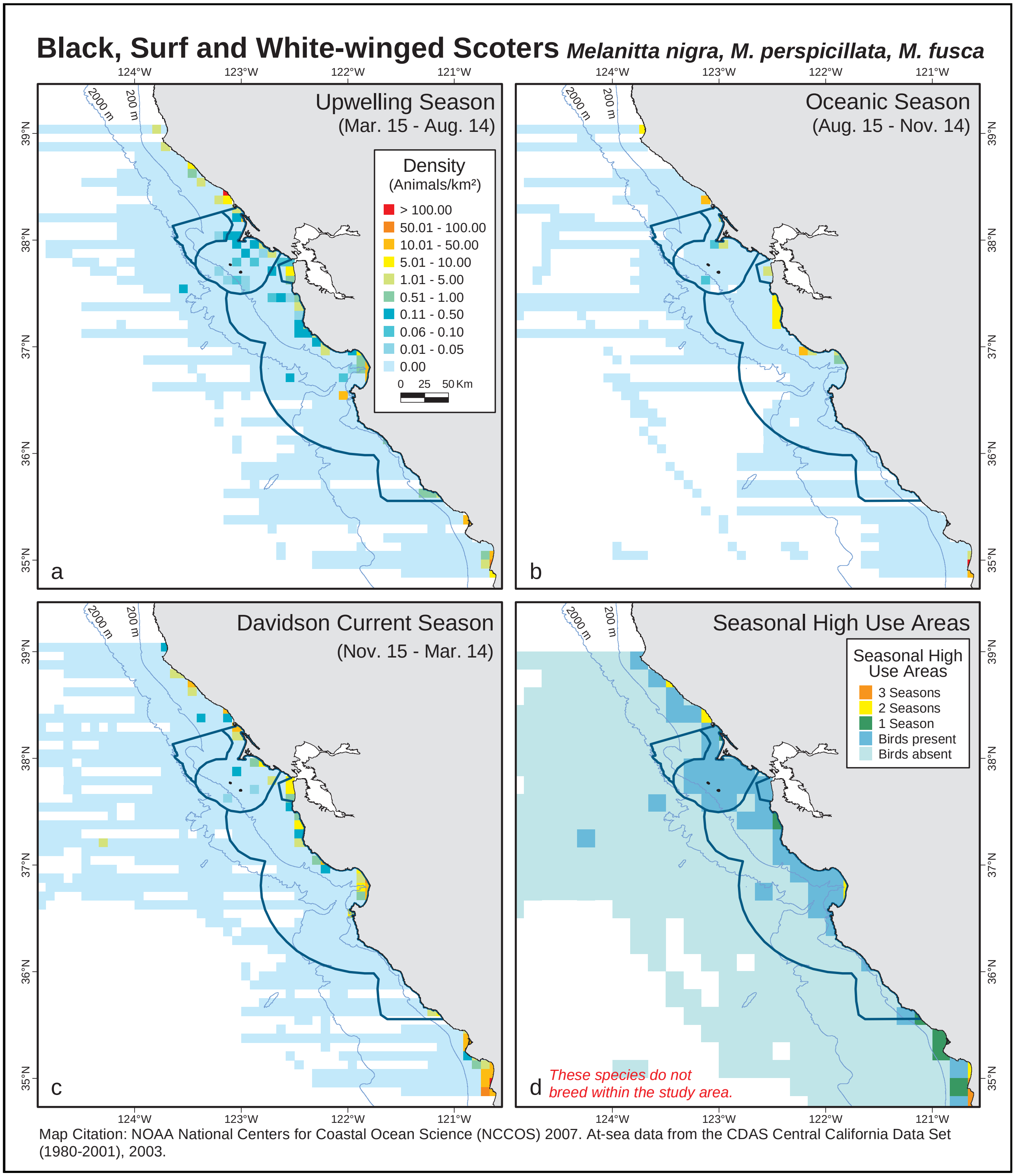


Figure 3.6. Black, Surf and White-winged Scoters: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the combined at-sea densities (birds/km^2) of Surf Scoter, White-winged Scoter and Black Scoter (*Melanitta perspicillata, M. fusca,* and *M. nigra*, respectively) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no scoter species were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

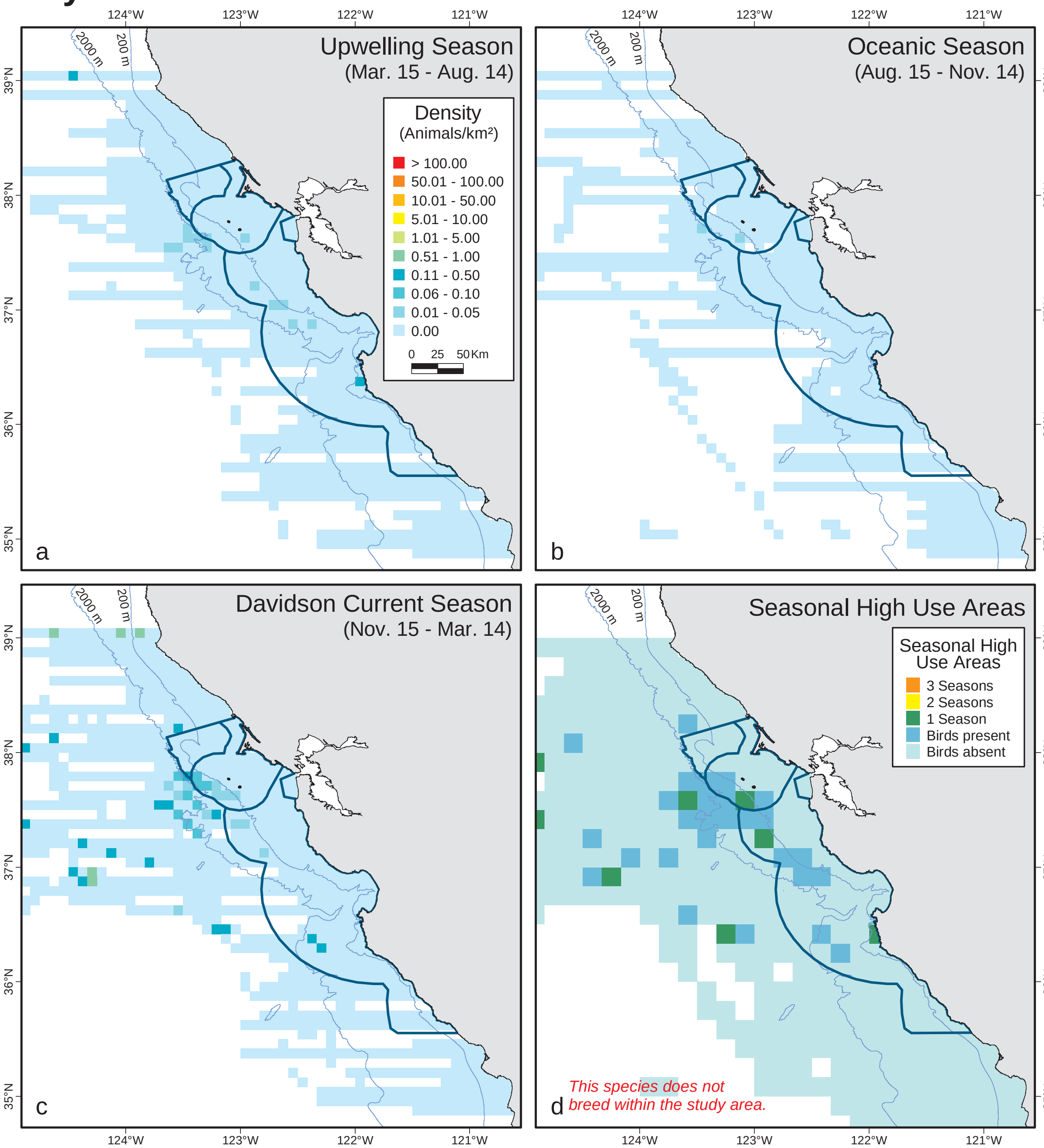
The distribution of White-winged, Surf and Black scoters in the north/central California study area is very similar to that of the grebes although the scoters are somewhat less abundant and more restricted closer to shore. There, scoters forage mostly just outside the surf break. On the outer coast, the abundant Surf Scoter dominates over the other two scoters, and Black Scoters, which occur in more protected waters, are rare. Surveys in CDAS recorded 1,787 sightings of scoters that included 42,691 individuals; more than half were identified as Surf Scoter. Scoters occurred in the study area during all three ocean seasons.

The most important areas for Surf Scoters within the study area were the San Francisco Bay tidal plume, especially southward along the Pacifica shore to Half Moon Bay, and the shallow parts of Bodega, Monterey, Estero and San Luis Obispo bays. These birds nest on the Arctic tundra along the north slope of North America; specific nesting areas of birds found wintering in or adjacent to the marine sanctuary boundaries have not been identified. The San Francisco Bay area has a large wintering population of surf scoters.

The apparent movement of these sea ducks offshore, i.e. to the outer parts of the Gulf of the Farallones, in the Upwelling Season is an artifact of their migration north or south, to or from Alaskan breeding areas. That portion of the population wintering south of central California takes the shortest distance across the Gulf of the Farallones; the offshore density cells highlighted in the maps is a record of flying scoters.

These birds do not forage far from the mainland beach, where they eat invertebrates; several dozen usually winter around the Farallon Islands. The inshore distribution of these ducks, like the grebes, makes them vulnerable to coastal oil spills. See Tables 3.5 and 3.11 for related summary information.

Laysan Albatross *Phoebastria immutabilis*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.7. Laysan Albatross: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Laysan Albatross (*Phoebastria immutabilis*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Laysan Albatross were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3J that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Laysan Albatross nests in the Hawaiian Islands, and on other islands in the central Pacific Ocean; small, growing colonies were recently found off Mexico. In the study area, where it qualifies as being rare (90 sightings of 97 individuals in the CDAS data set), it occurs regularly in waters over the continental slope and deeper depths (mean depth was 2,376 m). Average distance from shore of the sightings was 71.3 km. Therefore, it occurs over deeper waters than the black-footed albatross. A multiple regression model of nine independent variables explained 6.9% of the variation in cell density; see Table 3.8. Important variables were a positive relationship to ocean depth, and inverse ones to distance to land, and year.

The Laysan Albatross concentrates along the continental slope off central California and was most abundant during the Davidson Current Season. Abundance in the study area has increased slightly between 1985 and 2002, perhaps reflecting the factors, unknown, that also have led to recent colonization of west coast islands (off Mexico).

Albatrosses are generalists that feed on anything (squid are important prey, but other live or dead prey found at the surface are taken). See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

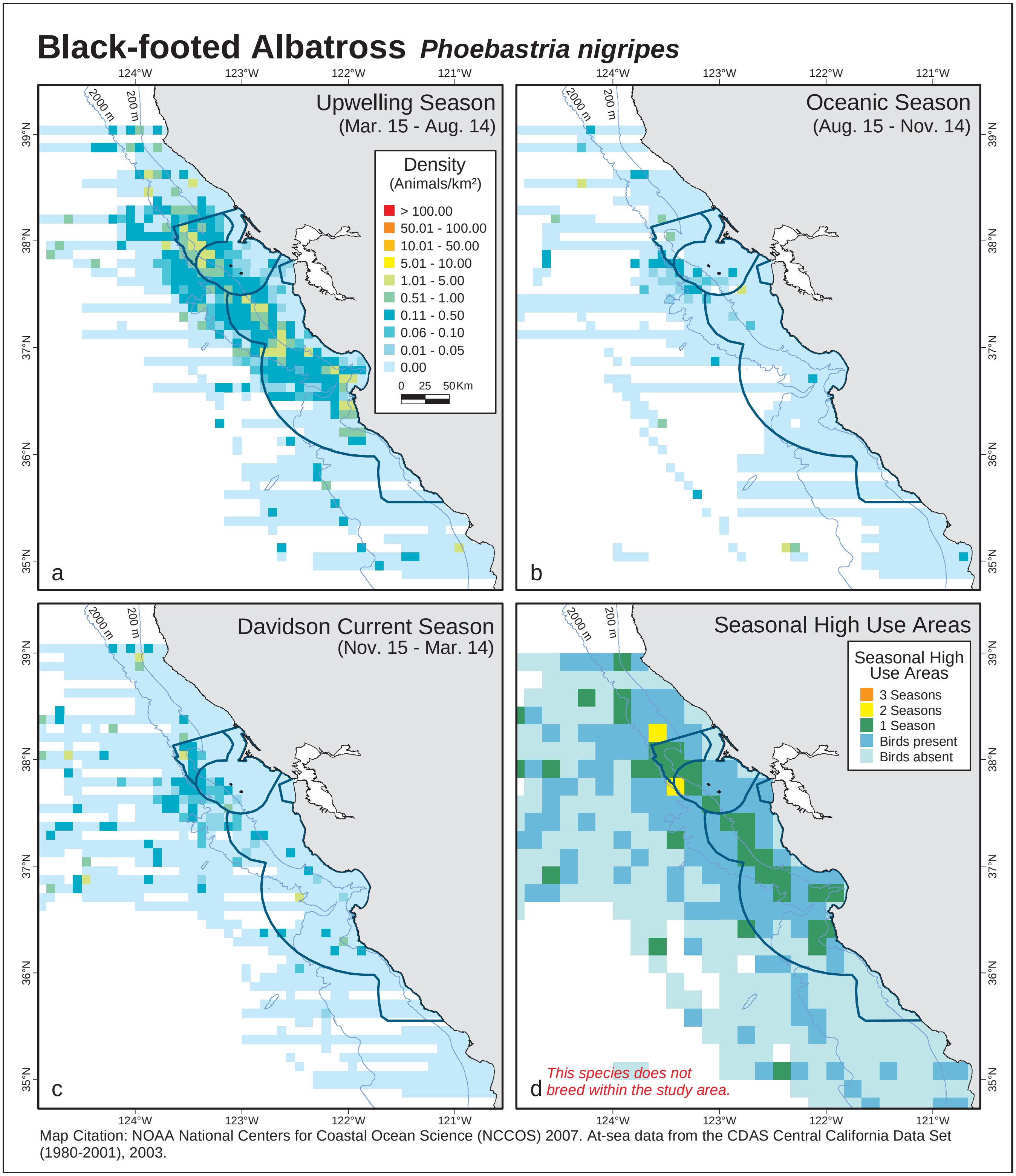


Figure 3.8. Black-footed Albatross: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km²) of Black-footed Albatross (*Phoebastria nigripes*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Black-footed Albatrosses were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3H that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

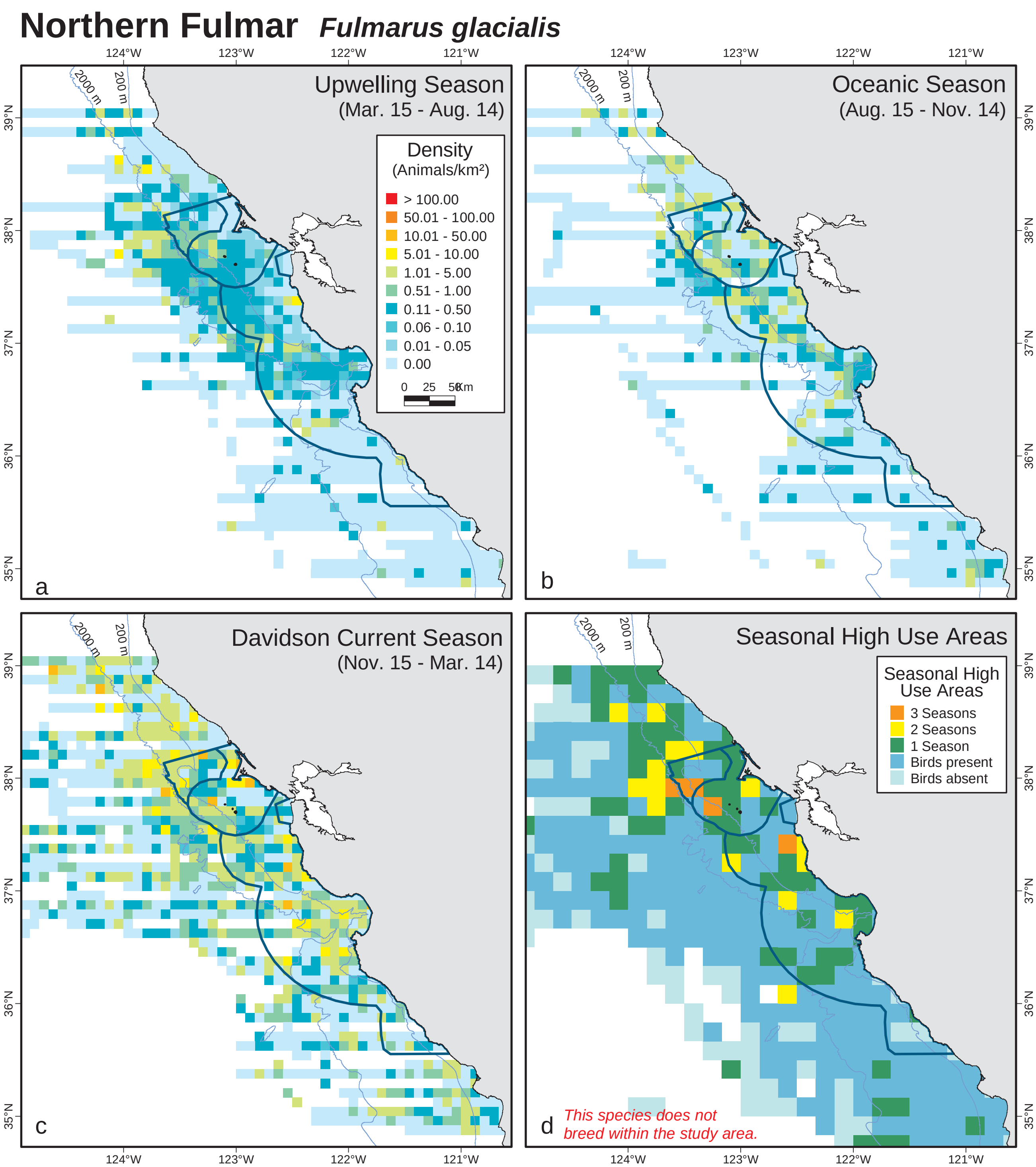
RESULTS AND DISCUSSION

The Black-footed Albatross is common off central California although it nests in the Hawaiian Islands. Surveys in CDAS logged 2,584 sightings of 3,570 individuals. A multiple regression model of nine independent variables explained 22.2% of the variation in cell density. Important variables were: a positive relationship to ocean depth, and inverse relationships for distance to land, and for year. Occurring mainly west of the outer shelf, this albatross was more abundant as depth increased, although it was found in waters over relatively shallower depths during the Upwelling Season (mean depth 955 m) compared to >2,000 m during the remainder of the year. Mean distance from shore was also much closer during the Upwelling Season (28.6 km) compared to >67 km during other seasons. Population size in the study area decreased as the years advanced from 1985 through 2002, although a slight increase occurred during the last few years of cooler water (see discussion of climate shifts toward end of chapter). Eight maps are provided for this species, four of which have a western extent to show the full offshore extent of the data for this species. The species occurred in all three National Marine Sanctuaries in the study area, and in all three ocean seasons.

Areas of highest density, most within the boundaries of the north/central California National Marine Sanctuaries, were Cordell Bank, the outer portions of Fanny Shoal and Farallon Escarpment, as well as these canyons: Pioneer, Ascension and Monterey. These are commercial fishing areas as well, as this species is especially attracted to fish offal and by-catch left by trawlers. This attraction explains the "trail" of albatross (relatively higher cell density) that extends across the Gulf of the Farallones to the Golden Gate, and across inner Monterey Bay to the important fishing port of Moss Landing; these birds were following fishing vessels. Recent fishery closures for demersal fish species along the U.S. west coast has likely affected the occurrence patterns of this species, with a corresponding decrease in numbers or density of albatross visiting these waters, i.e., they would be more dispersed than when the fishing activity was greater.

Albatrosses are generalists that feed on almost anything (any live or dead prey at the surface) of edible size. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.


Sophie Webb



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.9. Northern Fulmar: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/ km^2) of Northern Fulmar (*Fulmarus glacialis*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Northern Fulmars were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3G that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

Northern Fulmar, which nests on islands in the Aleutian Island chain and Bering Sea, is common in waters over the continental slope, as well as the outer waters of the continental shelf off north/central California. The species also occurs well offshore, as demonstrated in Appendix 3G, showing a greater western extent. Surveys in CDAS (1980-2001) recorded 4,486 sightings of 6,345 individuals. In some winters, fulmars were particularly abundant, such as in 1986, 1991, 1996 and 1999.

A multiple regression analysis of nine independent variables explained 21.3% of the variability of this species' cell density. Important explanatory variables were: season, ENSO and year (see Table 3.8). The species' occurrence was greatest during the Davidson Current Season, but it occurred during all three seasons. The species was especially prevalent during La Niña. For a subarctic species, surprisingly high densities are present during the Upwelling Season, when breeding should be underway far to the north; many of these individuals exhibit heavy molt indicating that they might be juveniles.

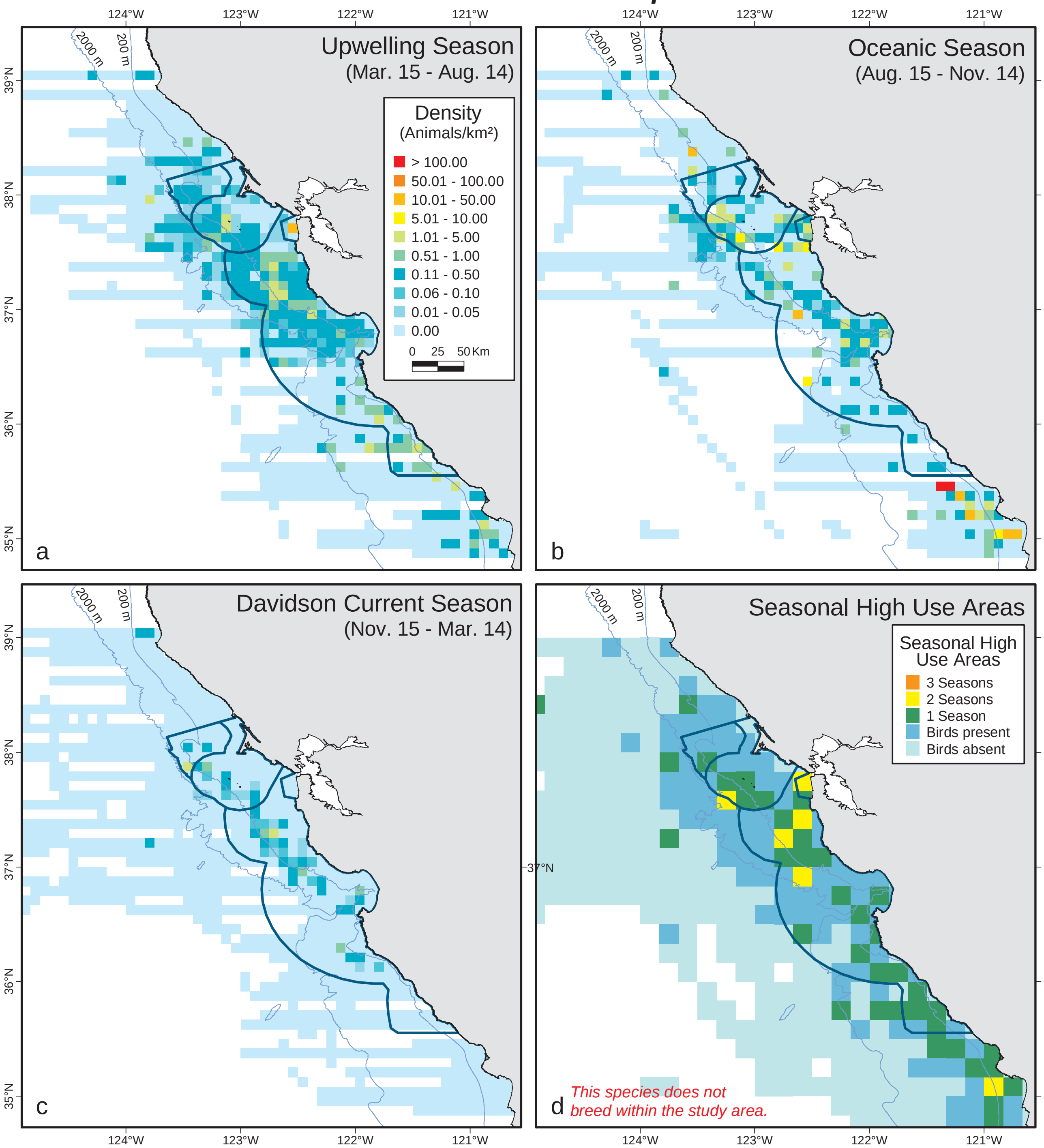
The species' population trajectory during the study period exhibited a curvilinear pattern: a slight decline between 1985 and 1989, followed by an increase from 1990 to 2002. Numbers rose particularly in the last few years (2000-2002), perhaps in response to a shift from a warm to a cool ocean period (see section on response to climate change).

Like the albatrosses, this species is attracted to trawlers, where the species scavenges offal. Therefore, areas of concentration for Northern Fulmars during the study period were (and may still be) important areas of traditionally higher fishing activity, such as Cordell Bank, Fanny Shoal, and nearby canyons. This pattern is better illustrated during the Upwelling Season, when the species is much less abundant. In that season, the species spreads to visit various widely spaced hotspots; see Table 3.5. Although fulmars are widespread off central California, the boundaries of the National Marine Sanctuaries encompass an important area for this species.

Northern Fulmars are generalists that feed on live and dead prey found at the surface. They are one of the few marine species that feed extensively on gelatinous zooplankton, e.g., jellyfish. See Tables 3.5 - 3.11 for related summary information.

Sophie Webb

Pink-footed Shearwater *Puffinus creatopus*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.10. Pink-footed Shearwater: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Pink-footed Shearwater (*Puffinus creatopus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Pink-footed Shearwaters were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

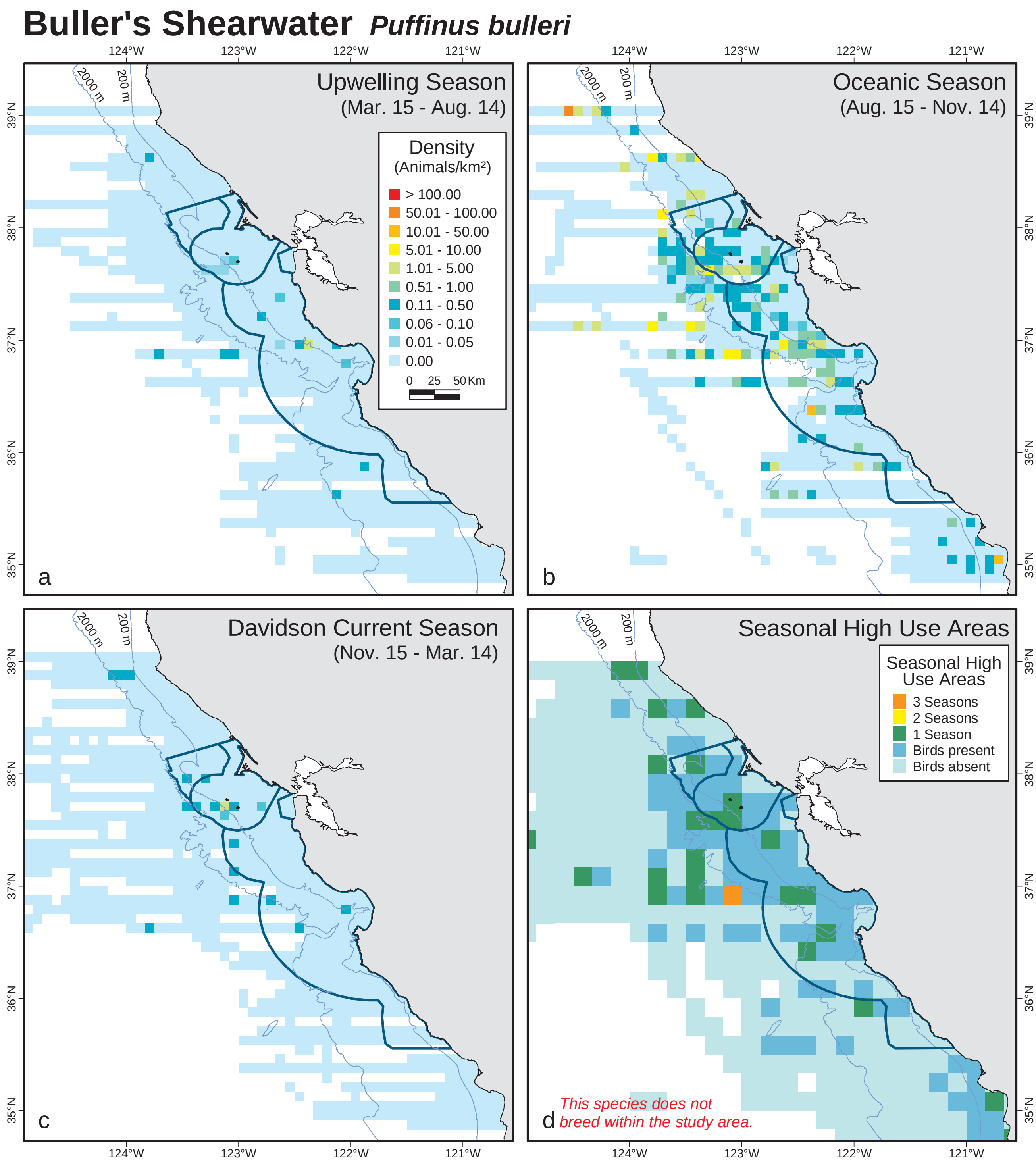
The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Pink-footed Shearwater occurs commonly in the study area. Surveys in CDAS (1980-2001) tallied 1,842 sightings of 4,553 individuals. A multiple regression model of nine independent variables explained 13.1% of the variation in its density. Important variables were season and inverse relationships with ocean depth and distance to land; see Table 3.8. Pink-footed Shearwater occurred in the study area during all three ocean seasons.

The Pink-footed and Sooty Shearwaters differed in their seasonal spatial occurrence patterns. When the two species overlapped in time (though the Pink-footed was most abundant during the Oceanic Season), the Pink-footed occurred over deeper waters (mean depth 725 ± 25 m). Competition between the two species may be a factor that explains these differences. This is best illustrated by the Pink-footed Shearwater's low relative densities in inner Monterey Bay, where there are deep waters but where the Sooty Shearwater is especially abundant. Like the Sooty Shearwater, abundance of the Pink-footed shearwater has decreased in the study area between 1985 and 2002.

Pink-footed Shearwaters feed on fishes, squid and invertebrates that they acquire by pursuit plunging to a depth of 5-10 m. Often they feed in association with albacore (*Thunnus albacares*). See Tables 3.5, 3.9, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.11. Buller's Shearwater: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Buller's Shearwater (*Puffinus bulleri*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Buller's Shearwaters were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3F that include a greater western extent.

DATA SOURCES AND METHODS

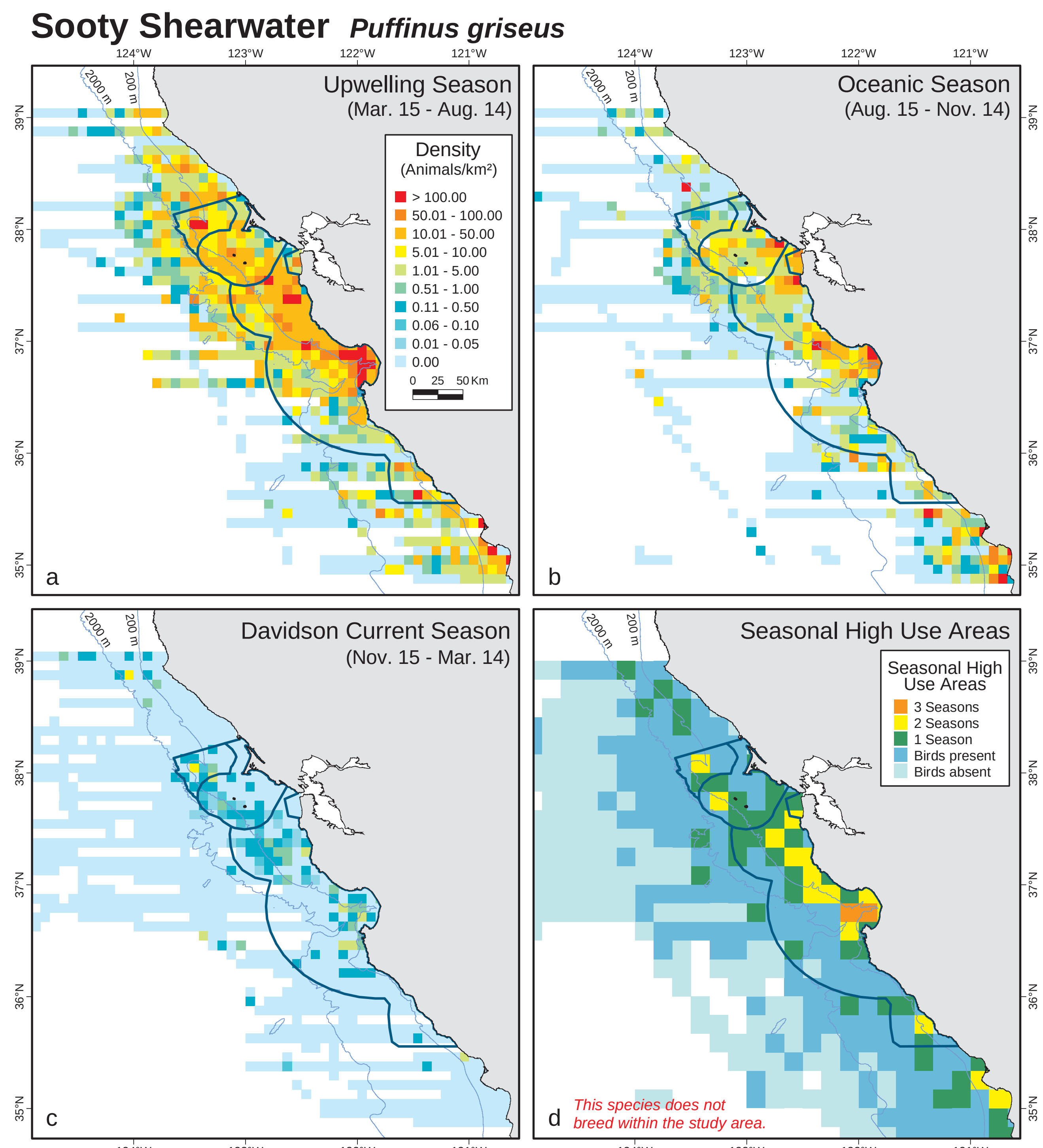
The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Buller's Shearwater is a common species in the study area and reaches its greatest abundance, by far, in waters of the National Marine Sanctuaries, during the Oceanic Season. However, the species did occur in the study area in all three ocean seasons. Surveys in CDAS recorded 601 sightings of 2,804 individuals. This species breeds on islands in the subtropical waters off the North Island of New Zealand. Compared to other shearwaters that occur in the study area, it occurs farther offshore, over the continental slope and beyond.

Insufficient data were available to conduct a regression analysis to indicate habitat features of importance to this species. However, it is attracted to prey that have been forced to the surface by schools of albacore tuna (*Thunnus albacares*). The extent to which the tuna occur near the continental shelf varies from year to year (a function of water temperature), and so does the presence of Buller's Shearwater. Their occurrence was too irregular from year to year for any long-term trends in population numbers to be evident.

Buller's Shearwaters feed mostly on fish (particularly saury) and squid by pursuit plunging and aerial pursuit. Likely they can forage in the subsurface, probably to depths of 10 m. See Tables 3.5, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.12. Sooty Shearwater: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Sooty Shearwater (*Puffinus griseus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no

Sooty Shearwaters were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas not surveyed appear white; no information was available for these areas. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3E that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods

RESULTS AND DISCUSSION

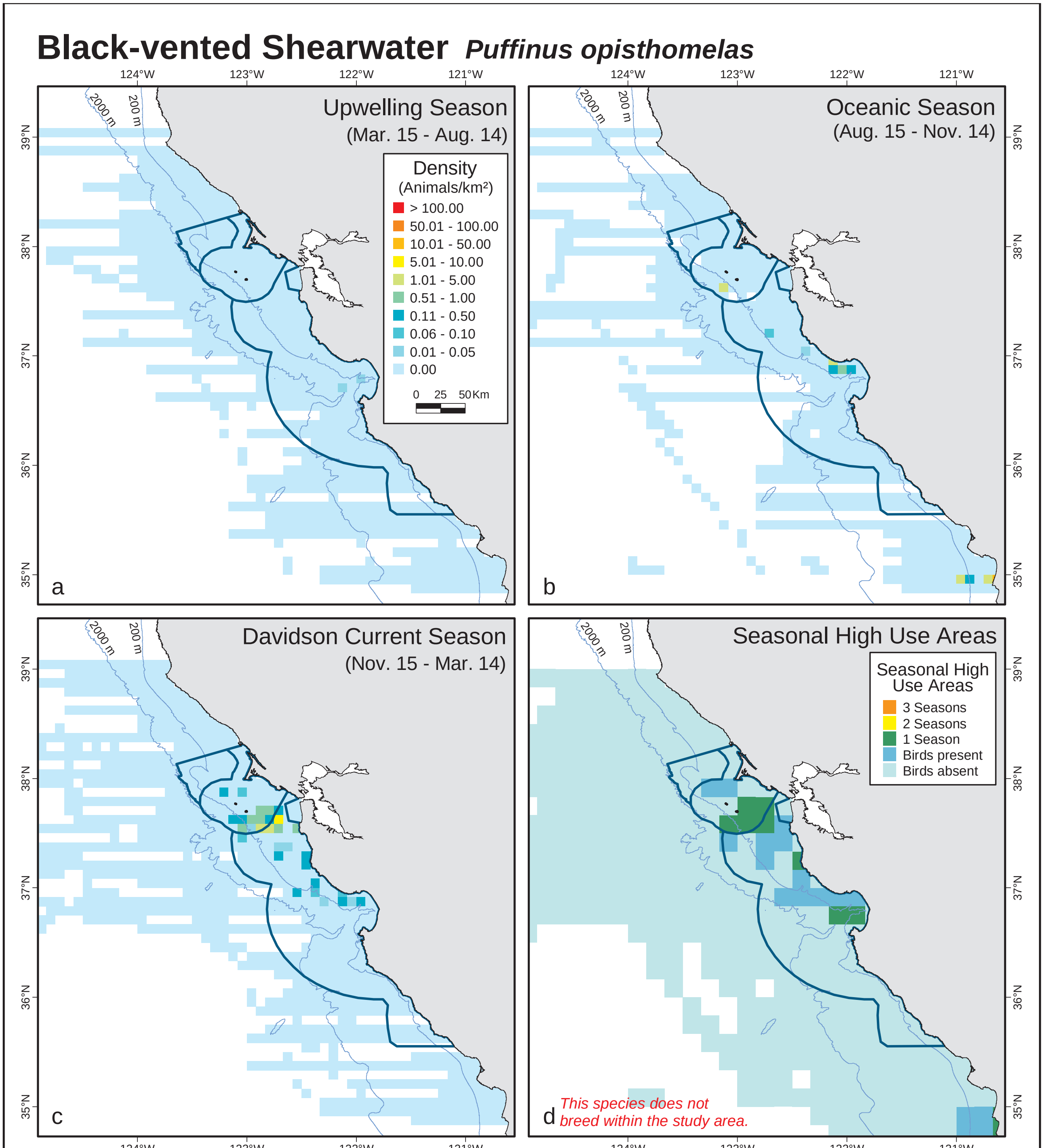
Sooty Shearwaters nest in the sub-Antarctic, particularly on islands of Tierra del Fuego and New Zealand, and winter in the regions of the Peruvian Current and California Current. During the Upwelling Season, the Sooty Shearwater is the most abundant marine bird off California, and this is the case, by far, for waters within the boundaries of the north/central California National Marine Sanctuaries. Surveys in CDAS tallied 20,750 sightings of 323,176 individuals, indicating that the species usually occurs in large concentrations.

A multiple regression analysis of nine independent variables in the CDAS data set explained 43.3% of the variation in cell density, with: 1) season, 2) an inverse relationship to year, and 3) ENSO being the three most important variables; see Table 3.8. These results further reflect the restriction of this species' occurrence off California largely to the Upwelling Season, and to greater abundance when the ocean climate is unaffected by short-term climate anomalies. In other words, Sooty Shearwaters were less abundant in the study area during both El Niño and La Niña. From a decadal perspective they declined over the years, although this effect was curvilinear: a slight increase between 1985 and 1991, a steep decline to 1998, and a moderate increase subsequently to 2002, when ocean temperatures cooled and productivity increased. Whether or not the latter increase is a response to the shift to cool ocean temperatures from 1999-2002 remains to be seen. The continental shelf and upper slope are the main habitats frequented by this species (mean ocean depth where Sooty Shearwaters occurred in the CDAS data set was 380 ± 10 m). Sooty Shearwaters occurred in the study area during all three seasons.

In the CDAS data set, the Sooty Shearwater was present in greatest densities in Monterey Bay. Throughout the California Current (Veit *et al.,* 1997), this species has declined severely in abundance during the recent warm regime (1976-1999), as noted above. Even now, though, it is still very abundant in Monterey Bay, probably because of the large anchovy source there (on which it feeds). Other important areas (but not comparable to Monterey Bay), include Pioneer and Ascension canyons, Farallon Escarpment and Fanny Shoal, as well as the ocean area off Pacifica and Estero/San Luis Obispo bays. National Marine Sanctuary waters become even more important to this species during the Oceanic Season, as remnants of the population, just before their long southward migration, fatten on the oil-rich anchovies.

Sooty Shearwaters feed on fish, squid, and euphausiids acquired by pursuit plunging to a depth of 10-15 m. During the early Upwelling Season their main prey are euphausiids and squid, a diet that shifts more to oily fish, such as anchovy, in the late Upwelling Season. See Tables 3.5 - 3.11 for related summary information.

Sophie Webb



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.13. Black-vented Shearwater: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Black-vented Shearwater (*Puffinus opisthemelas*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5’ latitude by 5’ longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Black-vented Shearwaters were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species’ spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10’ latitude by 10’ longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

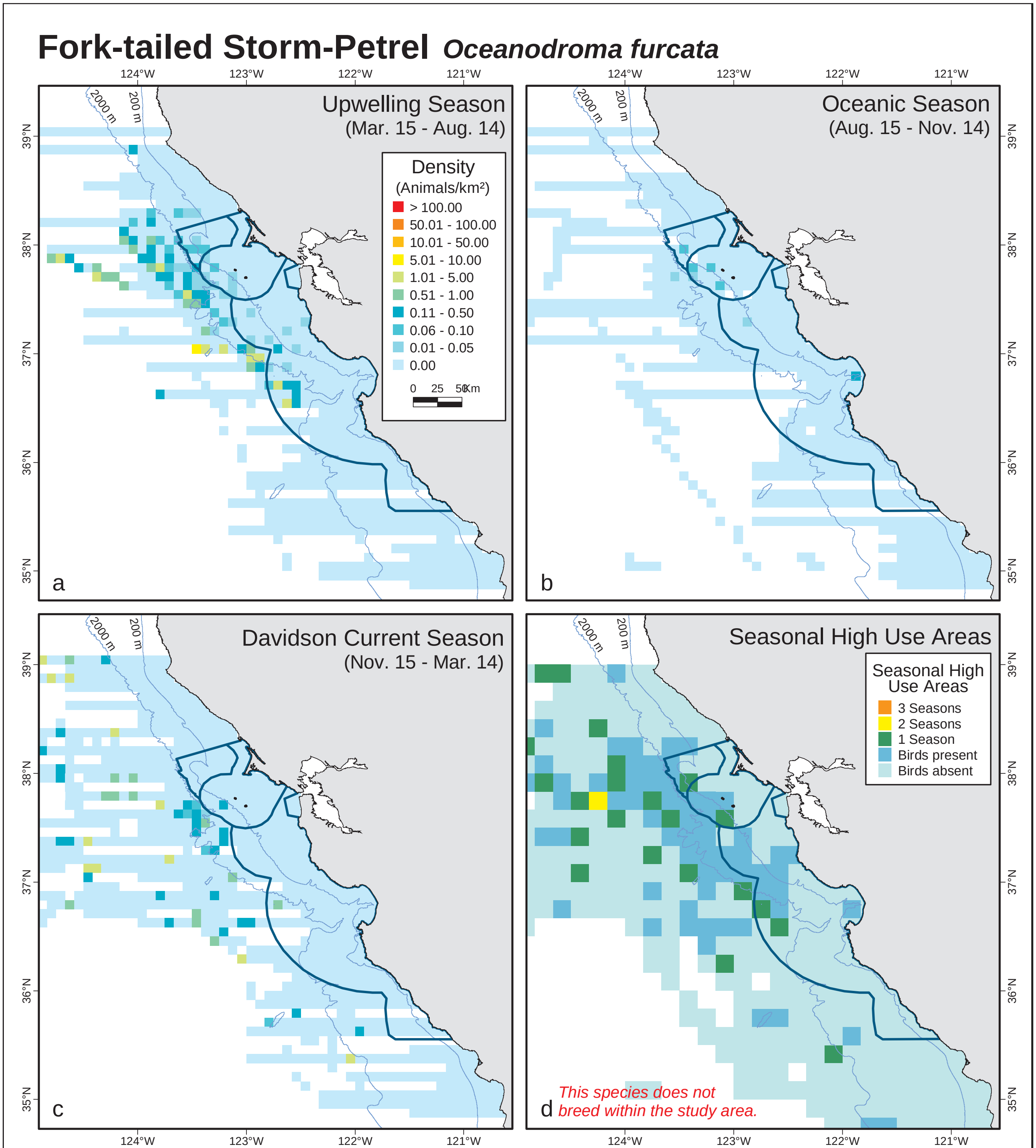
DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods

RESULTS AND DISCUSSION

The Black-vented Shearwater occurs uncommonly in the study area principally during the Davidson Current Season and mainly during years of unusually warm-water temperatures (e.g., El Niño periods). Surveys in CDAS recorded 160 sightings of 1,752 individuals. Such low numbers precluded the use of a regression analysis to determine important habitat variables. The species was completely absent during the Upwelling Season, when the population is frequenting waters off its nesting islands in Mexico (Baja California). Almost all sightings during the Oceanic Season off central California, especially north of Monterey Bay, occurred during El Niño periods in 1994 and 1997. The sightings for this species in the study area occurred mostly over the continental shelf, within the bounds of the National Marine Sanctuaries. Although not reflected in the CDAS data, Black-vented Shearwaters do occur in all three National Marine Sanctuaries off north/central California.

Black-vented Shearwaters feed mostly on fish that they capture by pursuit plunging to shallow depths. See Tables 3.5, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.14. Fork-tailed Storm-Petrel: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Fork-tailed Storm-Petrel (*Oceanodrama furcata*) in three ocean seasons - Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Fork-tailed Storm-petrels were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3B that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

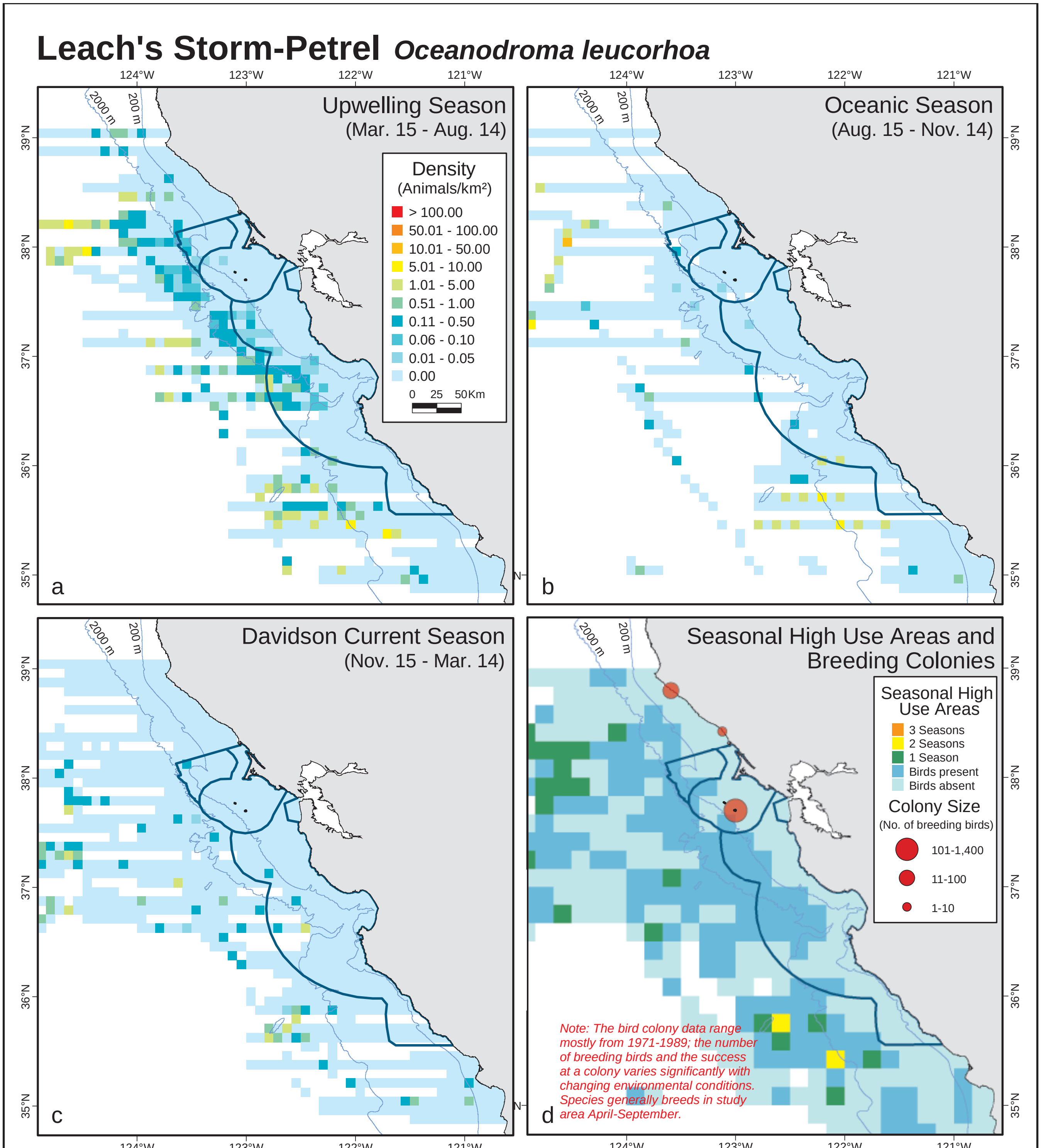
RESULTS AND DISCUSSION

The Fork-tailed Storm-Petrel is uncommon in the study area and is on California's "Species of Special Concern" list (McChesney *et al.,* in press a); the species was infrequent in the study area until the cool water period of 1999-2002. Surveys in CDAS recorded 326 sightings of 674 individuals.

Fork-tailed Storm-Petrels typically occupied waters over the outer continental slope and beyond (mean depth water 2,509 ± 78 m); thus, only very low densities occurred within the National Marine Sanctuary boundaries. The Farallon Escarpment was an important area of concentration. A multiple regression model of nine independent variables explained only 9.2% of the variation in cell density, and the top three variables for this species were ENSO period, season and ocean depth; see Table 3.8. These results reflect this species' peak abundances during La Niña, when an influx of this species into central California occurred. In the study area, densities were highest in 1985, 1991, 1995-96, and 1999, with all but 1995-96 being years of La Niña.

Looking at the longer-term trends, there appeared to be an increase in abundance toward the end of the study period in conjunction with a cold-water period (1999-2002), and a seasonal component was also apparent in this. Specifically, during the warm-water period of 1976-1998, this species was more abundant during the Davidson Current Season, but thereafter, the abundance peak shifted to the Upwelling Season. Overall, the species was most concentrated during the Upwelling Season, and occurred within the study area in all three ocean seasons.

Fork-tailed Storm-Petrels feed on invertebrates and larval fish found at the surface. See Tables 3.5, 3.8, 3.8, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from Ainley and Lewis (1974) and Carter et al. (1992).

Figure 3.15. Leach's Storm-Petrel: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Leach's Storm-Petrel (*Oceanodroma leucorhoa*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Leach's Storm-Petrels were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3A that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods

Data on colony sizes are dated and were obtained from Ainley and Lewis (1974), Sowls *et al.,* (1980) and Carter *et al.,* (1992).

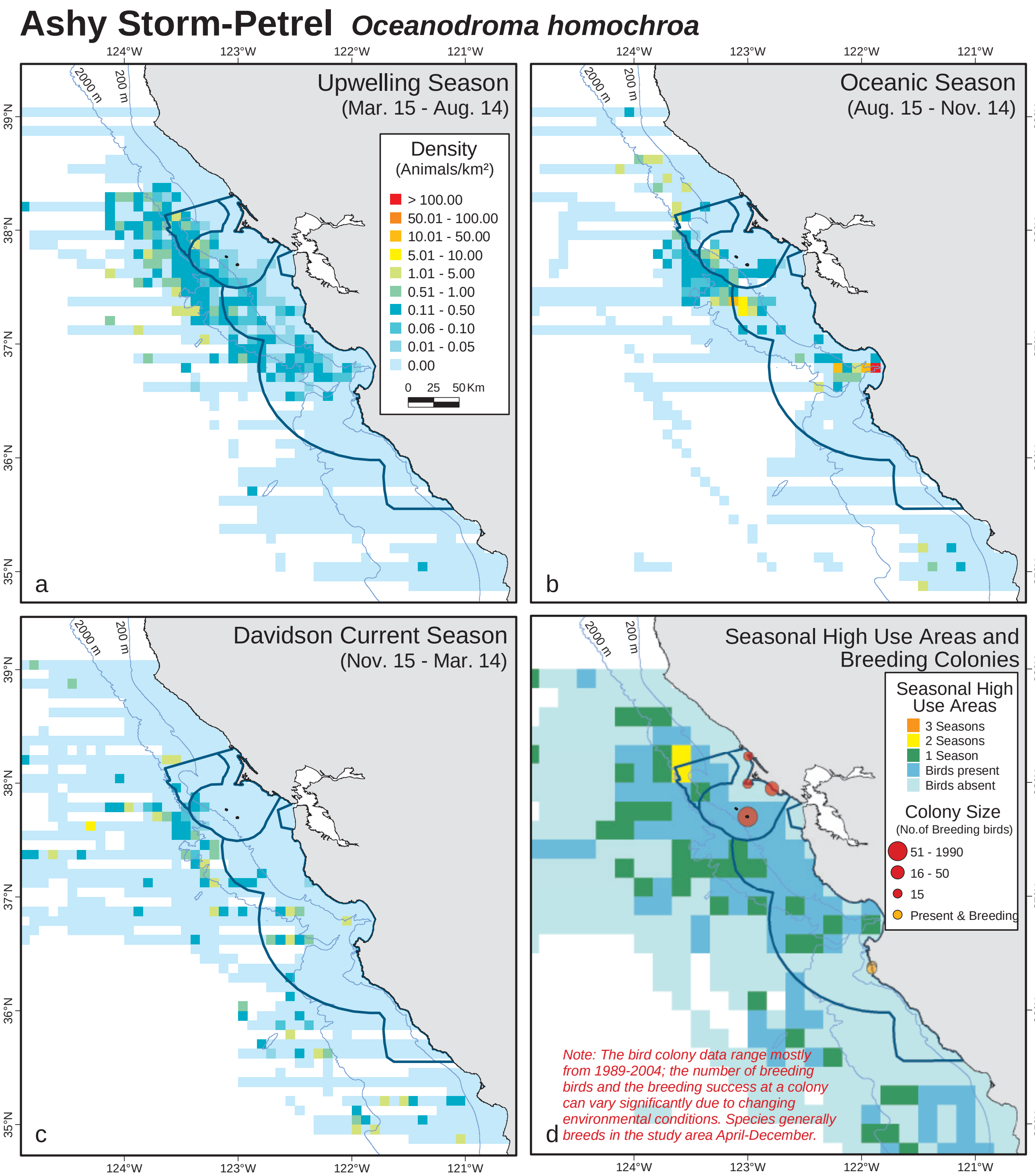
RESULTS AND DISCUSSION

The Leach's Storm-Petrel has a breeding population numbering in the millions among islands ringing the northern North Pacific; this species nests south to Baja California in the eastern Pacific (Carter *et al.,* 1992). In comparison, the estimated 12,551 birds breeding at sites along the California coast is small. This low number relative to its Pacific population, and the fact that this species is highly migratory, suggests that many of the birds seen in the study area are migrants. This was also indicated by the lack of importance in a multiple regression model of distance to colony as a factor explaining this species' variation in cell density; see Table 3.8. At-sea surveys recorded in CDAS contained 1,118 sightings or 1,576 individuals, despite survey effort being sparse in the offshore waters where this species frequents.

Leach's Storm-Petrel is a common species that frequents waters much farther offshore than the other storm-petrels, i.e., well beyond the continental slope. Thus, the National Marine Sanctuary boundaries (and most of the data sets in this study) do not encompass much of this species' preferred habitat. The species was most abundant during the Upwelling Season (breeding) and occurred relatively closer to the coast than in other seasons. This species visits the small Farallon and other colonies only at night, and are at sea or attending nest burrows during the day. During the Oceanic and Davidson Current seasons few birds occurred in waters near the shelf. The birds present during the latter two seasons likely were migrants from more northern populations.

A multiple regression model of nine independent variables in the CDAS data set explained 28.4% of variation in cell density, indicating that this species responded consistently to the variables examined. Most important of the nine variables were season, distance to the 2000 m isobath, and ENSO period (periods of unusually warm or cool ocean temperature); see Table 3.8. At sea, abundance of this species in the study area has increased between 1985 and 2002, and it was more abundant during periods of warm-water conditions. This contrasts with apparent trends at the main colony in the study area (South Farallon Islands), where the species appears to have declined dramatically since the early 1970s (PRBO, unpubl. data; G. J. McChesney, unpubl. data).

Leach's Storm-Petrels feed on invertebrates and larval fish captured at the surface. See Tables 3.5, 3.8, 3.9., 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from: Whitworth et al. (2002), Sydeman et al. (1998), McChesney et al. (2000), and Carter et al. (1992).

Figure 3.16. Ashy Storm-Petrel: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Ashy Storm-Petrel (*Oceanodroma homochroa*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no

Ashy Storm-petrels were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas. Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3C that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods

Data on colony sizes are from Whitworth *et al.,* (2002) for Bird Rock, Point Reyes and Double Point Rocks; from Sydeman *et al.,* (1998) for South Farallon Islands; and from McChesney *et al.,* (2000a) for Bench Mark-227X, Castle Rocks and Mainland, and Hurricane Point Rocks. Because storm-petrels nest in small rocky crevices and are active at colonies only at night, estimating breeding population sizes is extremely difficult. For this species, estimates are based mainly on mist-net studies such as capture-recapture, in addition to nest searches, but can also be estimated from at-sea surveys (Spear and Ainley, 2007).

RESULTS AND DISCUSSION

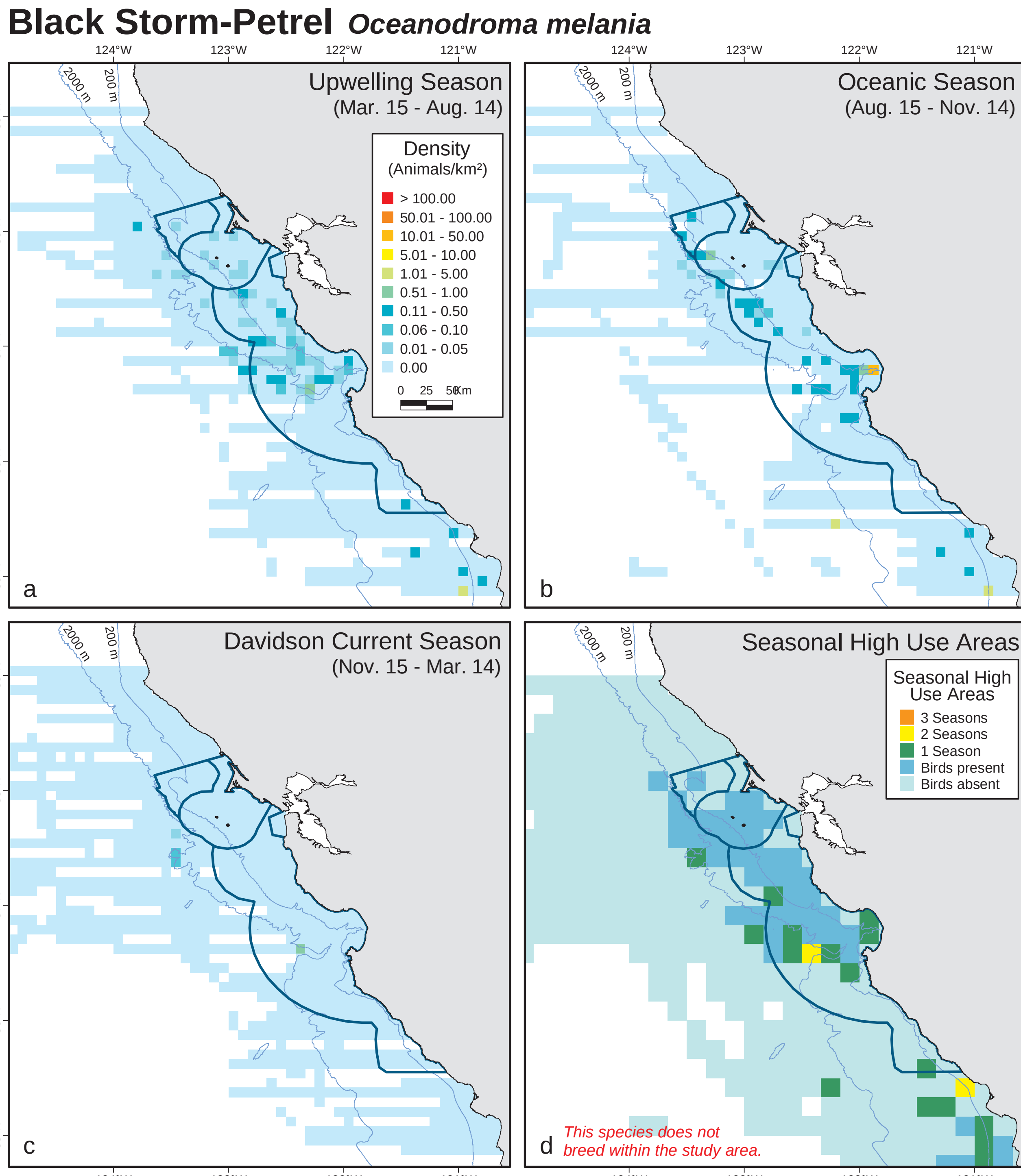
Ashy Storm-Petrel is endemic to the California Current and is considered by the State of California to be a "Species of Special Concern" because of apparent declines and threats (Carter *et al.,* in press). The largest colony of this species in the world occurs at the South Farallon Islands. This species is common in the study area and the most abundant storm-petrel in waters of the central California National Marine Sanctuaries. Surveys in CDAS recorded 1,472 sightings of 4,339 individuals.

A multiple regression model of nine variables explained 17.3% of variation in cell density, with important explanatory variables for this species being ENSO period (i.e., periods of unusually warm or cold ocean temperature), ocean season, and year; see Table 3.8. The species is more abundant during the Oceanic Season and during years of La Niña, indicating that when ocean temperatures are cold, Ashy Storm-Petrels are more concentrated closer to the Farallon breeding colony. During nesting (Upwelling Season), this species occupies waters mainly over the outer slope (mean depth of water 1,615 ± 52 m), mostly outside of National Marine Sanctuary boundaries. During the period of molt (Oceanic Season), Ashy Storm-Petrels move inshore to frequent shallower slope waters (mean depth of ocean 1,144 ± 61 m) and a large concentration occurred over the Monterey Canyon. Eight maps are provided for this species, four of which have a western extent to show the full offshore extent of the CDAS data for this species. The species occurs in all three National Marine Sanctuaries in the study area, and in all three ocean seasons.

In recent years, this post-breeding concentration has shifted to the area around Cordell Bank (not shown on the maps). As the species begins its seasonal return to the Farallon nesting colony (Davidson Current Season), they shift to the north again to deeper waters of the outer slope (mean depth of ocean 2,579 ± 121 m). Ashy Storm-petrels seems to be most dispersed during the Davidson Current Season, but in all seasons the Farallon Escarpment is by far the area where this species most importantly concentrates. Overall, observed at-sea densities of Ashy Storm-Petrels increased from 1985 to 2002 in a curvilinear fashion: steeper increase in numbers occurred between 1985 and 1992, followed by a less steep increase to 2002.

In the study area, Ashy Storm-Petrels nest primarily at the South Farallon Islands. Recent discoveries of small colonies along the northern Big Sur Coast and Point Reyes-Drakes Bay areas (McChesney *et al.,* 2000a, Whitworth *et al.,* 2002) suggest that additional undiscovered, but small colonies may exist. A capture-recapture study on the South Farallon Islands indicated that numbers there declined 40% between the early 1970s and 1992 (Sydeman *et al.,* 1998), and surveys in 2002 at Bird Rock (Marin County) indicated decline since 1989 (Whitworth *et al.,* 2002). At-sea surveys do not support this pattern (Spear and Ainley 2007, unpubl. data).

The Ashy Storm-Petrel feeds on invertebrates and larval fish found at the surface. See Tables 3.5, 3.7, 3.8, 3.9, and 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.17. Black Storm-Petrel: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/ km^2) of Black Storm-Petrel (*Oceanodrama melania*)) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Black Storm-Petrels were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species in Appendix 3D that include a greater western extent.

DATA SOURCES AND METHODS

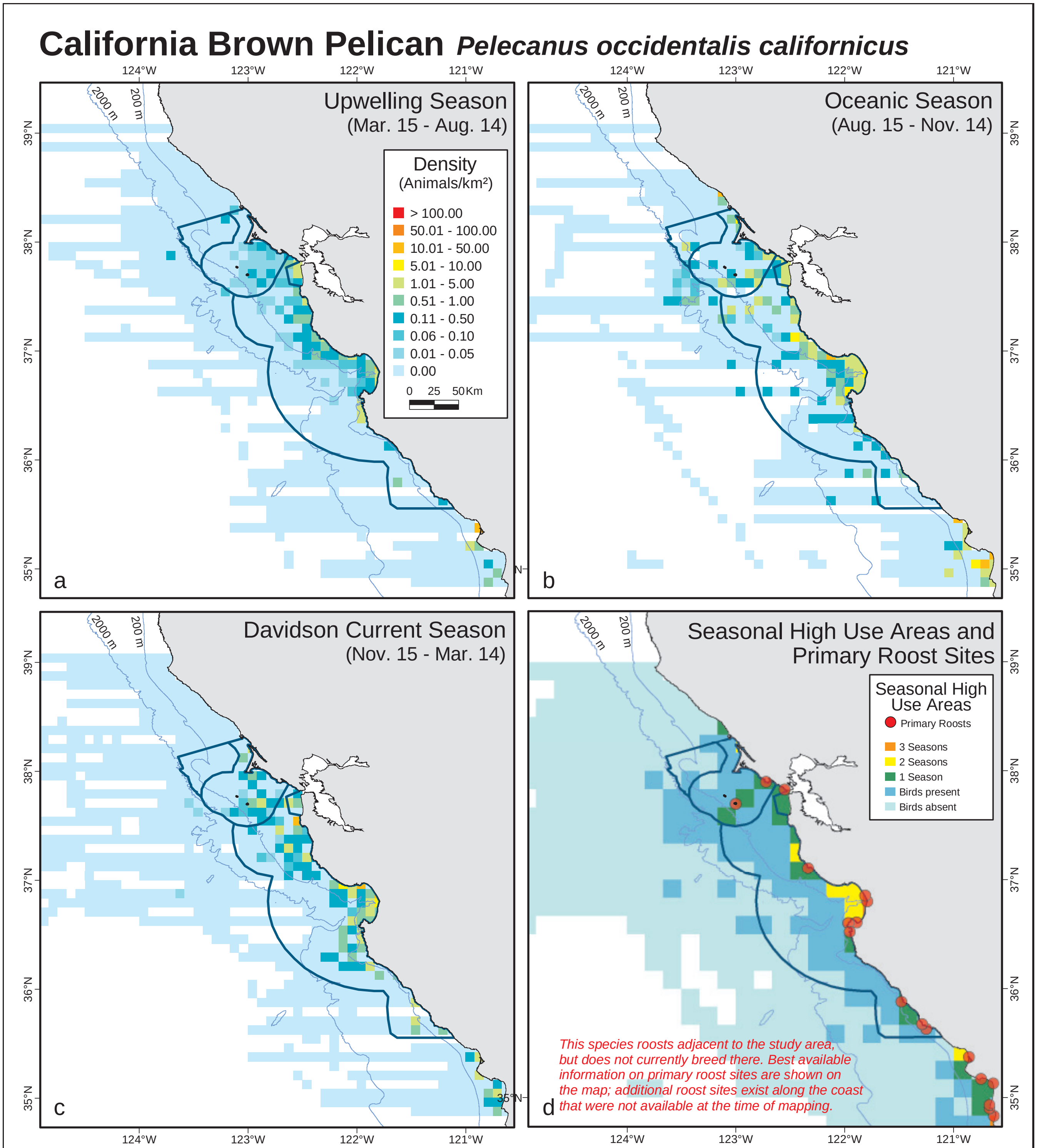
The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods

RESULTS AND DISCUSSION

The Black Storm-Petrel, a species on the State of California's "Species of Special Concern" list, nests on islands off Baja California Mexico and southern California during the Davidson Current Season and early Upwelling Season. The species is uncommon in the study area, where surveys in CDAS recorded 187 sightings of 477 individuals. One of these sightings was of 250 individuals within a larger flock of Ashy Storm-Petrels over Monterey Canyon. Otherwise, Black Storm-Petrel occurred primarily along the continental slope during the late Upwelling and Oceanic seasons, and only during warm-water years. It is mostly absent in the study area during the Davidson Current Season and during all seasons in other than warm-water years.

Black Storm-Petrel feeds on invertebrates and larval fish found at the surface; see Tables 3.5, 3.10 and 3.11 for related summary information.

Sophie Webb



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Information on roost locations provided by Judd Muskat, California Dept. of Fish and Game (CDFG).

Figure 3.18. California Brown Pelican: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of California Brown Pelican (*Pelecanus occidentalis californicus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no California Brown Pelicans were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas.

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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

The species does not currently breed in the study area, however pelicans do roost in large numbers at many coastal locations. The information mapped for primary roost locations was provided by Judd Muskat (CDFG); Dan Anderson (UC Davis) reviewed and updated this information, but it is dated. A new assessment of brown pelican roosts in California is currently in development.

RESULTS AND DISCUSSION

The California Brown Pelican declined dramatically in the 1950-1960s, primarily from organochlorine contamination, and is included on the California State and Federal endangered species lists. Recovery efforts have resulted in considerable increases since the 1970s. The species is now considered common year round in Monterey Bay and to the south, and is common further north from June to November. Some biologists think the species has fully recovered and propose it should be removed from the endangered species lists, a proposal supported by most marine ornithologists who are knowledgeable about this species. A petition to to de-list the species is currently being considered by the U.S. Fish and Wildlife Service (C. Harrison and D. Ainley, pers. comm., 2007)

At-sea surveys in the CDAS central California data set (1980-2001) recorded 1,447 sightings of 3,003 individuals. The species frequents waters near to shore (mean distance to land 10.3 ± 0.4 km) and rarely occurs in waters deeper than the shelf break (mean depth 266 ± 21 m). Consistent with these patterns are results of a multiple regression model of nine independent variables that explained 15.2% of the variation in density; important variables were season, and inverse relationships to distance to land and latitude; see Table 3.8. Therefore, the broad shelf of central California is well suited to this species; its occurrence becomes more sporadic north of Pt. Reyes. Inshore Monterey, Estero and San Luis Obispo bays are especially important, where this species is common year round; the San Francisco Bay tidal plume is also important. Abundance of this species in the study area has increased between 1985 and 2002.

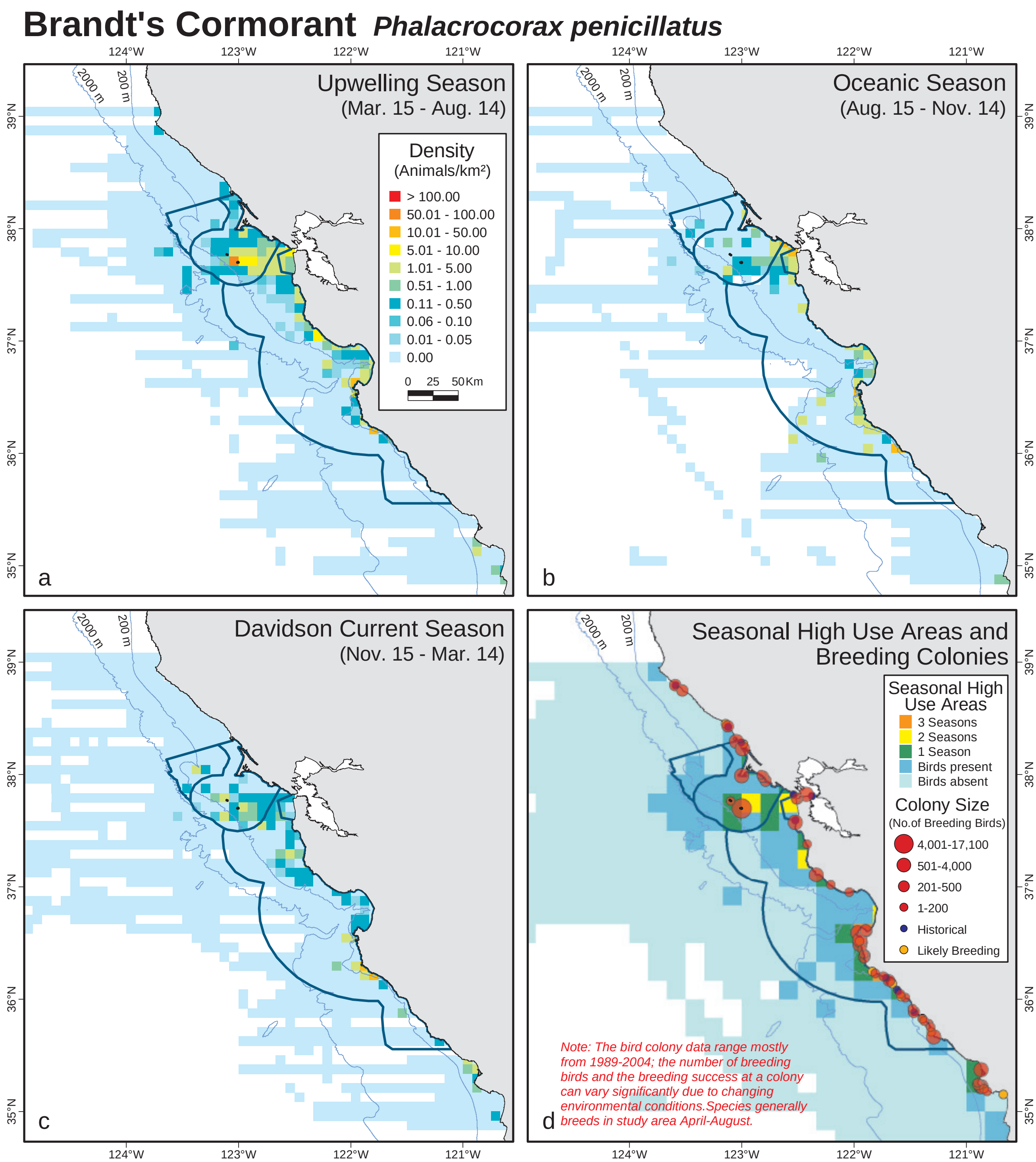
North of Monterey and Estero/San Luis Obispo bays, this species' presence is much more seasonal and varies with ocean climate. Previously, most sightings of pelicans in the Gulf of the Farallones occurred during the Davidson Current and Upwelling seasons, particularly during warm-water years when many birds forgo breeding at southern colonies and follow warmer waters northward. In the last decade, though, more and more wintering birds remain in central California waters, while others move through the area to spend their non-breeding time farther north. Most recently, the species commonly occurs in sanctuary waters year-round or for most of the year.

This population breeds outside of the study area on islands off Baja California, Mexico and southern California (north to the Channel Islands). A small colony did occur at Point Lobos, Monterey County until the 1960s. Along the central California coast, Brown Pelicans are concentrated at roosts such as Morro Rock, Monterey Breakwater, Año Nuevo Island, South Farallon Islands, Bird Rock in Monterey County and Bodega Rock, with many of these roost sites shown on the map.

Nesting phenology in southern California and Baja California Mexico is variable but can begin as early as November and can extend through August. In the central California study area the species is less abundant during the peak of the breeding period of March through June, and is most abundant during the Oceanic Season; the species' presence in the study area constitutes a post-breeding dispersal from southern breeding grounds.

The California Brown Pelican preys exclusively on fish, especially anchovies, mackerel and sardines. It catches these fishes by plunging to just below the surface, mostly in shallow coastal waters. Pelicans also scavenge fish offal. See Tables 3.5, 3.8, 3.10 and 3.11 for related summary information.

Sophie Webb



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from: Capitolo et al. (2006), Capitolo et al. (2004), McChesney et al. (2001) and Carter et al. (1992).

Figure 3.19. Brandt's Cormorant: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Brandt's Cormorant (*Phalacrocorax penicillatus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Brandt's Cormorants were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Data on colony sizes were obtained from Carter *et al.,* (1992), McChesney *et al.,* (2000b), and Capitolo *et al.,* (2004a and b, 2006). Data from Capitolo *et al.,* (2004b) were from the last statewide assessment from surveys conducted in 2003.

RESULTS AND DISCUSSION

The Brandt's Cormorant, nearly endemic to the California Current region, is an abundant species within the study area. This region contains a huge part of this species' world population. Surveys in CDAS recorded 2,174 sightings of 10,016 individuals; based on CDAS, abundance of this species within the study area has remained stable between 1985 and 2002.

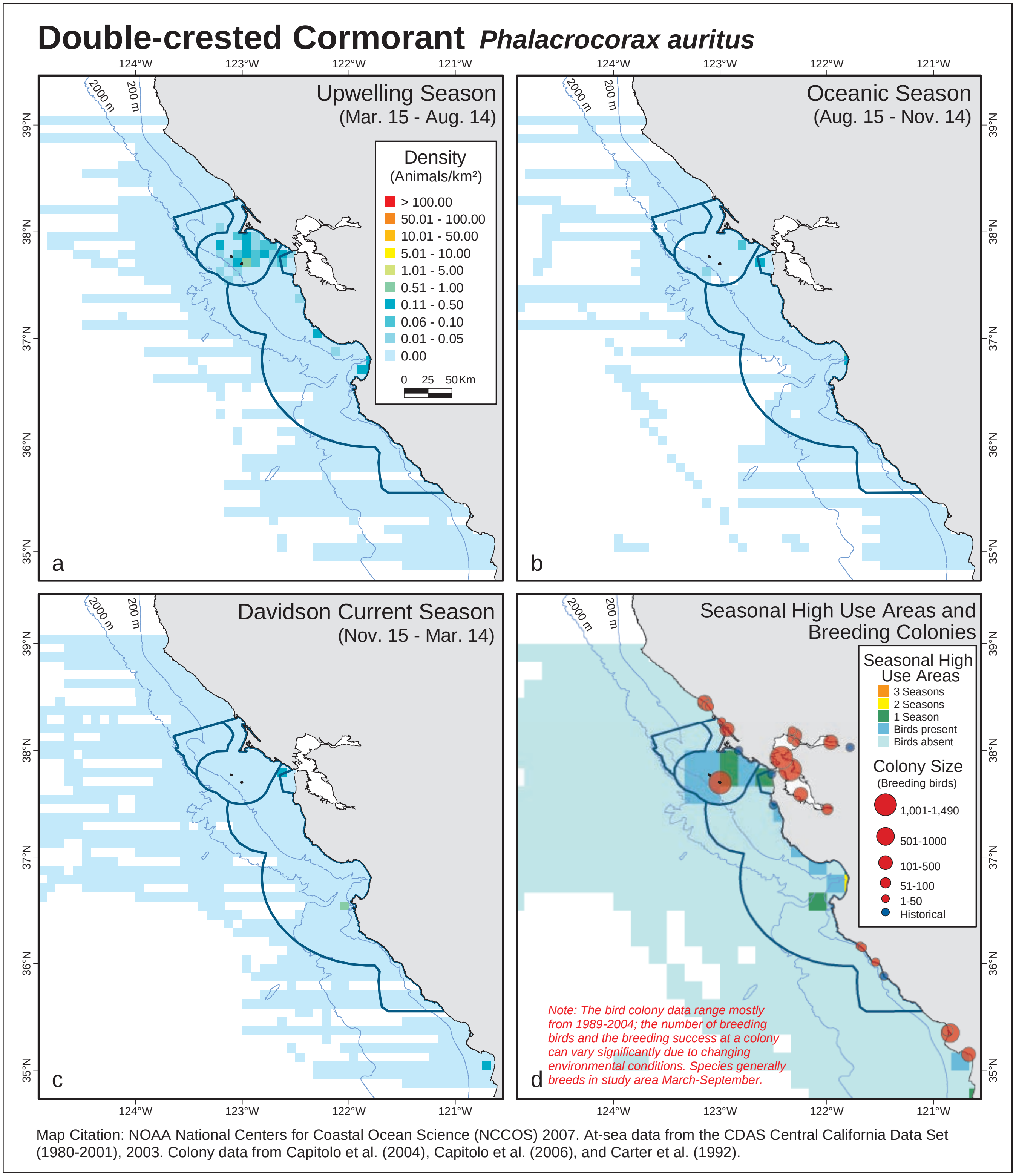
Densities of Brandt's Cormorants at sea were greatest within the boundaries of the National Marine Sanctuaries; to the north and south abundance dropped. A multiple regression model of nine independent variables explained 28.7% of variation in density; important variables were inverse relationships to distance to colony, distance to the 200 m isobath, and distance to land; see Table 3.8. This species occurred primarily over the shelf (mean depth 81 ± 8 m) and near to land (mean distance from shore was 6.8 ± 0.2 km) and colony. Brandt's cormorants were most abundant during the Upwelling (nesting) Season and were concentrated around the primary nesting colonies.

Also important to this species were the areas of the Farallon Escarpment and Ridge, San Francisco Bay tidal plume and inner Monterey Bay. The population became most concentrated in these areas during the breeding season, when they occurred in waters having a mean ocean depth of 60 m and a mean distance to land of 6.1 km. During the Oceanic and Davidson Current seasons this species mostly occurred over slightly deeper waters (mean depths of 247 m and 195 m, respectively) and farther offshore (mean distances 8.8 km and 12.4 km, respectively). Relatively speaking, however, these measures indicate that Brandt's cormorants were mostly close to the coast during this time. Brandt's Cormorant occurred in the study area in all three National Marine Sanctuaries and in all three ocean seasons.

Abundance of Brandt's Cormorants at-sea was not affected by ENSO. The decline in numbers at sea after nesting (Upwelling Season) may have been partially due to movement out of the area, as leg band returns from Farallon birds demonstrate a northern movement to Oregon and Washington, primarily of subadults. The decrease in abundance could also have been an artifact of cormorants spending more time roosting, and thus not at sea, during the non-breeding season. When oil spills occur in the study area, Brandt's Cormorant are often impacted by them.

Brandt's Cormorants nest during the Upwelling Season. This species typically nests in dense colonies of hundreds to thousands of birds on offshore rocks, islands, and certain mainland cliffs. It is the second-most abundant nesting species in the study area. The largest colony in the study area (and the world) occurs on the South Farallon Islands. Several other important colonies occur at nearshore colonies within Gulf of the Farallones (e.g., Point Reyes, Devil's Slide Rock and Mainland, Año Nuevo Island). Increases at these nearshore colonies in recent years may indicate an inshore population shift associated with the demise of rockfish (*Sebastes spp*.), an important prey taxon. Beyond the Gulf of the Farallones, this is the most abundant breeding seabird in the study area. Important nesting areas include Fish Rocks, Bodega Rock, Alcatraz Island, Pebble Beach-Point Lobos area, Cape San Martin, Piedras Blancas, and the Point Buchon-Diablo Canyon area. The large colony at Yankee Point was a new occurrence in 2003 (Capitolo *et al.,* 2004) and they also bred there in 2005; this species had not been recorded there in the past (USFWS, unpubl. data). Data from 2003 colony surveys in central California indicated a population decline since 1989 (Capitolo *et al.,* 2004b). A more detailed assessment of Gulf of the Farallones colonies from the mid-1980s to 2002 indicated no long-term trend overall but a substantial increase at nearshore colonies (G.J. McChesney, pers.comm.*,* 2004; USFWS, unpubl. data). In 2003, mild El Niño conditions led to reduced or no nesting efforts at many colonies, and some colonies switched to other nearby sites not typically used. Because numbers at certain colonies were not representative of typical recent patterns (G. J. McChesney, pers. obs.), other recent counts were substituted for 2003 data when available.

Brandt's Cormorants feed principally on fish that they catch by diving close to the sea floor. See Tables 3.5 - 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from Capitolo et al. (2004), Capitolo et al. (2006), and Carter et al. (1992).

Figure 3.20. Double-crested Cormorant: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Double-crested Cormorant (*Phalacrocorax auritus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Double-crested Cormorants were observed have a density of zero. Areas not surveyed appear white; no information was available. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Data on colony sizes were recently updated and obtained from Capitolo *et al.,* (2004a and b, 2006). Previous data came from Carter *et al.,* (1992). Aerial photographic surveys of most colonies were conducted in late May to early June by the U.S. Fish and Wildlife Service in cooperation with Humboldt State University and California Department of Fish and Game. Counts from photographs were made in most, but not all years for a given colony. Colonies that cannot be surveyed from the air, such as the bridges in San Francisco Bay, are counted from boats. To estimate breeding population sizes, nest counts were multiplied by two to account for both members of each nesting pair.

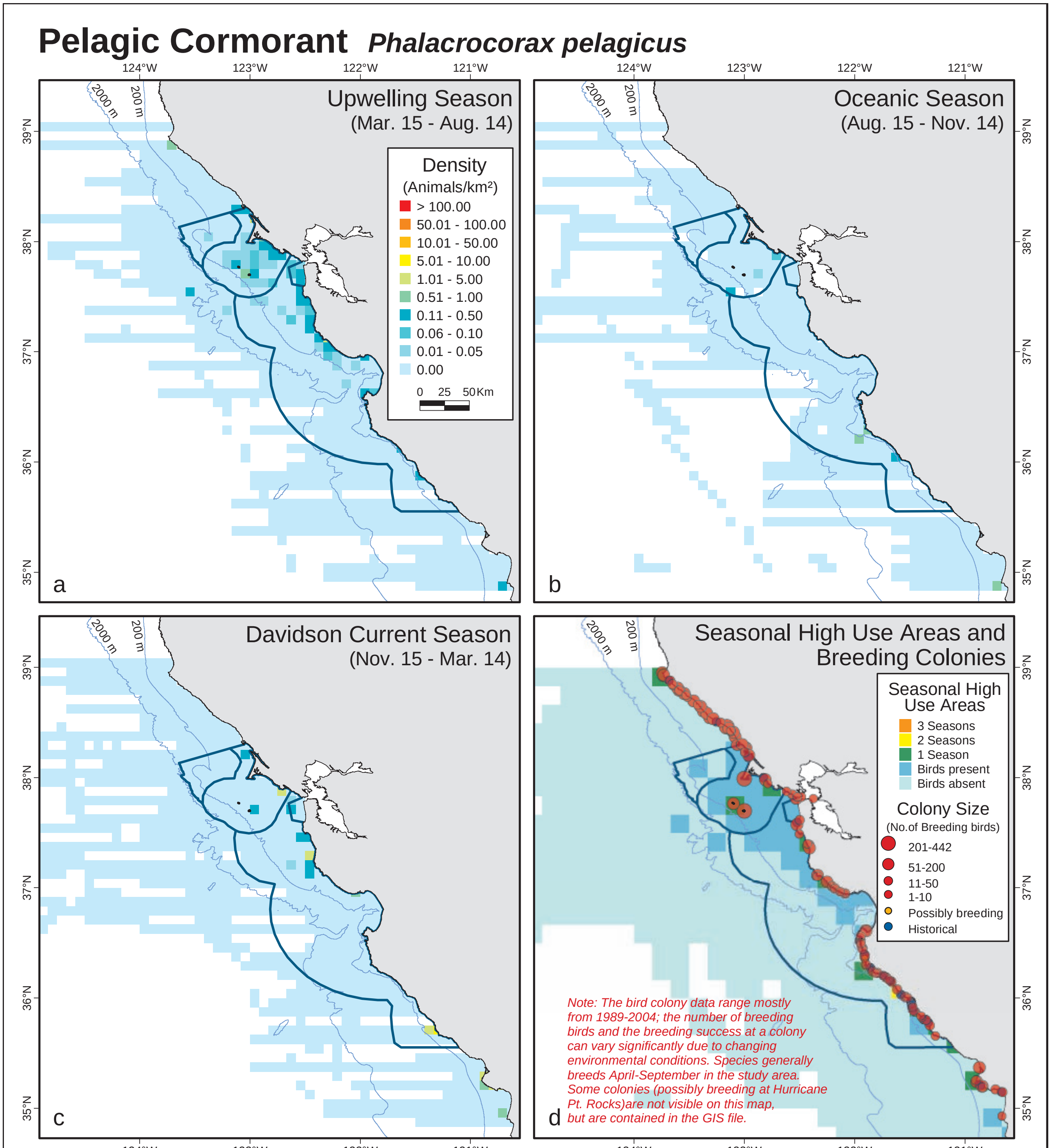
RESULTS AND DISCUSSION

The Double-crested Cormorant on the North American West Coast (outside of Mexico) is not usually a "marine" species; perhaps because, unlike the East Coast, the marine niche is occupied by other, more numerous cormorant species (inshore/coastal - the Pelagic Cormorant, and farther offshore, the Brandt's Cormorant). Along most of the East Coast (not including Central America), only the Double-crested Cormorant is present, except in the very far north (e.g., Newfoundland), where the Great Cormorant (*P. carbo*) occurs too. Along the central California coast, Double-crested Cormorants occupy and feed mainly in estuaries. However, a population does nest during the Upwelling Season at the South Farallon Islands, and thus accounts for much of the offshore occurrence of this species (commuting individuals) especially in the Gulf of the Farallones. A few Farallon individuals feed adjacent to the coast, but most commute to Tomales and San Francisco bays.

At-sea surveys in CDAS tallied 140 sightings of 352 individuals in marine waters of the study area; making this an uncommon species at sea. The species is more common in San Francisco Bay, where colonies occur on bridges, power transmission towers, and other man-made structures, such as structures on Alcatraz. A multiple regression model of nine independent variables explained 9.7% of the variation in density, with season being the most important variable; see Table 3.8. Like the other cormorant species, the Double-crested Cormorant was most abundant during the Upwelling Season and decreased dramatically from marine waters during the Oceanic Season. It was virtually absent from marine waters during the Davidson Current Season, being found then only in San Francisco Bay (distribution not shown) and at inland water habitats. This pattern was due to their departure from the Farallones abruptly after the breeding season. Then, most individuals remain inside San Francisco, Tomales or other coastal bays, or frequent adjacent reservoirs.

Several large breeding colonies occur in San Francisco Bay, South Farallon Islands, and Morro Bay; ssee also Appendix 1A. Most colonies are associated with estuaries. At breeding colonies, this species has increased substantially in the last 25 years as it recovers from historical declines (Carter *et al.,* 1992, 1995; Capitolo *et al.,* 2004).

Double-crested Cormorants feed principally on schooling fish that they catch by diving to mid-depths in shallow water. See Tables 3.5 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data primarily from Carter et al. (1992), with updates from Warzybok et al. (2002) and McChesney et al. (2005).

Figure 3.21. Pelagic Cormorant: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Pelagic Cormorant (*Phalacrocorax pelagicus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Pelagic Cormorants were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Data on colony sizes were obtained primarily from Carter *et al.,* (1992), with additional updates from Warzybok *et al.,* (2002) for the South Farallon Islands and from McChesney *et al.,* (2005) for colonies at San Pedro Rock and Devil's Slide and Mainland. Pelagic Cormorants typically nest in relatively small colonies (<100 pairs) on steep island and mainland cliffs. Most estimates are based on direct counts of nests; occasionally, bird counts are used. Carter *et al.,* (1992) adjusted nest or bird counts with correction factors to account for nests that had failed and nests that had not been built at the time of the survey.

RESULTS AND DISCUSSION

The Pelagic Cormorant is uncommon in the study area. At-sea surveys in CDAS recorded 265 sightings of 434 individuals, a ratio indicating that its tendency to form flocks is much less than that of other cormorants. In the study area, greatest densities occurred within the Sanctuary boundaries; to the north and south, at-sea sightings for this species were sparse.

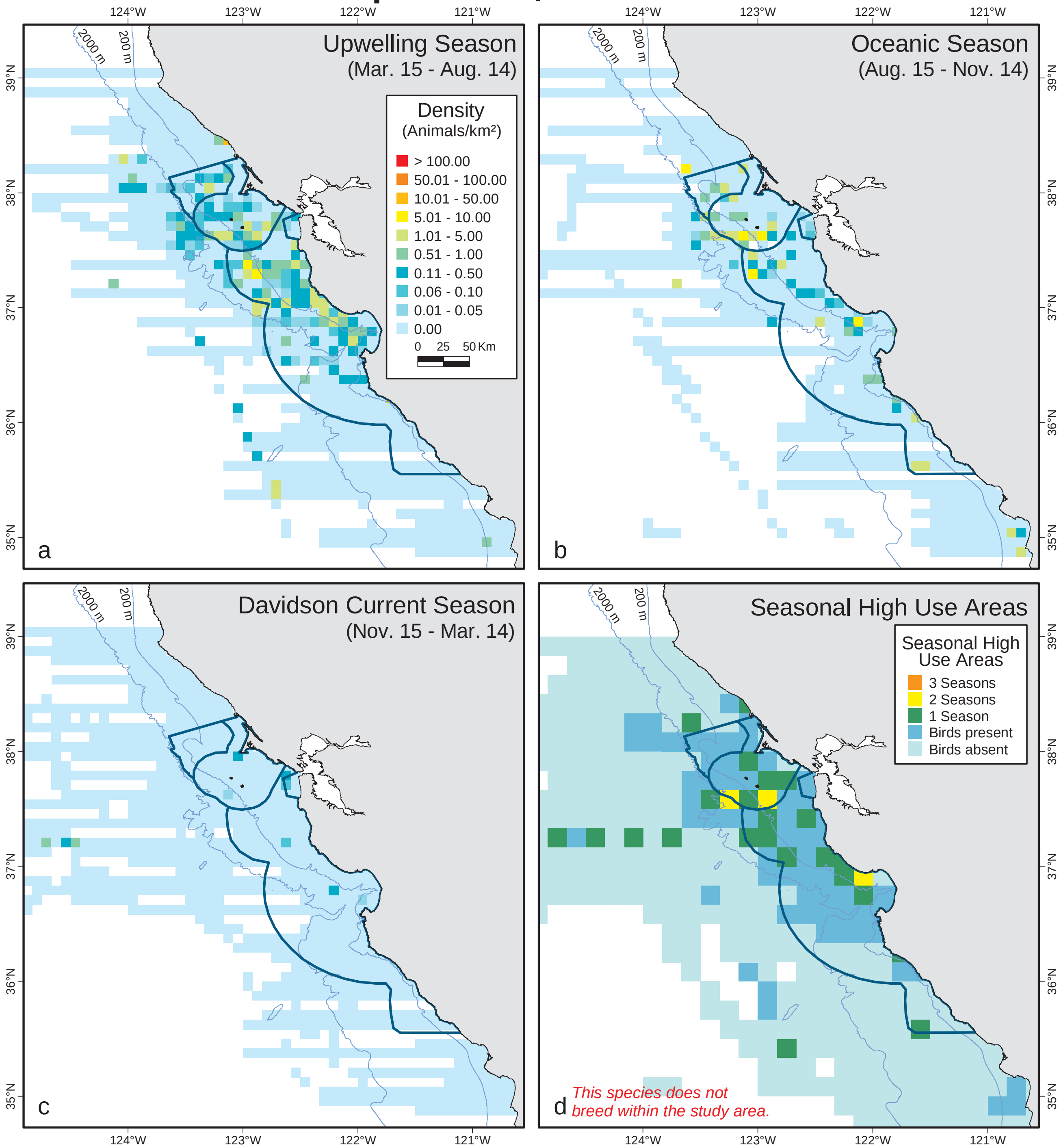
A multiple regression model of nine independent variables explained only 6.1% of variation in density, principally through inverse relationships to distance to colony, distance to the 200 m isobath, and distance to land; see Table 3.8. Similar to the Marbled Murrelet and scoters, this species occurs in waters of shallow depths (mean depth 57 ± 9 m) and close to land (mean distance to land 5.4 ± 0.4 km). These reported average depths and distances are likely biased deeper and farther from shore than the species true habitat pattern, because most research vessels approached only to about 1.5 km from shore and thus the species' preferred habitat is under-sampled. Many individuals of this species forage over rocky reefs immediately adjacent to the coastline.

Like Brandt's Cormorant, the Pelagic Cormorant was most abundant during the Upwelling (nesting) Season, and numbers appeared to be unaffected by interannual climatic variation. This species occurred in the study area during all three ocean seasons. The species was found close inshore during the Davidson Current Season (mean depth 40 m, mean distance to shore 6.0 km), farthest offshore during the Oceanic Season (mean depth 311 m, mean distance to shore 11.2 km), and generally in habitats of intermediate measures during the Upwelling Season (mean depth 59 m, mean distance to shore 5.2 km). Highest at-sea densities during the Upwelling (nesting) Season were likely an artifact of individuals spending more time in the water foraging then than they do during the non-breeding period. In the latter, they spend a lot of time roosting. Thus, like the Brandt's Cormorant, their abundance along the central California coast probably does not decrease as much as comparison of the seasonal maps might suggest.

Pelagic Cormorants colonies are widely distributed. The largest breeding colony in the study area is on the South Farallon Islands (see also Appendix 1A). Within the study area, abundances are greater north of Monterey. Other important nesting sites include the Point Arena area, Russian Gulch, Point Reyes, Seal Rock Cliffs/Martin's Beach area, Punta del Año Nuevo, and Cannery Row.

Pelagic Cormorants feed principally on benthic fish (e.g., rockfish, blennies, sculpins) and invertebrates (e.g., grass shrimp), which they catch by diving. See Tables 3.5, 3.7, 3.8, 3.9, 3.10 and 3.11 for related summary information.

Red-necked Phalarope *Phalaropus lobatus*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.22. Red-necked Phalarope: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Red-necked Phalarope (*Phalaropus lobatus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter.

To provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Red-necked Phalaropes were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Red-necked Phalarope, like the Red Phalarope, occurs commonly in the study area during southward and northward migrations that take them between nesting areas on the Arctic tundra and wintering areas in waters off South and Central America. On surveys in CDAS, when the two phalarope species were differentiated, 782 sightings of 7,670 Red-necked Phalaropes were recorded. Their migrations took place mainly during the early and late Upwelling Season (when they were most abundant). Thus, their time in the Arctic was relatively short. The Red-necked Phalarope, occurring principally over the continental shelf, was concentrated farther inshore than the Red Phalarope. This is best seen in central California where, on boat surveys, the two species could be differentiated; on aerial surveys, which spanned the entire coast, they were not. During the Oceanic Season occurrence was scattered, and the species was almost absent during the Davidson Current Season.

A multiple regression model of nine independent variables in CDAS for both Red and Red-necked Phalaropes (grouped together for regression analysis) explained only 9.6% of the variation in cell density; see Table 3.8. This was a relatively low value given their abundance. Perhaps this was due to the differences in habitat use by the two species, thus masking the effect of environmental variables in the analysis; grouping the two species for the analysis, as well as the fact that both were rapidly moving through the study area, likely homogenized habitat preferences. Important variables for these species were ENSO (more abundant during La Niña), and negative relationships with ocean depth (indicating association with the mid-slope waters for both; mean depth 941 m) and distance from land (mean distance 27.7 km). Within the study area, abundance of these species has remained stable between 1985 and 2002.

These species feed on small invertebrates and fish eggs concentrated at the surface especially along convergence lines. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

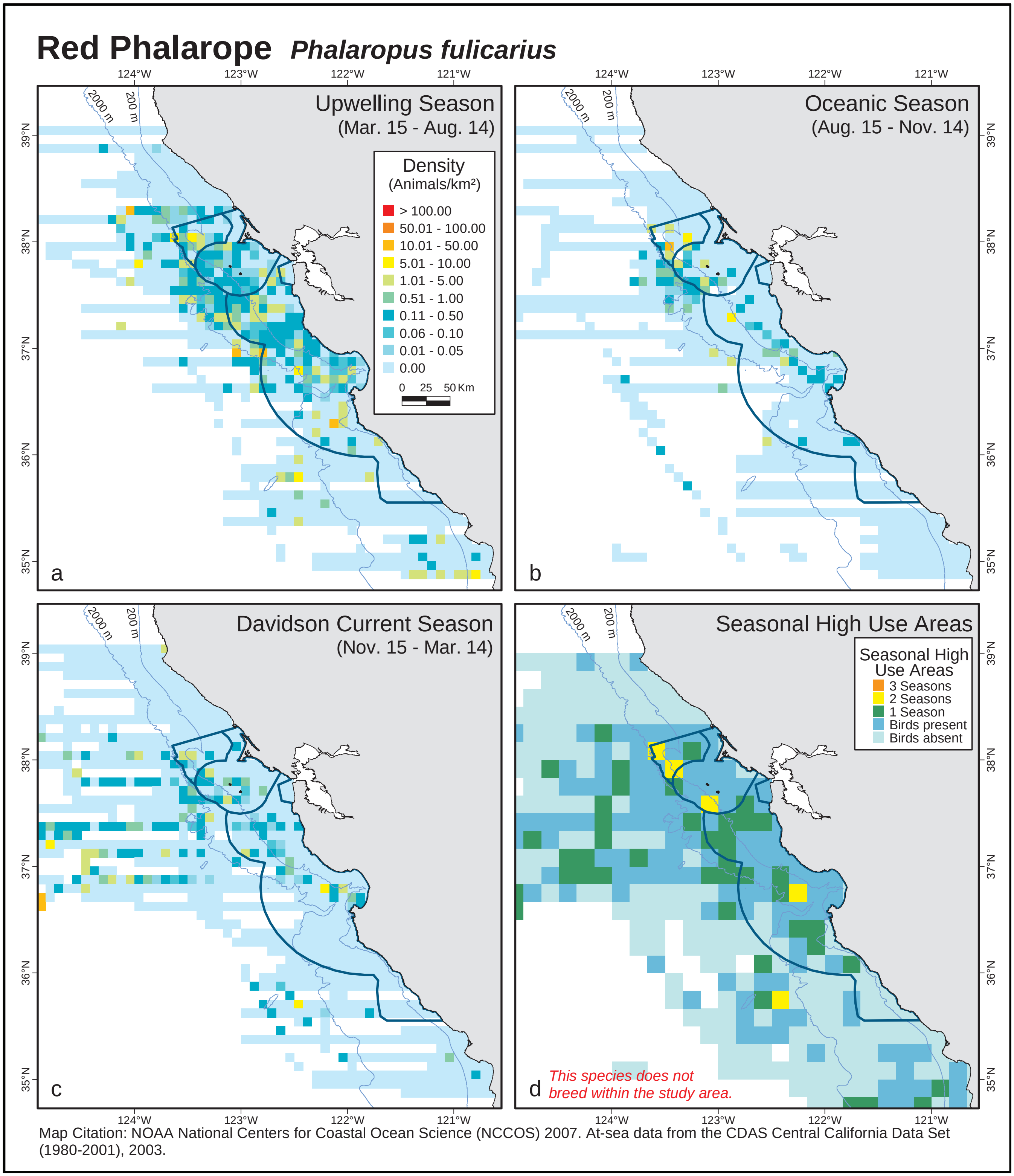


Figure 3.23. Red Phalarope: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/ km^2) of Red Phalarope (*Phaloropus fulicarius*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Red Phalaropes were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

To provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude. The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas, Because the sighting data for this species extends significantly beyond the western extent of the standard map frame used in this project, additional maps are provided for this species that include a greater western extent.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

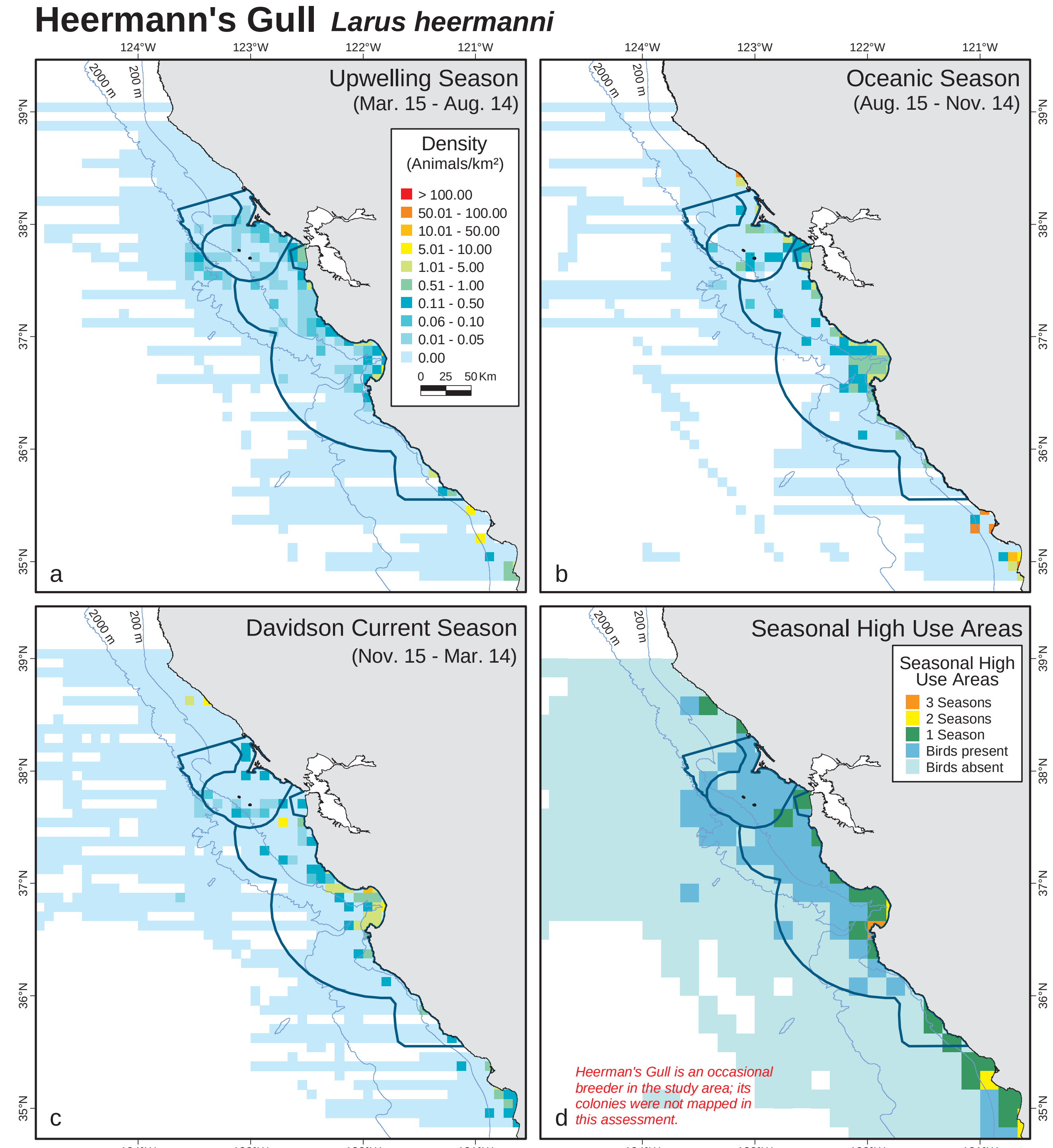
RESULTS AND DISCUSSION

Red and Red-necked Phalaropes are two shorebirds that occupy marine habitats, mostly during their non-breeding season. The Red Phalarope, like the Red-necked Phalarope, is common in the study area during its southward and northward migrations, between nesting areas on the Arctic tundra and wintering areas in waters off South and Central America. On surveys contained in CDAS (1980-2001) when the two phalarope species were differentiated, 1,546 sightings of 8,451 Red Phalaropes were recorded. Their migrations took place mainly during the early and late Upwelling Season (when they were most abundant). Thus, their time in the Arctic was relatively short. These species were not as abundant in the study area during the Davidson Current Season, except during warmwater periods, when relatively few Red Phalaropes occurred in the study area. Red Phalarope occurred in the study area during all three ocean seasons.

Red Phalaropes were concentrated over the continental slope, more so than the Red-necked Phalarope, which was found relatively closer to shore. This is best seen in waters off central California where, on boat surveys, the two species were differentiated; on aerial surveys, which spanned the entire coast, they were not. Occurrence during the other two seasons was much more scattered.

A multiple regression model of nine independent variables in CDAS for both Red and Red-necked Phalaropes (grouped together for regression analysis) explained only 9.6% of the variation in cell density; see Table 3.8. This was a relatively low value given their abundance. Perhaps this was due to the differences in habitat use by the two species, thus masking the effects of environmental variables in the analysis. Grouping the two species for the analysis, as well as the fact that both were rapidly moving through the study area, likely homogenized habitat preferences. Important variables for these species were ENSO (more abundant during La Niña), and negative relationships with ocean depth (indicating association with the mid-slope waters for both; mean depth 941 m) and distance from land (mean distance 27.7 km). Within the study area, abundance of these species has remained stable between 1985 and 2002.

Red and Red-necked phalaropes feed on small invertebrates and fish eggs concentrated at the surface, especially along convergence lines. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.24. Heermann's Gull: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/ km^2) of Heermann's Gull (*Larus heermanni)* in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Heermann's Gulls were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

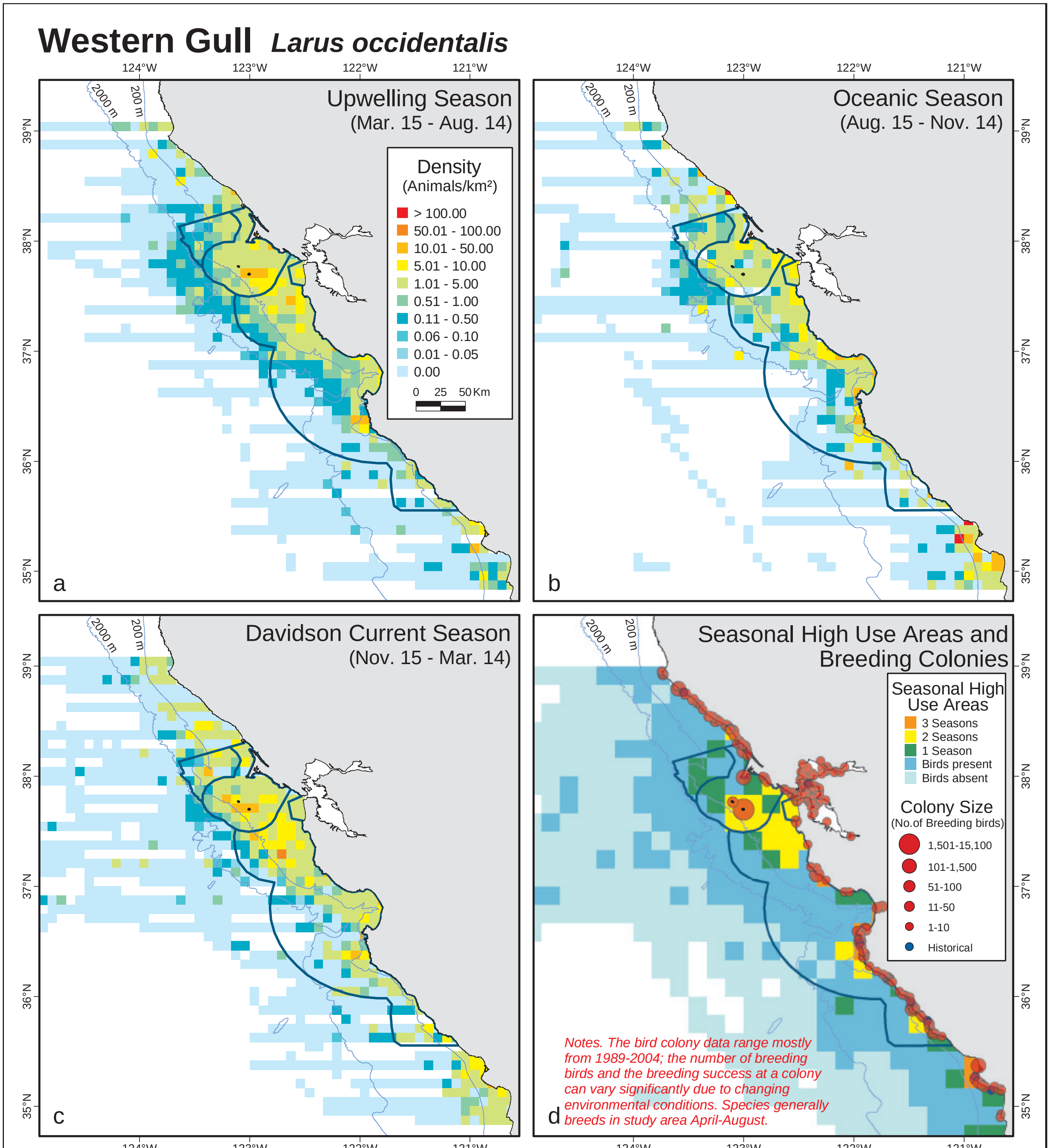
RESULTS AND DISCUSSION

Heermann's Gull was the third most abundant gull species in the data set; the surveys in CDAS recorded 828 sightings of 1,790 individuals. Therefore, relative to others, Heermann's Gull was considered a common species. This species is present mostly during the late summer and fall (Upwelling and Oceanic seasons), but it can occur year-round, especially during warm-water years. The species leaves the area starting in late winter (Davidson Current Season) to nest mostly on islands in the Gulf of California. The species is known to occasionally breed in or adjacent to the study area (Acatraz Island, 1979-91; Shell Beach Rocks, 1980; Roberts Lake Seaside, Monterey Co., 1999+; and Ano Nuevo Island, 1994-1996).

The Heermann's Gull is a kleptoparasite of Brown Pelicans. Heermann's Gull is represented in the study area by a large proportion of subadults. Like the pelican, it mostly nests on islands in the northern Gulf of California, at the same time as the pelican. Not surprisingly, its occurrence patterns are very similar to those of the pelican.

The species occurs primarily over the continental shelf, and mostly offshore of river mouths and bays. Based on data from the shipboard surveys in CDAS, the mean distance from land for this gull was 11.1 ± 0.6 km and the mean depth over which it was sighted was 402 ± 41 m. These reported average depths and distances are likely deeper and farther from shore than they actually were because most research vessels approached only to within about 1.5 km of shore and thus the closest-to-shore habitat was under-sampled. A multiple regression analysis of nine independent variables in CDAS explained 6.5% of the variance in density, with the top three variables for this species being: distance to land (closer to land, higher abundance); ENSO period (more abundant during El Niño); and latitude (more abundant in southern part of study area). It is likely that including pelican density as a variable would result in a marked improvement of the variance in density explained by the regression analysis. This species was most concentrated in inner Monterey Bay and other near-coast protected areas, where the abundance of Heerman's Gull increased in the study area between 1985 and 2002.

Heermann's Gulls are generalist feeders, consuming anything edible that it finds at the surface; however this gull mostly feeds on small pelagic fish that it steals from pelicans when the latter are filtering the prey from the water caught in their pouch after a plunge. See Tables 3.5, 3.8, 3.9, and 3.10 and 3.11 for related information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Most colony data from Carter et al.(1992); additional sources are Warzybok et al.(2002) and McChesney et al. (2005).

Figure 3.25. Western Gull: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km²) of Western Gull (*Larus occidentalis*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species.

Cells that were surveyed but in which no Western Gulls were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Most data on colony sizes were obtained from Carter *et al.,* (1992), with additional updates from Warzybok *et al.,* (2002) for South Farallon Islands and from McChesney *et al.,* (2005) for San Pedro Rock and Devil's Slide Rock and Mainland. Western Gulls nest in colonies ranging from single pairs to thousands of pairs. At greatest density, nests are a few meters apart. Most population estimates are based on counts of nests.

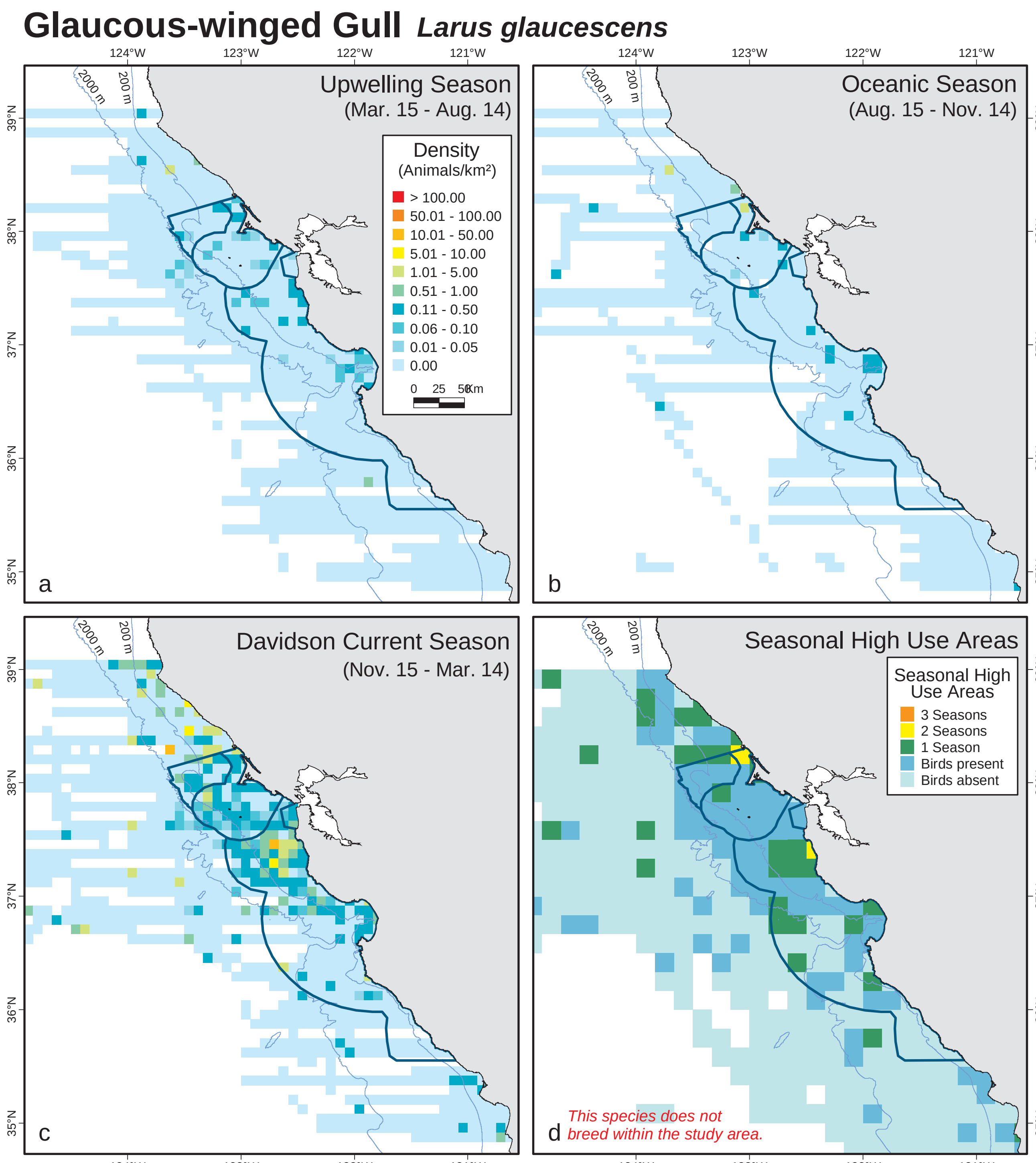
RESULTS AND DISCUSSION

The Western Gull is endemic to the California Current System and occur year-round in the study area. The species begins to occupy its nesting colonies during the Davidson Current Season (winter) and continues to occupy them through the Upwelling Season (spring/summer). The gulls' marine distribution is little changed by season; the species is considered to be abundant within the study area. At-sea surveys in CDAS recorded 14,726 sightings of 34,504 individuals.

A multiple regression model of nine independent variables in the CDAS data explained 44.2% of the variation in at-sea density, through the following three variables: inverse relationships with distance to colony, inverse relationships with distance to land, and ENSO. These results reflect the widespread distribution of this species primarily over the continental shelf, except off the Gulf of the Farallones, and southeast along the slope to Monterey Canyon. Off the Farallones during the Upwelling (nesting) Season the species occurs over the continental slope and beyond (e.g., over the Farallon Escarpment), perhaps in response to intraspecific competition among the large number of individuals associated with the Farallon Islands. The species is most abundant in the Gulf of the Farallones south to Año Nuevo, an area that includes the Farallon Escarpment and Ridge; Pioneer and Ascension canyons also appear to be important areas. The species is also prevalent in Estero and San Luis Obispo bays. Within the study area, abundance of this species has decreased from 1985 to 2002.

Within the study area, Western Gull breeding colonies are widely distributed (see also Appendix 1A, the bird colony data table). Breeding habitat ranges from small sea stacks to the largest islands, as well as mainland cliffs. They will also nest on man-made structures such as jetties, bridges, piers and rooftops. The largest colony in the world occurs on the South Farallon Islands. Other large colonies include Fish Rocks, Point Reyes, Red Rock, the former Alameda Naval Air Station, Alcatraz Island, Año Nuevo Island, Cape San Martin, and Morro Rock. Overall, numbers had increased between 1980 and 1989 (Carter *et al.,* 1992). In more recent years, the South Farallon Islands colony appears to be declining (Warzybok *et al.,* 2002).

Western Gull is a generalist, feeding on anything edible that occurs at the sea surface, although it principally feeds on fish, such as juvenile rockfish, and pelagic invertebrates (e.g., euphausiids). See Tables 3.5, 3.7, 3.8, 3.9, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.26. Glaucous-winged Gull: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/ km^2) of Glaucous-winged Gull (*Larus glaucescens*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Glaucous-winged Gulls were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Glaucous-winged Gull breeds north of the study area, along the coast from Oregon to Alaska. After breeding, it disperses south. The species occurs in the study area during all seasons, but begins arriving in the study area during the Oceanic Season and peaks in abundance during the Davidson Current Season. Considered uncommon based on CDAS data, surveys recorded 548 sightings of 990 individuals. The species is more abundant in the northern part of the study area, and is represented primarily by subadults, with the majority of adults remaining closer to the breeding areas to the north. A multiple-regression analysis of nine independent variables explained 17.1% of the variance in density with the top three variables for this species being season, latitude, and a negative relationship with ocean depth; see Table 3.8. The latter reflects the fact that the majority of these gulls occur in waters from the shelf to the mid-slope (mean depth of where they occurred was 461 ± 61 m), although some individuals did occur far offshore, well beyond the slope.

The Glaucous-winged Gull is a generalist feeder, taking anything found edible at the sea surface dead or alive. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

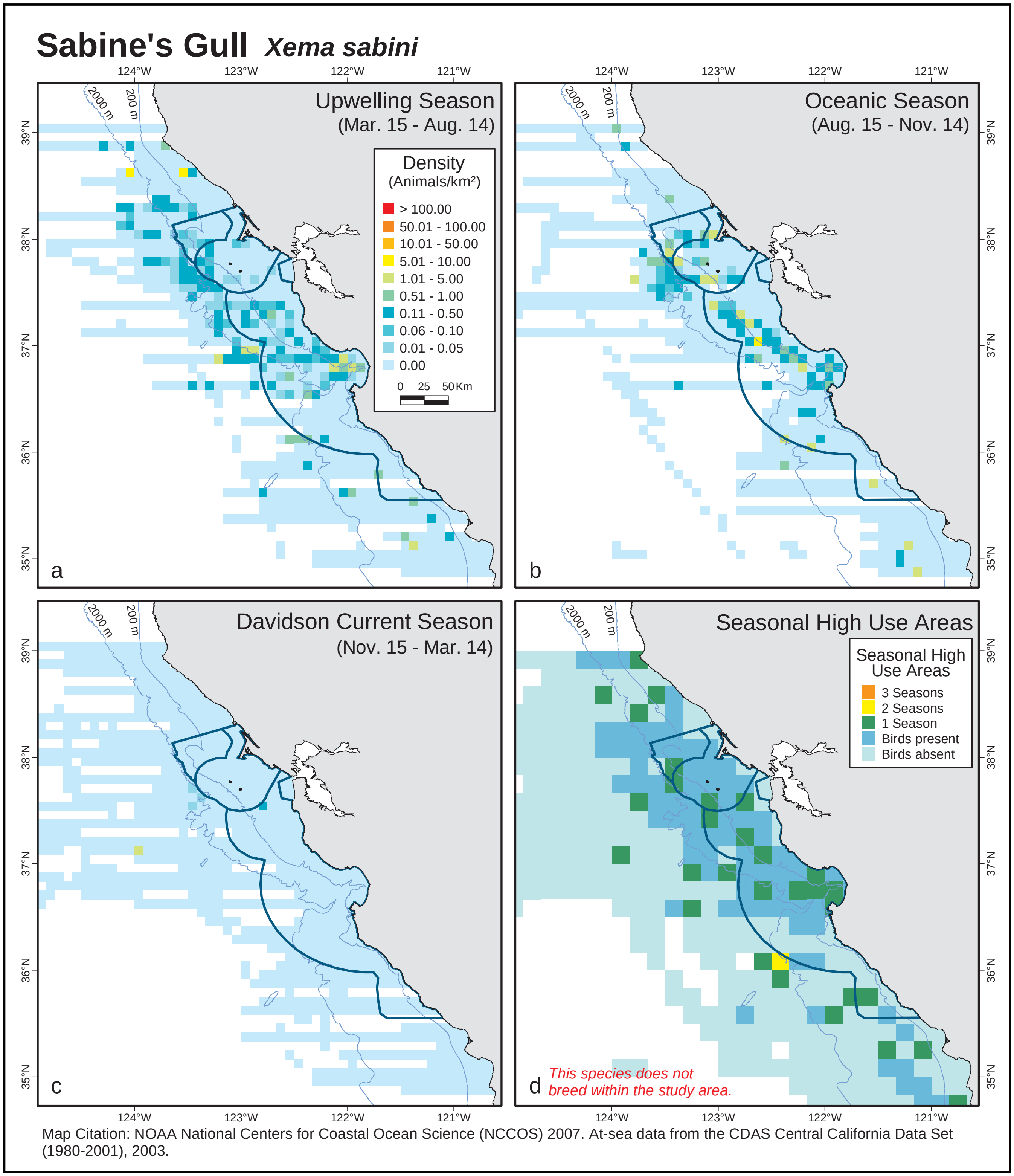


Figure 3.27. Sabine's Gull: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Sabine's Gull (*Xema sabini*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Sabine's Gulls were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

Sabine's Gull occurs principally in waters over the continental slope and beyond, and mostly outside of National Marine Sanctuary boundaries. Therefore, it occurs over deep waters, far from shore. Surveys in CDAS recorded 595 sightings of 1,652 individuals. It is present only as a migrant between its nesting area in the Arctic and wintering area in waters off Peru. It migrates north during the Upwelling Season (April-May) and south during the Oceanic Season (August), and is mostly absent during the Davidson Current Season.

Sabine's Gull feeds on a variety of small fish and pelagic invertebrates (e.g., krill) while in the study area. See Tables 3.5, 3.10 and 3.11 for related summary information.

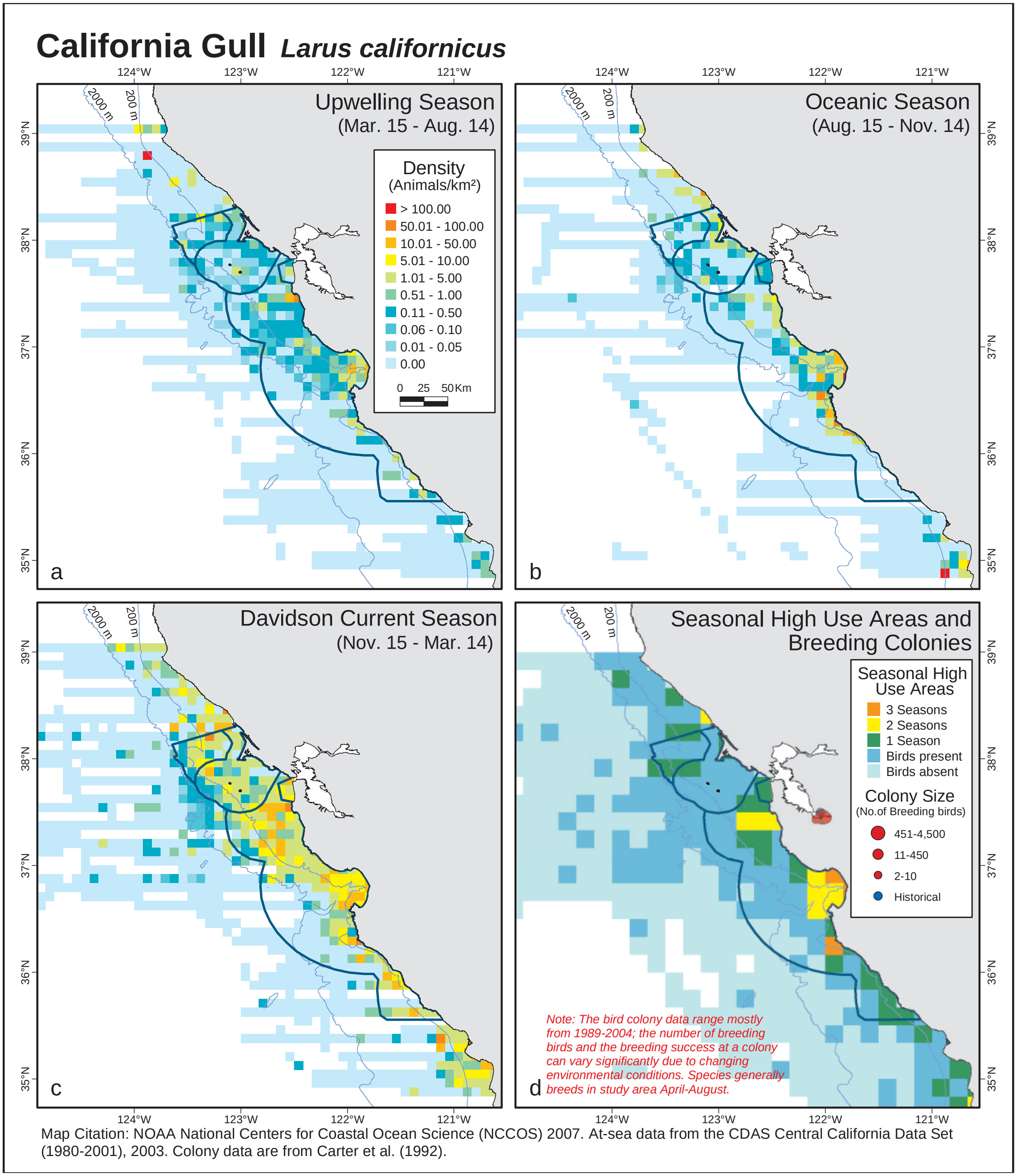


Figure 3.28. California Gull: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/ km^2) of California Gull (*Larus californicus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no California Gulls were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

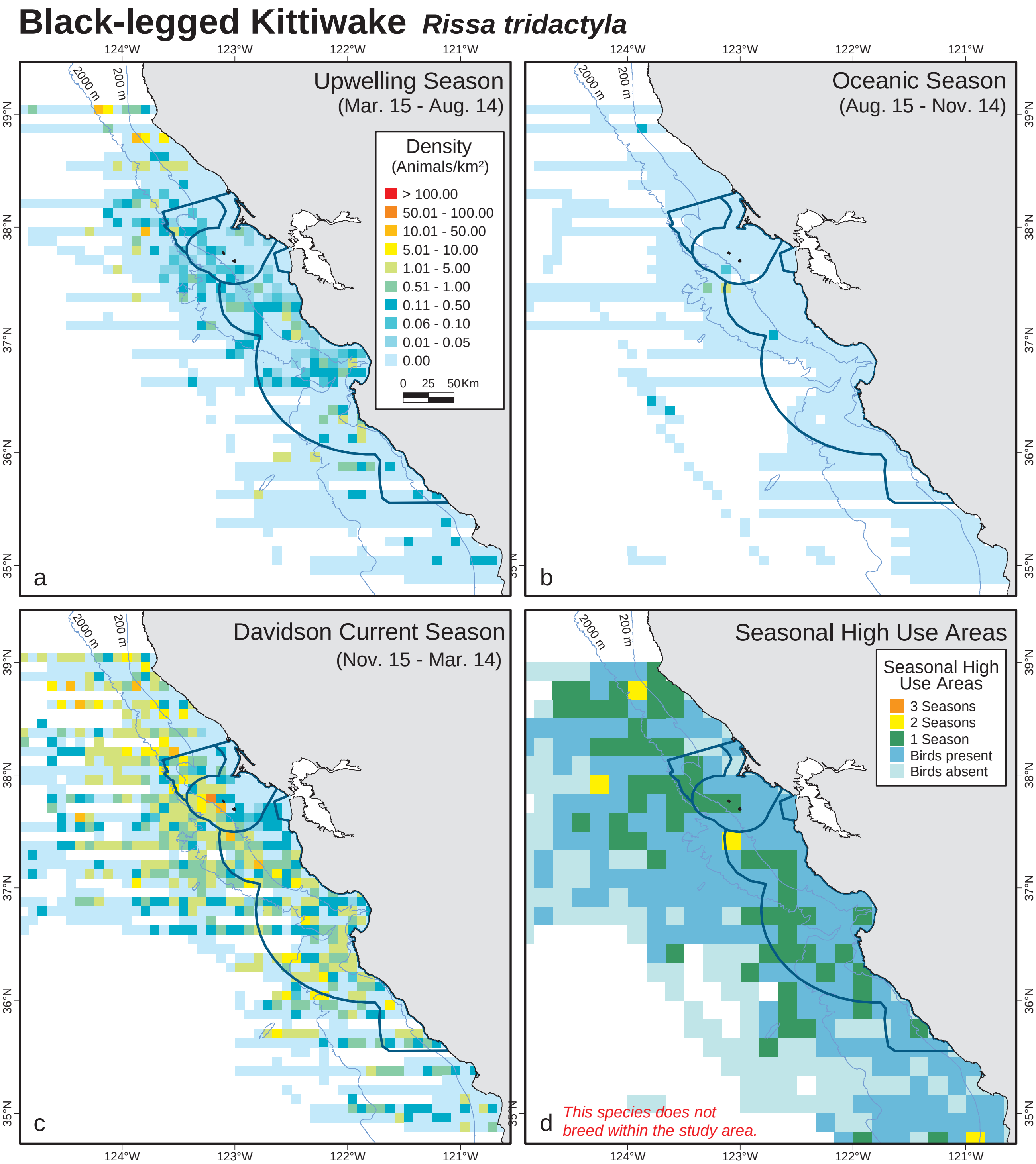
Data on colony sizes were obtained from Carter *et al.,* (1992).

RESULTS AND DISCUSSION

The California Gull is the second most abundant gull species in the study area, after Western Gull. Surveys in CDAS recorded 4,210 sightings of 18,034 individuals. Like the Western Grebe, California gulls breed primarily on inland lakes from Nevada to South Dakota and the Canadian prairie provinces. A breeding population was established in San Francisco Bay in the early 1980s, where numbers have grown dramatically in recent years (see Strong etl al. 2004). California Gulls from all these breeding locations migrate to the Pacific Coast after nesting.

Large numbers are present in the study area during the Oceanic Season, although their densities are highest during the Davidson Current Season. A multiple-regression model of nine independent variables explained 24.0% of variation in density for this species; important variables were season, latitude (more abundant in the north), and an inverse relationship to year (i.e., they declined slightly in abundance from 1985 to 2002 over the years). This species occurs primarily over waters from the continental shelf to those of the mid-slope (mean depth of 319 ± 17 m), thus, in the study area, mainly in waters bounded by the central California National Marine Sanctuaries. This species occurs in the study area during all three ocean seasons.

The California Gull is a generalist feeder, consuming anything edible that it finds at the surface. See Tables 3.5, 3.7, 3.8, 3.9, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.29. Black-legged Kittiwake: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Black-legged Kittiwakes (*Rissa tridactyla*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Black-legged Kittiwakes were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

The Black-legged Kittiwake, like the Northern Fulmar, breeds nests on many of the Aleutian Islands, as well as on islands along the northern coast of North America and Asia. Large numbers winter in the California Current area. It is a common species in the study area; surveys in CDAS recorded 2,079 sightings of 5,003 individuals. A multiple-regression model of nine independent variables explained 28.9% of variation in cell density. Important variables were season, ENSO period, and year (increasing in abundance). See Table 3.8 for more information on regression results for other species.

The Black-legged Kittiwake was most abundant in the study area during the Davidson Current Season and less so during the early Upwelling Season; it was largely absent during the late-Upwelling Season and Oceanic Season (which corresponds to its breeding season at northern-latitude nesting sites). Abundance was highest during periods of La Niña. Most kittiwakes occurred in waters overlying the continental slope, and deeper waters seaward of National Marine Sanctuary boundaries (mean depth of ocean 1,408 m; mean distance from shore was 29.0 km). A minority of kittiwakes occurred over the shelf, mainly where it is narrow. There was an "invasion" of kittiwakes in 1999, coincident with La Niña. Black-legged Kittiwakes occur in all three sanctuaries during all three ocean seasons (although the mapped data do not reflect it, Black-legged Kittiwakes do occur in the Cordell Bank National Marine Sanctuary during the Oceanic Season).

Kittiwakes feed on fish, pelagic invertebrates and plankton they catch by dipping and plunging to the surface; they are scavengers. See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

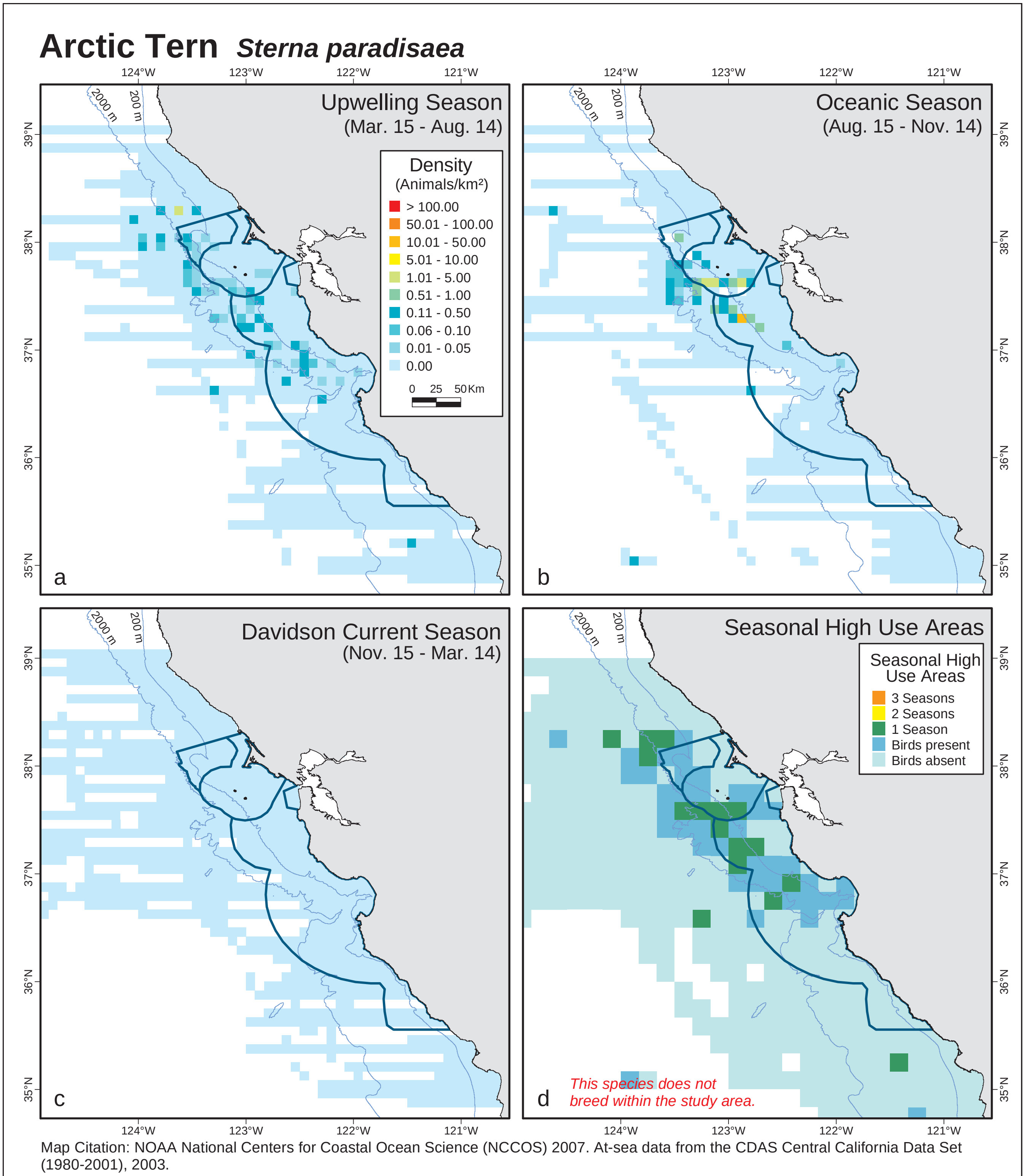


Figure 3.30. Arctic Tern: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Arctic Tern (*Sterna paradisaea*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5’ latitude by 5’ longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Arctic Terns were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species’ spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10’ latitude by 10’ longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

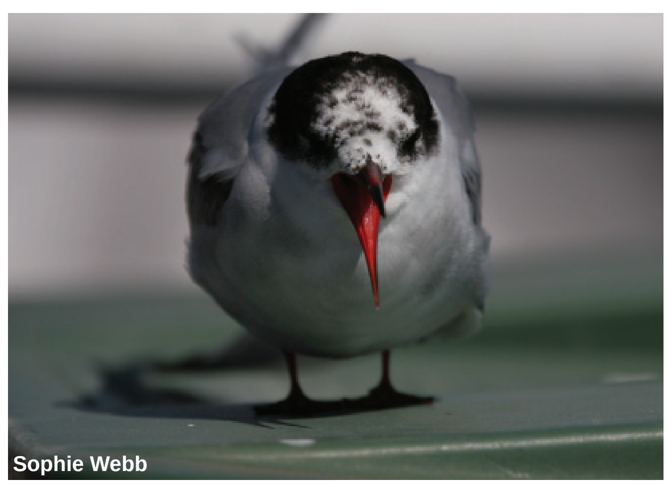
DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

Unlike most of the terns that frequent the study area, this species is found mainly in deep waters beyond the continental shelf. The Arctic Tern (and very similar Common Tern), as with the Sabine’s Gull, are found in the study area only during their migration between Arctic breeding areas and southern wintering areas, and have an identical temporal occurrence pattern as the Caspian and Elegant Terns. Surveys in CDAS recorded 262 sightings of 1,539 Arctic Terns. Generally, this species’ migration occurs well offshore, over the continental slope and beyond, where their presence is often associated with prey driven to the surface by albacore (*T. albacares*). The terns’ northward movement is during the early Upwelling Season, and the southward during the late Upwelling and Oceanic seasons; the species is virtually absent during the Davidson Current Season.

Arctic Terns feed on small fish and invertebrates that they catch by shallow plunging. See Tables 3.5 and 3.11 for related summary information.



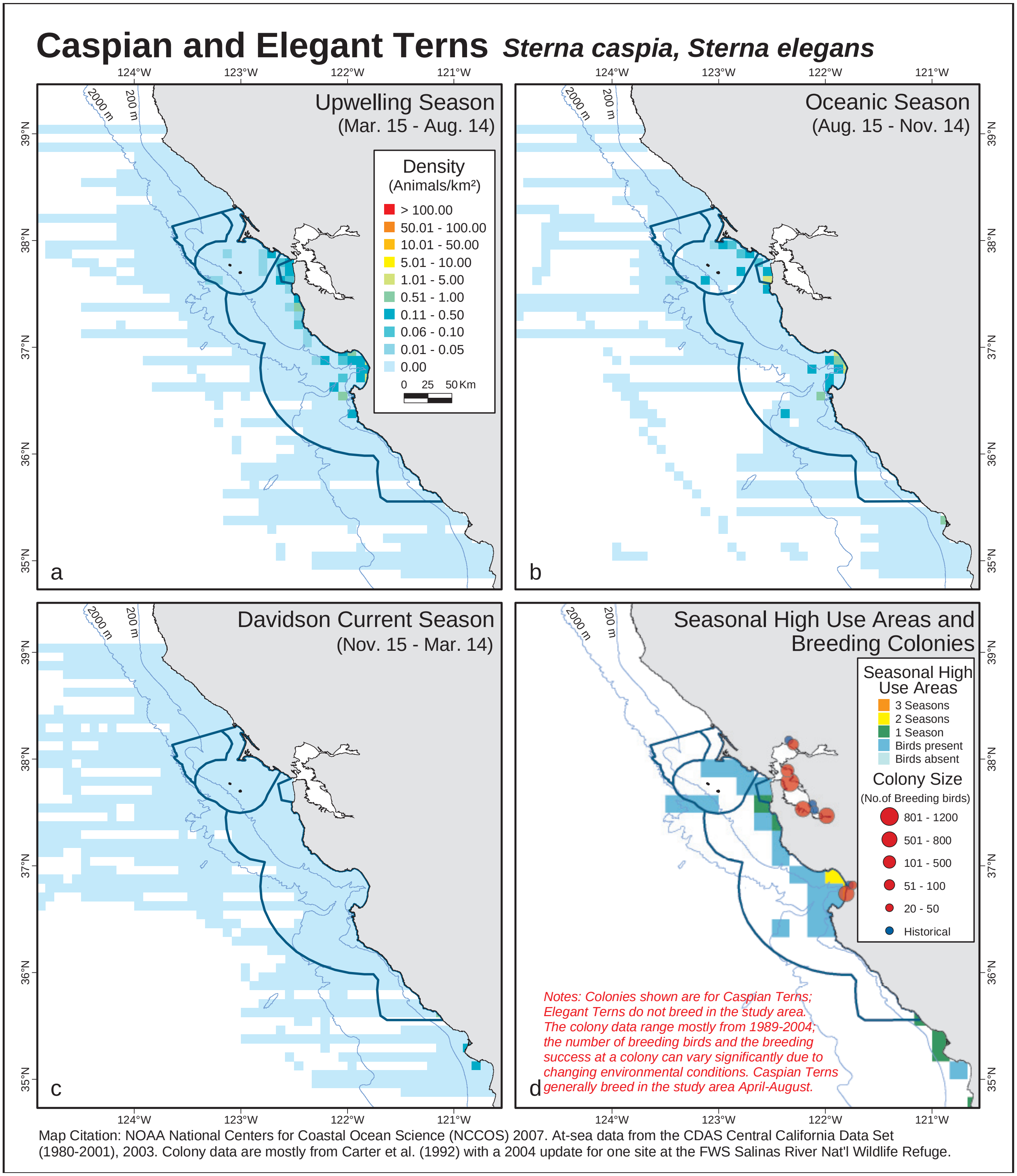


Figure 3.31. Caspian and Elegant Terns: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the combined at-sea density (birds/km^2) of Caspian Tern (*Sterna caspia*) and Elegant Tern (*S. elegans)*, in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Caspian or Elegant terns were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

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RESULTS AND DISCUSSION

Most of the terns in this region (with the exceptions of Arctic and Common terns) frequent shallow, inshore waters. The Elegant and Caspian terns occur regularly within the study area and primarily within the areas encompassed by the north/central California National Marine Sanctuaries, as well as other estuaries and bays, e.g., San Francisco Bay, Bolinas Lagoon. Both species are uncommon in the study area, although Elegant Terns can be locally common during periods of peak abundance. At-sea surveys used in CDAS recorded 98 sightings and 124 individuals of Caspian Tern, and 88 sightings and 186 individuals of Elegant Tern.

Caspian Terns nest in the study area during the Upwelling Season, after which they migrate south to waters off South America and out of the study area. Caspian Terns are present during the Oceanic Season, but almost absent during the Davidson Current Season. This species generally nests inland on artificial structures such as salt-pond levees, with two small populations in San Francisco Bay and another at Elkhorn Slough (see also Appendix 1A, the bird colony data table). Caspian Terns used to nest at the Moss Landing Salt ponds during a portion of this study period (in the early 1980s), but they no longer breed there. Since 1989-1990, several breeding sites have been abandoned and new sites colonized (Strong *et al.,* 2004). No trend in abundance is evident.

The Elegant Tern is a relatively large tern but smaller than the Caspian. Elegant Terns nest outside of the study area on islands and salt pond levees in the northern Gulf of California north to Long Beach, California. The Elegant Tern is present in the study area only during the late Upwelling Season and Oceanic Season, its post-breeding period. Important areas for these Elegant Terns are in the inner portion of Monterey Bay and within the San Francisco Bay tidal plume. Many of these terns roost at such places as Limantour Estero, Bolinas Lagoon and Elkhorn Slough. Like the Caspian Tern, the Elegant Tern is almost absent during the Davidson Current Season.

These two species feed entirely on small fish that they catch by plunging to shallow depths. See Tables 3.5, 3.7, 3.10 and 3.11 for related summary information.


Sophie Webb

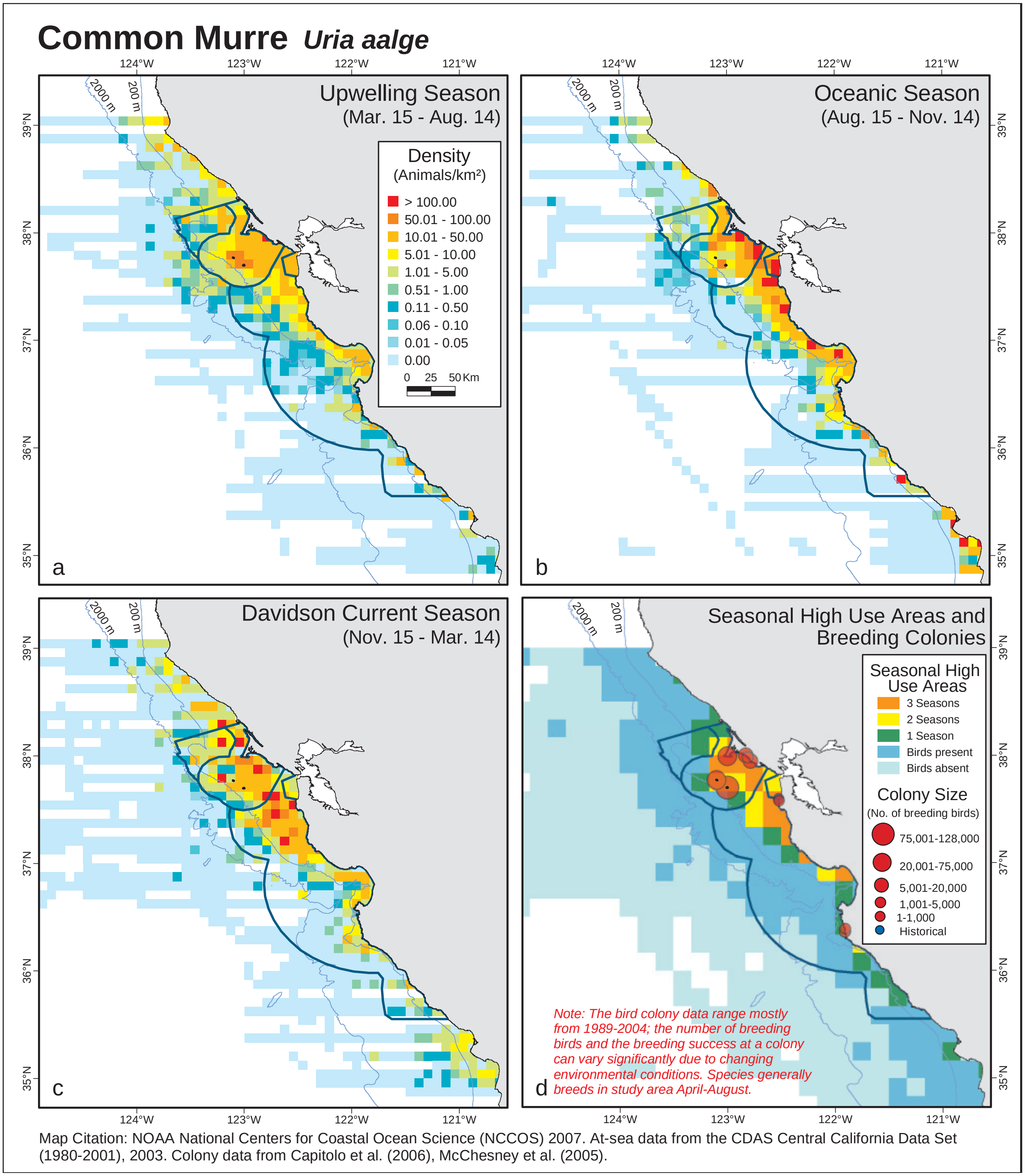


Figure 3.32. Common Murre: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Common Murre (*Uria aalge*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Common Murres were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

To provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods. Data on colony sizes were recently updated and obtained from Capitolo *et al.,* (2006) and McChesney *et al.,* (2005) for the 2004 breeding season. Aerial photographic surveys of colonies are conducted annually in late May to early June by the U.S. Fish and Wildlife Service in cooperation with Humboldt State University and California Department of Fish and Game. Murres nest in very dense aggregations, often shoulder-to-shoulder, and do not build nests; thus, estimating numbers is very difficult without aerial photography. Bird counts, therefore, were adjusted using a correction factor of 1.67 (Sowls *et al.,* 1980, Sydeman *et al.,* 1997) to account for pair members not present and nonbreeders present during the survey. An exception was at Devil's Slide Rock and Mainland, where a known number of breeding pairs was multiplied by two to provide number of breeding birds. This species demonstrates a clear pattern of diurnal nest attendance (Ainley and Boekelheide 1990).

RESULTS AND DISCUSSION

The Common Murre is very abundant in the study area, being the second most numerous marine bird (to Sooty Shearwater) in waters off central California, and is the most numerous breeding species in the study area. The at-sea surveys in CDAS logged 21,893 sightings of 141,964 individuals, with the ratio between these numbers confirming that murres usually occur in flocks. Within the study area, the species nests mainly within the Gulf of the Farallones at a complex of densely-occupied colonies, including the Farallon Islands, Point Reyes, Drakes Bay area (including Point Resistance, Millers Point Rocks, and Double Point Rocks), and a small colony at Devil's Slide Rock. This complex constitutes one of the largest, if not the largest, breeding population of this species south of Alaska. A relatively small, disjunct breeding population, the southernmost for this species, occurs on a complex of rocks ("Castle-Hurricane Colony Complex") off the northern Big Sur coast (Monterey Bay National Marine Sanctuary).

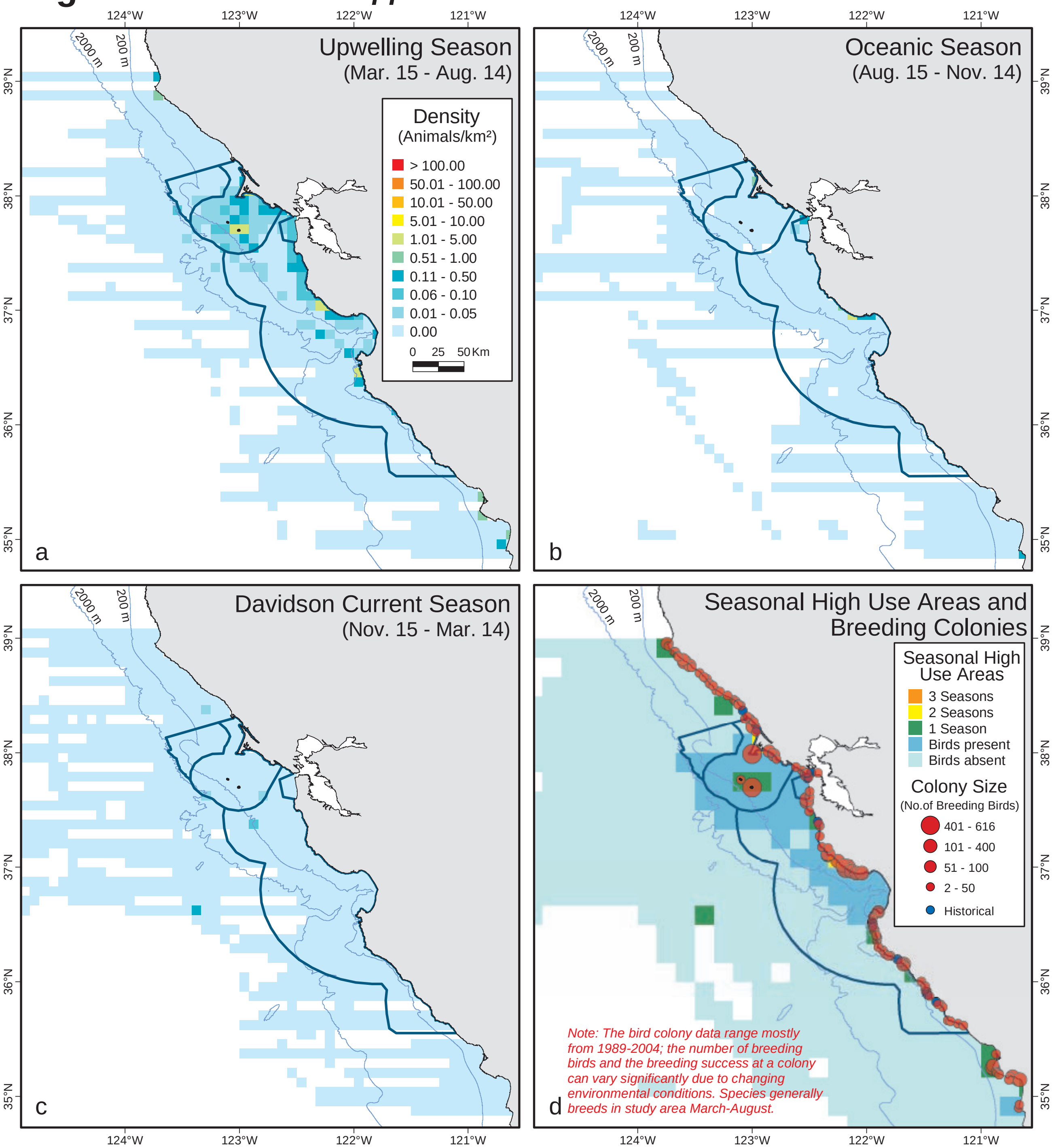
Common Murres reside in the study area year-round, being particularly abundant in waters overlying the shelf and upper slope (mean depth 110 ± 5 m), with little seasonal change in distribution. Murre densities in general, however, were significantly higher during the Upwelling Season, probably because the entire local breeding population is present at that time. During the other seasons, some breeding individuals likely disperse outside of the study area. Murres attend the breeding colonies at least sporadically during much of the non-breeding season, indicating that most of the breeding population remains within the area during the fall and winter. A multiple regression model of nine independent variables explained 52.3% of variation in density; especially through inverse relationships with distance to colony, ocean depth, and distance to land; see Table 3.8. No significant trend in Common Murre abundance existed between 1985 and 2002, and abundance was not affected by short-term climate fluctuations (e.g., periods of unusually warm or cold sea temperatures).

Near the large Farallon Island colonies during nesting, many Common Murres range seaward beyond the continental slope (and outside sanctuary boundaries), perhaps as a response to increased intraspecific competition for prey at that time. As a result, the Farallon Escarpment is an area of high concentration, as well as the Farallon Ridge and shelf waters inshore of it. Murres occur in Monterey Bay after nesting, especially during the Oceanic Season. During years of unusually warm waters (and depleted prey), murres occur more frequently inshore, especially along the coast from Point Reyes south to Año Nuevo Island, the usual area of concentration during the relatively warm Oceanic Season.

The central California Common Murre population is recovering from a large decline suffered in the late 1800s, with a small setback in recovery occurring the 1980s. This latter decline was attributed to large-scale mortality in a nearshore set gill-net fishery, oil spills, and the intense 1982-83 El Niño event (Takekawa *et al.,* 1990, Carter *et al.,* 2001). All central California colonies were affected, and a colony of about 3,000 murres at Devil's Slide Rock was extirpated. Closures to the gill-net fishery dramatically reduced anthropogenic mortality and the population began increasing again in the 1990s. By 2004, populations at some colonies had increased to near the pre-decline (early 1980s) level, although growth at the Castle-Hurricane colonies has been slower (G. J. McChesney, pers. comm.). A restoration project resulted in recolonization of the Devil's Slide Rock colony in 1996 (Parker *et al.,* 2007).

This species is a deep diver (to 180 m depth; Ainley *et al.,* 2002) that feeds on fishes and invertebrates. During winter and early spring, major prey include herring, market squid and euphausiids; the murre's diet then shifts mostly to juvenile rockfish and anchovies in mid-summer. See Tables 3.5 - 3.11 for related summary information.

Pigeon Guillemot *Cepphus columba*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from Carter et al. (1992), Warzybok et al. (2002) and McChesney et al. (2005).

Figure 3.33. Pigeon Guillemot: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km²) of Pigeon Guillemot (*Cepphus columba*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Pigeon Guillemots were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Data on colony sizes were obtained primarily from Carter *et al.,* (1992), with additional updates from Warzybok *et al.,* (2002) for South Farallon Islands and from McChesney *et al.,* (2005) for colonies at San Pedro Rock and Devil's Slide Rock and Mainland. Since Pigeon Guillemots nest in rock crevices and burrows, estimating breeding population size is very difficult. Most colonies are surveyed by counting birds rafting on the water or resting on the ground outside of nest sites. Breeding birds show a distinct diurnal pattern of when they sit at nest-cavity entrances (Ainley and Boekelheide 1990). Carter *et al.,* (1992) estimated breeding population sizes by adjusting bird counts with correction factors based on time of day of the survey. Counts from McChesney *et al.,* (2005) were adjusted using these same correction factors.

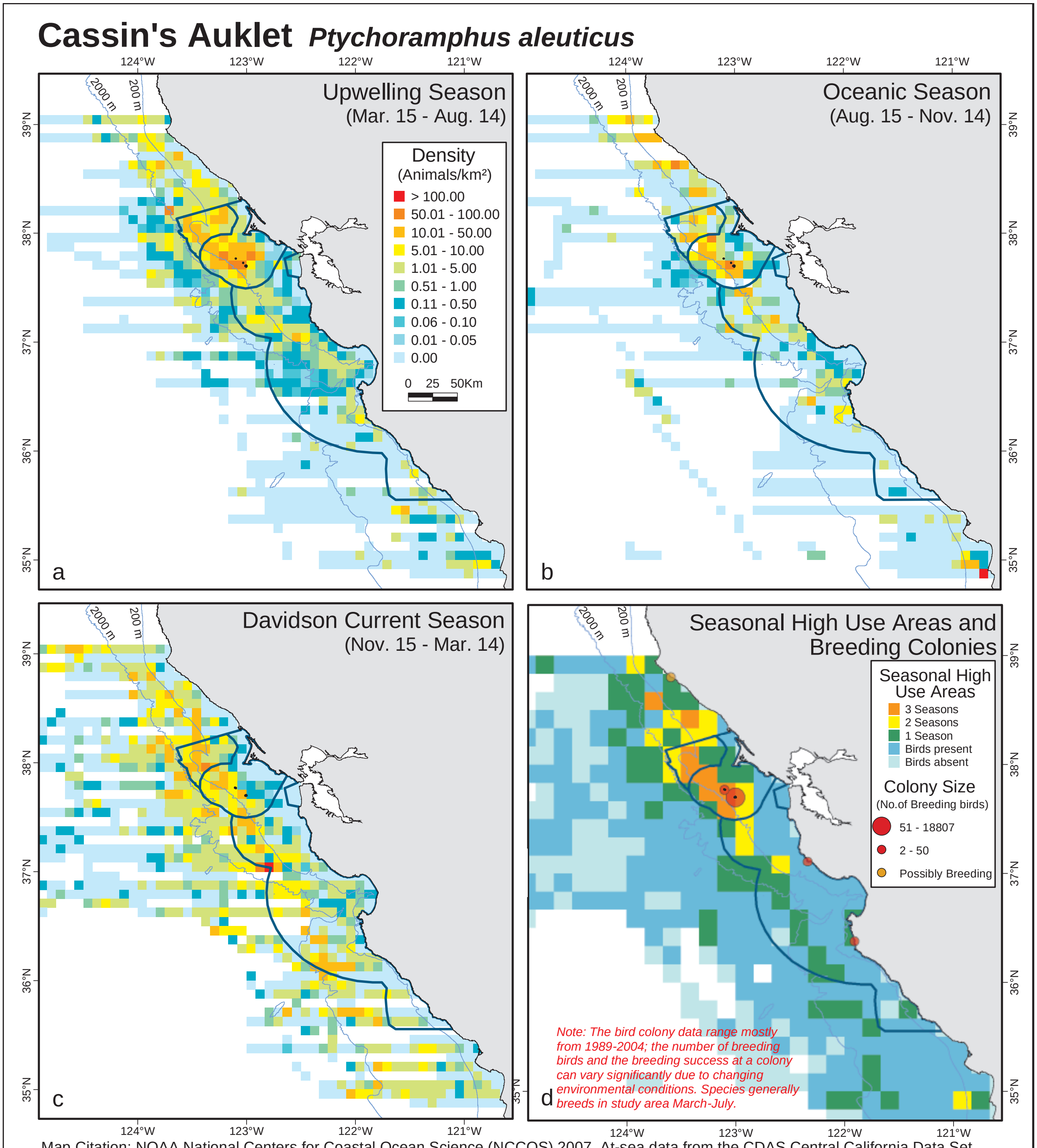
RESULTS AND DISCUSSION

The Pigeon Guillemot occurs uncommonly in the study area and mostly during the nesting season, which includes the Upwelling Season and the beginning of Oceanic Season; the species was almost absent in the Davidson Current Season. Surveys in CDAS recorded 467 sightings of 841 individuals. Because there was a relatively low number of at-sea sightings in CDAS, no regression model was attempted. The species frequents waters overlying rocky reefs close to nesting colonies. During the breeding season, this species congregates on the water within a few hundred meters of colonies, and since most at-sea surveys did not cover the nearshore area, densities close to shore are likely underrepresented and breeding colony data are a better representation of distribution (G. McChesney, pers.comm.).

One of the largest colonies anywhere occurs at the South Farallon Islands. Accordingly, a high density "halo" of guillemots extends around those islands (including the Farallon Ridge), with scattered individuals elsewhere. The National Marine Sanctuary boundaries encompass most of the areas where this species occurs in the study area. Important areas outside of the sanctuary boundaries are around Point Buchon, as well as Estero and San Luis Obispo bays.

In the study area, Pigeon Guillemots are one of the most widespread breeding species (see also Appendix 1A, the bird colony data table). In 1989, Pigeon Guillemots were the fifth-most abundant breeding seabird (Carter *et al.,* 1992). Beyond the Gulf of the Farallones, they were the second-most abundant breeder. Largest nesting areas include Fish Rocks, Point Reyes, South Farallon Islands, the southern San Mateo and Santa Cruz county coasts, Point Buchon area, and the Shell Beach area. Little overall trend was evident between 1980 and 1989 surveys (Carter *et al.,* 1992). Current data are inadequate to assess trends since 1989.

Pigeon Guillemots feed on benthic fish, such as juvenile rockfish, blennies and sculpins, and invertebrates, such as grass shrimp and octopus. Pigeon Guillemots mostly forage in rocky substrates. See Tables 3.5, 3.7, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from the following sources: Carter et al.(1992), Thayer and Sydeman (2002 a, b), Warzybok et al. (2002); and personal communications from Gerry McChesney, FWS.

Figure 3.34. Cassin's Auklet: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Cassin's Auklets (*Ptychoramphus aleuticus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Cassin's Auklets were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Data on colony sizes were obtained from Carter *et al.,* (1992), Thayer and Sydeman (2002a, b), Warzybok *et al.,* (2002), and McChesney *et al.,* (2000a), and McChesney (pers. comm.).

RESULTS AND DISCUSSION

Despite being listed by the state of California as a "Species of Special Concern" because of recent declines, Cassin's Auklet is abundant and widely distributed in the study area. Surveys in CDAS recorded 11,661 sightings of 69,733 birds.

Cassin's Auklets mainly frequent waters of the outer shelf and inner slope, both inside and outside marine sanctuary boundaries (mean depth of water where the species occurred was 354 ± 13 m), depending on season. A multiple regression model of nine independent variables explained 25.8% of variation in density. The top three variables included negative relationships with distance to land and distance to the colony, as well as with year; see Table 3.8. The decrease in density with year was very abrupt between 1984 and 1997. However, for the entire study period, 1985-2002, the relationship was curvilinear indicating that the population later stabilized and had possibly begun to increase with the switch to a cool water period that began in 1999. Should the population increase further, its distribution likely will expand in the waters around the Farallones, thus mimicking the "halo" of foraging individuals exhibited by other Farallon breeding species.

Cassin's Auklets were most abundant during the Upwelling (nesting) Season (mean density 462 birds per 100 km^2) compared to the Oceanic and Davidson Current seasons (188 and 132 birds per 100 km^2, respectively). This pattern is likely the result of individuals moving out of the study area after breeding. During the Davidson Current Season these auklets occurred farther offshore (mean depth was 1,338 m and mean distance from land was 35 km) than they did during the other two seasons. During the Upwelling Season, the primary occupied habitat shrank mostly to the slope and outer shelf (mean depth was 262 m, mean distance was from land (Farallones) 12.4 km) as the population became more centered around the Farallones colony, where the primary nesting population exists. These auklets visit colonies only at night and do so throughout most of the Davidson Current and Upwelling seasons. During the Oceanic Season, the Cassin's Auklet population moved northward toward Cape Mendocino, although it remained close to the shelf break (mean depth 385 m). Cordell Bank, Fanny Shoal and Farallon Escarpment were important foraging areas. During the Upwelling Season, the Cordell and Gulf of the Farallones National Marine Sanctuaries, plus the northern part of Monterey Bay National Marine Sanctuary, contained a sizeable proportion of the region's auklets. The species occurred in all three National Marine Sanctuaries during all three ocean seasons.

In the study area, Cassin's Auklets breed almost entirely at the South Farallon Islands; see also Appendix 1A, the bird colony data table. Recent discoveries of scattered small colonies indicate the species may be more widespread than previously known. The large Farallon colony has decreased in numbers markedly since the early 1970s (Carter *et al.*, 1992; Warzybok *et al.,* 2002), possibly due to declines in its favorite prey.

Cassin's Auklets feed by diving to shallow depths in deep waters, where it feeds on invertebrates (especially krill, amphipods and crab megalops) and larval fish. See Tables 3.5, 3.7, 3.8, 3.9, 3.10 and 3.11 for related summary information.

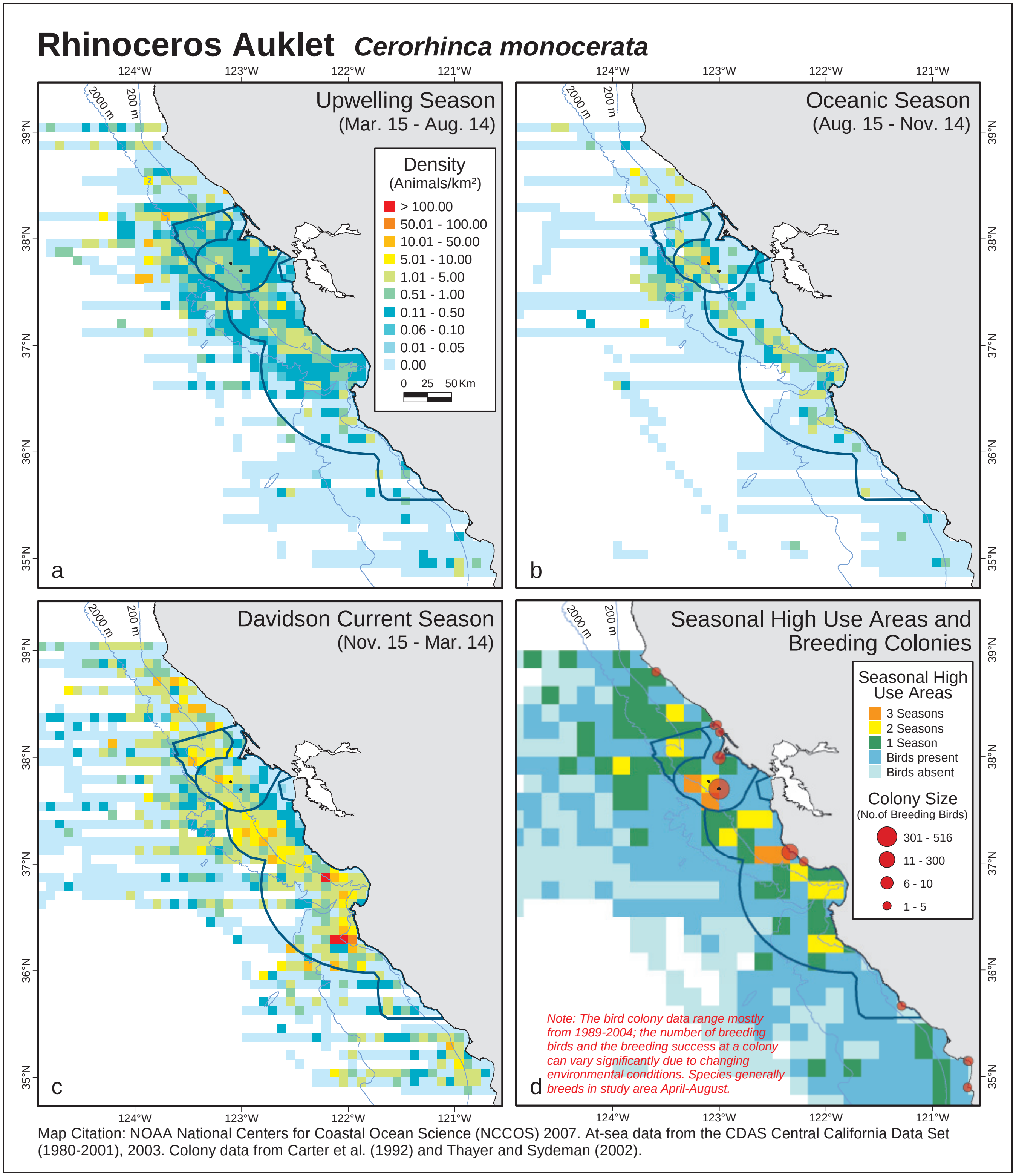


Figure 3.35. Rhinoceros Auklet: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Rhinoceros Auklet (*Cerorhinca monocerata*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Rhinoceros Auklets were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Data on colony sizes were obtained primarily from Carter *et al.,* (1992), Thayer and Sydeman (2002a,b), Warzybok *et al.*, (2002), McChesney *et al.,* (2000), and G.J. McChesney (pers.comm). Because this species nests in burrows and crevices and is active only at night and crepuscular periods, estimating breeding population size is difficult. Depending on the colony, estimates have been based on counts of nest burrows, birds counted on the water adjacent to nesting areas, or birds counted flying into colonies at dusk.

RESULTS AND DISCUSSION

In the study area, this species nests principally at the South Farallon Islands, with smaller nesting populations at Año Nuevo Island and several other sites (see Appendix 1A). At-sea surveys in CDAS recorded 5,415 sightings of 15,454 individuals. Based on the analysis of the combined data sets described in this section, the abundance of Rhinoceros Auklets has increased significantly since the 1970s (Ainley *et al.*, 1994). Based on patterns apparent in the maps, the current at-sea population probably far exceeds the nesting population in central California (Michelle Hester, pers. comm.). Therefore, if there was more nesting habitat (e.g., burrows, holes, crevices on offshore islands), the nesting population would probably be much larger.

In the CDAS central California data set, Rhinoceros Auklets occurred principally in waters overlying the slope (mean depth where the species occurred was 762 ± 22 m), particularly over the shelf break, and including the Farallon Escarpment. A sizeable proportion of the population occurs outside of the National Marine Sanctuary boundaries. This is especially true in the vicinity of the Gulf of the Farallones during the Upwelling (nesting) and Oceanic seasons, when these auklets occur farther offshore (mean depths 791 m and 1,370 m, respectively). This expansion of habitat, causing a 'halo' of increased density around the islands, may be a response to the large numbers nesting at the Farallones, a pattern exhibited by the Western Gull and Common Murre as well (see those map discussions). The species' concentration, especially along the shelf break and upper continental slope, is particularly evident during the Oceanic Season, at which time the nesting populations are no longer associated with colonies. Rhinocereos Auklet occurred in the study area during all three ocean seasons.

A multiple-regression model of nine independent variables in the CDAS data set explained 19.8% of variation in cell density; important variables were a negative relationship to distance to land, and positive ones to season and ocean depth; see Table 3.8. The relationship with season reflected a dramatic increase in abundance during the Davidson Current Season (mean density of 161 birds per 100 km^2) compared to the Upwelling and Oceanic seasons (mean densities of 48 and 62 birds per 100 km^2, respectively). This increase during the Davidson Current Season was likely due to an influx of birds from the north where much larger populations breed compared to those of the study area.

Rhinoceros Auklets recolonized the South Farallon Islands in the early 1970s after nearly a century of absence (Ainley and Boekelheide, 1990). Since then, numbers on the islands have increased and other colonies have been founded. These auklets now nest south to the northern Channel Islands off southern California (Carter *et al*., 1992).

Rhinoceros Auklets feed by diving, probably to relatively deep depths (100 m; Ainley and Boekelheide, 1990), capturing mostly fish but also euphausiids. Important prey include juvenile rockfish, anchovy and saury. See Tables 3.5 - 3.11 for related summary information.

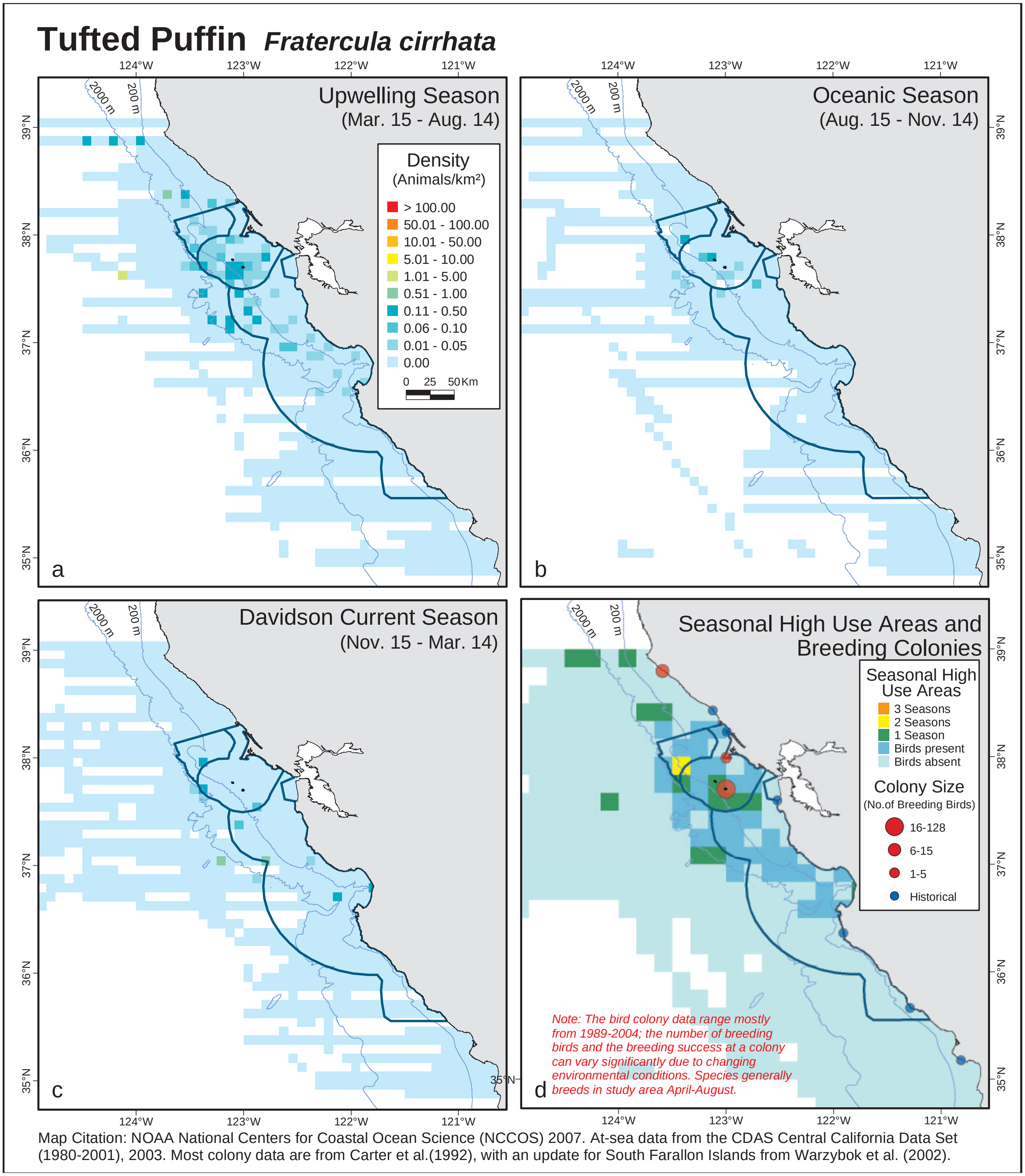


Figure 3.36. Tufted Puffin: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km²) of Tufted Puffin (*Fratercula cirrhata*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species.

Cells that were surveyed but in which no Tufted Puffins were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Most data on colony sizes were obtained from Carter *et al.,* (1992), with additional updates from Warzybok *et al.,* (2002) for South Farallon Islands. Because this species nests in burrows and crevices, estimating breeding population size is difficult. However, they have a distinct diurnal pattern of when they sit by cavity entrances, especially during the evening (Ainley and Boekelheide 1990). Therefore, most estimates were based on bird counts adjusted with a correction factor (based on time of day) to account for breeding birds not observed on the survey (Carter *et al.,* 1992). Estimates at South Farallon Islands were based on counts and monitoring of potential nesting pairs throughout the breeding season (Warzybok *et al.,* 2002).

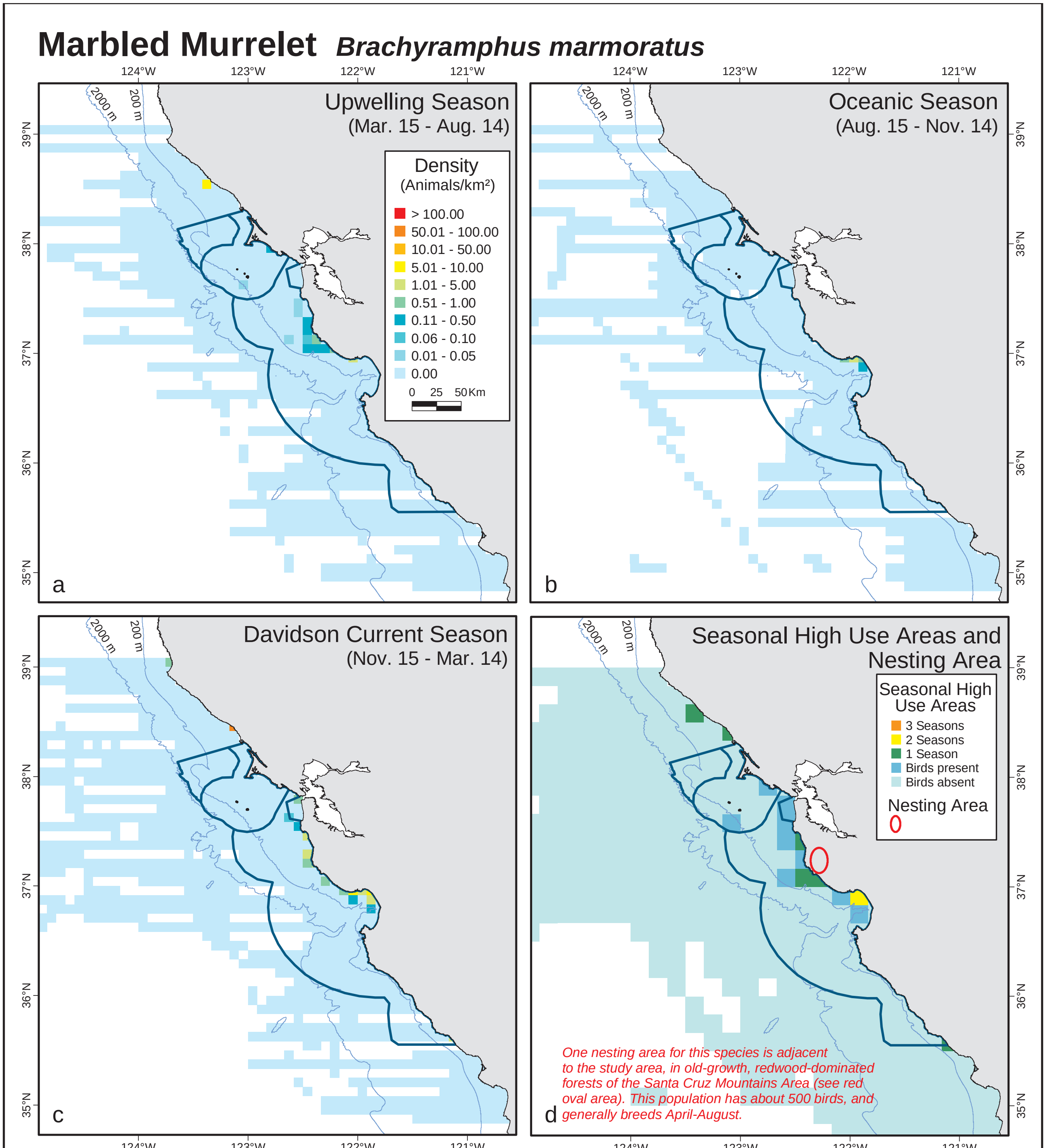
RESULTS AND DISCUSSION

Tufted Puffin is listed by the State of California as a "Species of Special Concern" because of long-term declines and contraction of the breeding range (McChesney *et al.,* in press b). The largest colony in California is at the South Farallon Islands; even so, that population included only 128 breeding birds in 2002. Overall, the species is considered to be uncommon in the study area. Surveys in CDAS recorded 197 sightings of 245 individuals. Accordingly, a high density "halo" of puffins extended around those islands (including the Farallon Escarpment), with scattered individuals elsewhere during the Upwelling Season. The National Marine Sanctuary boundaries encompass these areas of high density. Having migrated north after breeding during the Upwelling Season, Tufted Puffins are all but absent during the remainder of the year.

A multiple-regression model of nine independent variables explained only 10.1% of the variation in this species' cell density; the top three variables were negative relationships with distance to colony, year, and distance to the 200 m isobath; see Table 3.8. These results are consistent with the maps: presence was strongly affected by the location of the Farallon colony, and the preferred habitat over the upper slope (mean depth of occurrence was 487 m). This species' negative relationship between density and year reflected an appreciable decrease in abundance within the study area between 1985 and 2002.

In the study area, few Tufted Puffins nest outside the South Farallon Islands colony; see also Appendix 1A, the bird colony data table. During the 19th and early 20th centuries, this species was more common and widespread in California. Now only a remnant population exists. Reasons for the decline and lack of recovery are unclear but include introduction of feral animals to large islands and alterations of the marine food web due to overfishing and changes in climate (Ainley and Lewis, 1974).

Tufted Puffins can dive to depths exceeding 100 m when foraging on fish and invertebrates (such as squid). See Tables 3.5, 3.7, 3.9, 3.10 and 3.11 for related summary information.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Information on nesting area provided by Steve Hampton, CDFG, 2006.

Figure 3.37. Marbled Murrelet: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) of Marbled Murrelet (*Brachyramphus marmoratus*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no Marbled Murrelets were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

The information on the Marbled Murrelet breeding population adjacent to the study area was from Steve Hampton (CDFG), pers. comm. 2006.

RESULTS AND DISCUSSION

The Marbled Murrelet is designated a Federal threatened species and a California state-listed endangered species. This species has shown a decline since the beginning of the study period (1980). At-sea surveys in the CDAS central California data set recorded 170 sightings of 357 individuals. Based on CDAS (1980-2001), the species is considered to be uncommon in the study area. During breeding in the Upwelling Season, it is found in coastal waters adjacent to where it nests, i.e. the old growth forest, inland from Año Nuevo, in the Santa Cruz Mountains area (see below). It moves to and from its nesting sites at dawn and dusk. Most Marbled Murrelets occurred in ocean waters within 1-2 km of shore. After breeding, the majority of the population moved to northern Monterey Bay for the remainder of the year. Therefore, the Monterey Bay National Marine Sanctuary includes most of the important marine habitat for this population. Marbled Murrelets tend to spread farther offshore during warmwater periods.

Adjacent to the study area, the species nests in old-growth, redwood-dominated forests of the Santa Cruz Mountains. The current population estimate of Marbled Murrelets in this area is approximately 500 birds for the entire Santa Cruz Mountain area, including Big Basin Redwoods State Park, as well as nearby parks and surrounding areas. The area includes the drainage areas of Pescadero, Butano, Gazos, Waddell, and Scott Creeks. This estimate of 500 includes all marbled murrelets - adults, juveniles, etc. The number of breeding pairs is probably much less than 200, and the number actually nesting in a given year could easily be less than that. In 2004, the Fish and Wildlife Service reported that the southern population in California could be gone within the next several decades. Old-growth forest logging, predation and oil spills are key threats to this small, tree-nesting seabird's survival.

Given its rareness and the restricted area occupied by this species, a multiple-regression model of nine independent variables of the CDAS data set explained only 4.7% of variation in density; the top three variables included ENSO period (higher abundance during La Niña - cool water periods), and negative relationships with distance to land and latitude. In addition to La Niña, this species was also more abundant during the Davidson Current Season (mean density 4.3 birds per 100 km^2) than during the Upwelling and Oceanic seasons (mean densities 1.3 and 0.3 birds per 100 km^2, respectively). Higher at-sea abundance during the Davidson Current Season likely reflected individuals being free of nesting duty.

The Marbled Murrelet feeds by diving in shallow waters, where it preys on euphausiids and fish (e.g., smelt, anchovy, juvenile rockfish). See Tables 3.5, 3.8, 3.9, 3.10 and 3.11 for related summary information.

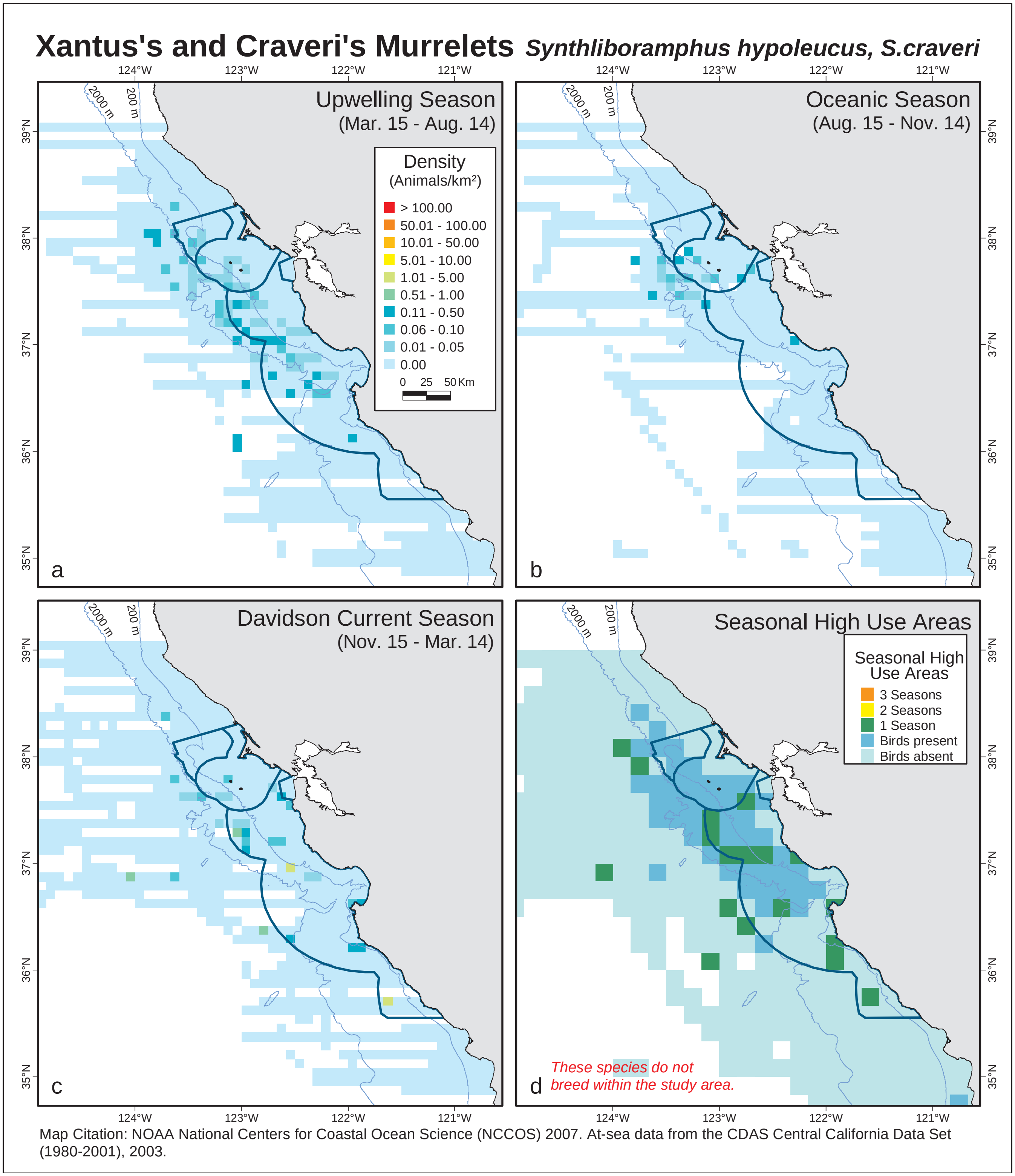


Figure 3.38. Xantus's and Craveri's murrelets: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the combined at-sea densities (birds/km^2) of Xantus's Murrelet (*Synthliboramphus hypoleucus*) and Craveri's Murrelet (*Synthliboramphus craveri*) in three ocean seasons – Upwelling, Oceanic, and Davidson Current, displayed in cells of 5' latitude by 5' longitude. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas, while allowing comparisons among marine bird species. Cells that were surveyed but in which no murrelets were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

In order to provide an integrated look at the patterns of a species' spatial and temporal occurrence and abundance in the study area, map d shows seasonal high-use areas, displayed in cells of 10' latitude by 10' longitude, and also breeding colonies (when available). The seasonal high use map provides a further synthesis of densities presented in maps a, b and c, and portrays the relative importance of various areas to the species. Areas with consistently high use are highlighted. See the Data and Analyses section of this chapter for further explanation of high-use areas.

DATA SOURCES AND METHODS

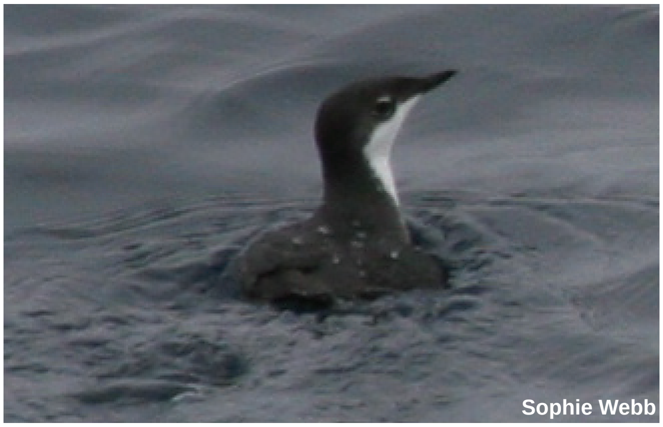
The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

RESULTS AND DISCUSSION

Xantus's Murrelet, a California state-listed threatened species, frequents waters in the study area, mostly over the continental slope and deeper depths. Craveri's Murrelet, although not rarely sighted, appears to occur in the same general habitat but perhaps further offshore. The two species are impossible to tell apart in aerial surveys; thus they are treated together here. Xantus's Murrelet nests on islands off northwest Baja California, Mexico and the California Channel Islands during the late Davidson Current Season and Upwelling Season. Craveri's Murrelet breeds enitirely in Mexico on islands in the Gulf of California and southwestern Baja California. The two species are seen most frequently in the study area during the Upwelling (post-breeding) season and to a lesser degree, during the early Davidson Current (pre-breeding) seasons. This occurrence pattern represents post-breeding and pre-breeding movements of this species.

These seabirds do not appear to be well detected by aerial surveys, which would explain their concentration off the Gulf of the Farallones where shipboard surveys have been more frequent. Even unidentified murrelets appear to be sparse in suitable habitat lying to the north and south (where aerial surveys have been conducted). Xantus Murrelet is considered to be uncommon in the study area and Craveri's Murrelet is rare. Together, the species occur (sparsely) in the study area during all three ocean seasons.

Xantus Murrelets are generalist feeders; their diet includes euphausiids and small fish, such as anchovies. Craveri's Murrelets have a similar diet. See Tables 3.5, 3.10 and 3.11 for related summary information.



Sophie Webb

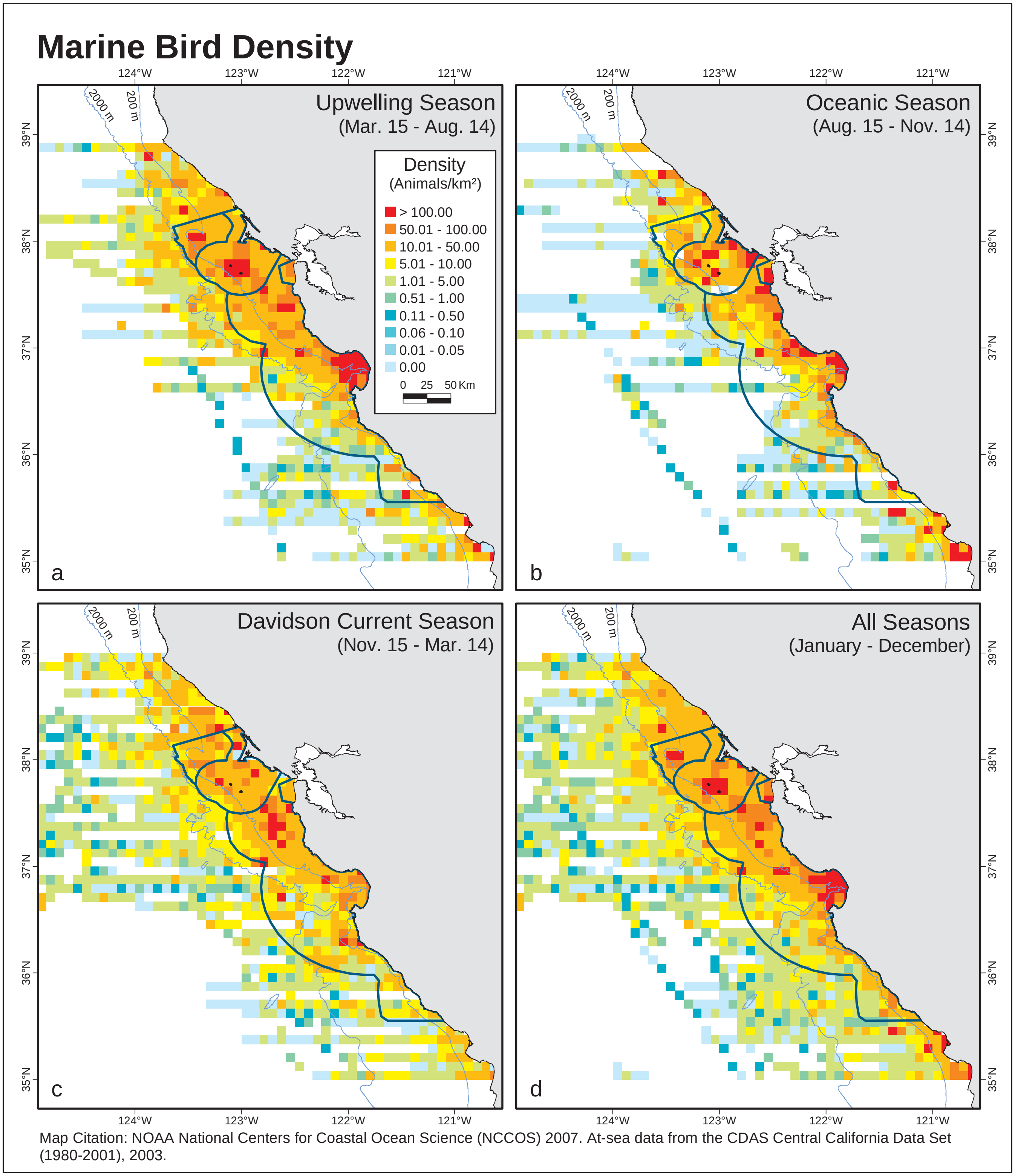


Figure 3.39. Marine bird density, by season and for all seasons.

ABOUT THESE MAPS

Maps a, b and c show the combined density (birds/km^2) of 76 species of marine birds in the Upwelling, Oceanic, and Davidson Current seasons, displayed in 5' latitude by 5' longitude cells. Map d shows density for all seasons and years combined. Densities are based on combined data of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas. Cells that were surveyed but in which no birds were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

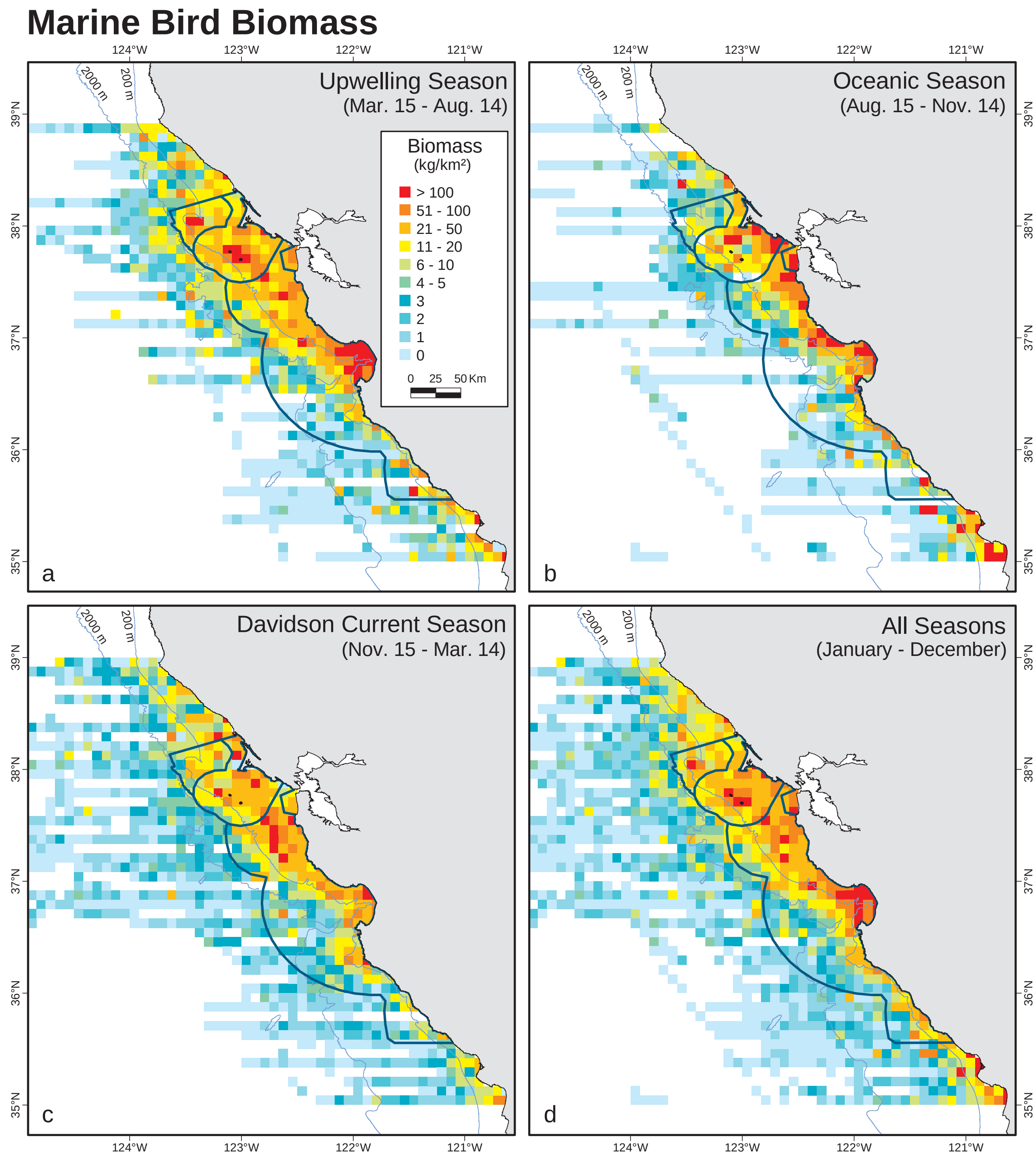
RESULTS AND DISCUSSION

Overall marine bird density in the study area is dominated by two abundant marine bird species: Common Murre and Sooty Shearwater.

Based on visual inspection of the maps, density was highest, with cells of highest values most widespread as well, during the Upwelling Season. Except for a few highest-density hotspots (see Tables 3.5 and 3.6), marine birds were distributed relatively evenly at high density (>10 individuals per km^2) over the shelf and slope, from north to south in the study area. Particular hot spots were: inshore Monterey Bay, Farallon Ridge and Cordell Bank. The pattern during of the Upwelling Season map generally matched the pattern on the all seasons map. This is because upwelling dominates the processes that contribute to the trophic richness in this system.

During the Oceanic Season, highest density areas increased in prevalence inshore. This was because more feeding habitats occurred inshore, where in shallower depths, more microhabitats were available. In this season, hot spots were the San Francisco Bay tidal plume, inshore near Año Nuevo, innermost Monterey Bay and San Luis Obispo Bay.

Bird density shifted more to mid-shelf during the Davidson Current Season. The California Counter Current altered the oceanography sufficiently to bring more feeding opportunities offshore.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.40. Marine bird biomass, by season and for all seasons.

ABOUT THESE MAPS

Maps a, b and c show the combined biomass density (birds/km^2) of 76 species of marine birds at sea in three ocean seasons - the Upwelling, Oceanic, and Davidson Current, displayed in 5' latitude by 5' longitude cells. Map d shows density for all seasons and years combined. Densities are based on the combined data sets of several studies; see the Data and Analyses section of this chapter. These analyses provide an example of how marine birds may respond to short-term excursions from the usual marine climate. For a description of how these periods were chosen, see the following topic in the introduction and summaries sections of the bird chapter: “Response to Variation in Marine Climate”.

In this comparison, densities were converted to biomass by multiplying density by body mass of each species. This comparison, where it includes all species, emphasizes the larger-bodied species, such as Sooty Shearwater and Common Murre, which make a larger contribution to the overall biomass.

The color and mapping intervals were selected to show the most structure and highlight significant areas. Cells that were surveyed but in which no birds were observed have a density of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

Calculating Biomass. Data on average biomass for each species were derived from Body Weights of 686 Species of North American Birds (Dunning, 1993); see Appendix 2. In a few instances, a species was not listed in this reference; in these cases, the biomass of a closely related bird of a similar size was used. Four overall biomass maps were developed: three ocean season biomass maps and one “all seasons” biomass map. The length and width of the survey trackline in a given cell were used to estimate the area sampled on a particular survey. The number of marine birds seen in a cell was divided by the area sampled in the cell to estimate overall marine bird density per cell. If a cell was surveyed more than once, densities were averaged, with an adjustment made for effort. Once the weighted densities had been determined for each species in each cell, densities of each species were multiplied by the average body mass of that species. These ‘biomass densities’ were then summed for each cell and the results plotted.

RESULTS AND DISCUSSION

In general, the biomass maps are dominated by two, relatively heavy-bodied, numerically dominant species: Common Murre and Sooty Shearwater. These maps are also influenced, to a lesser degree, by the species identified as abundant in the study area (see Table 3.11).

High biomass densities generally occurred over the shelf and upper slope. More specifically, looking first at a summary of all seasons, high biomass densities occurred in: Gulf of the Farallones, especially around the Farallon Islands; San Francisco Bay tidal plume; the area off Half Moon Bay; the area just south of Point Año Nuevo; and in inner Monterey Bay.

During the Upwelling Season, high biomass densities occurred over the shelf and upper slope, with highest density areas occurring mainly at Monterey Bay, Farallon Ridge, and Cordell Bank. The distribution of high biomass during the Upwelling Season mimicked that described in the all seasons map (map d), likely because upwelling dominates the processes that bring avian prey to the region.

During the Oceanic Season high biomass was concentrated more over the inner shelf than in the Upwelling Season, particularly evident from Pt. Reyes to Monterey, as well as in San Luis Obispo Bay. The inner shelf is fragmented into more, mostly depth-defined, microhabitats, thus offering more feeding opportunities to birds.

During the Davidson Current Season, virtually the entire continental shelf from Pt. Reyes to Pt. Sur exhibited high marine bird biomass. With the counter current in full swing, additional factors (e.g., other than upwelling, depth, etc.) were affecting the availability of prey in the region.

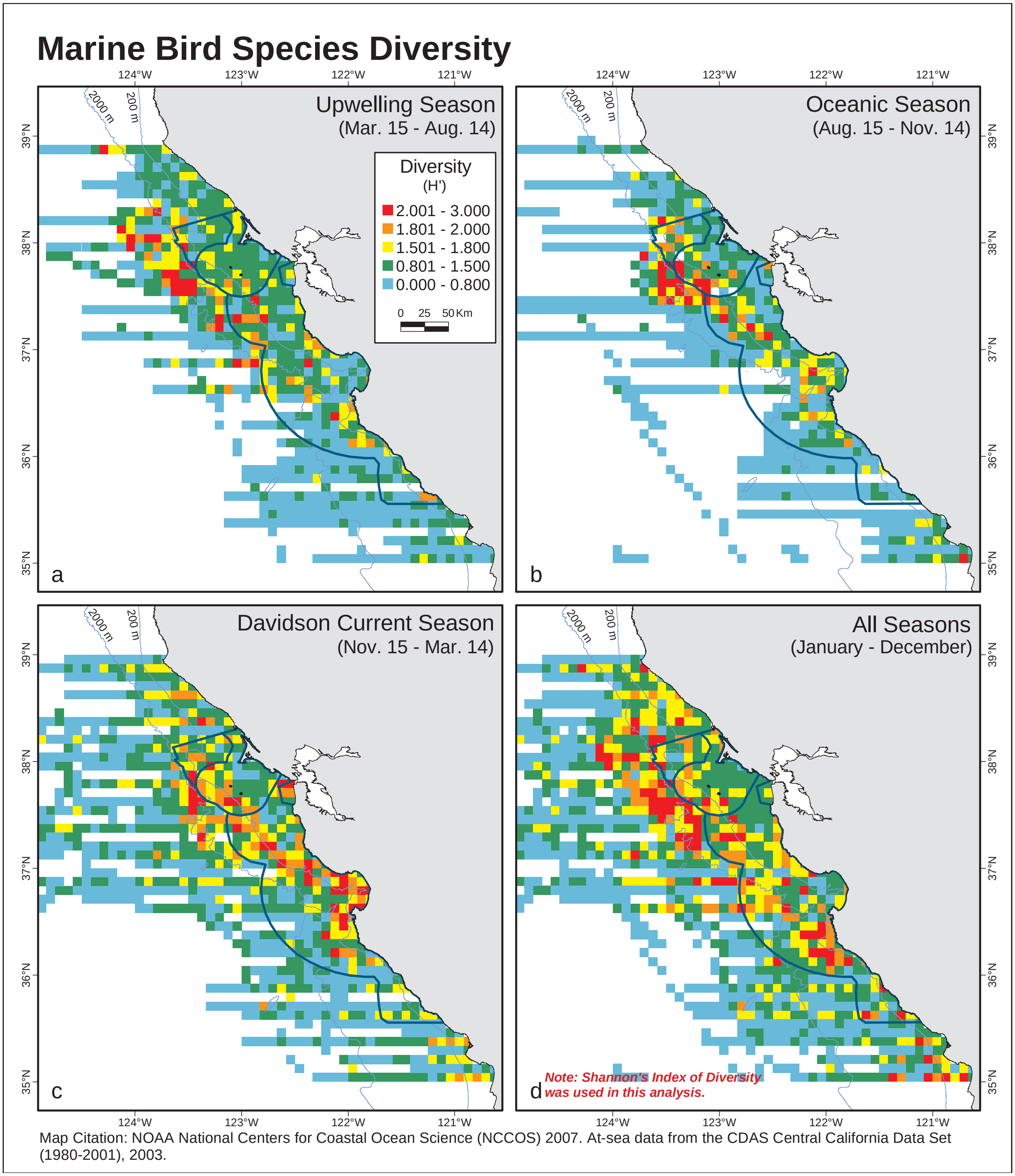


Figure 3.41. Marine bird diversity, by season and for all seasons.

ABOUT THESE MAPS

Maps a, b and c show the diversity of marine birds at sea, based on data from 76 species in the Upwelling, Oceanic, and Davidson Current seasons, displayed in 5' latitude by 5' longitude cells. Map d shows diversity for all seasons and years combined. Species diversity was calculated using density as variable in the Shannon Index of diversity (Shannon and Weaver 1949). All 76 marine bird species that had been recorded in the data set and study area were included in the analysis. This diversity index (H') measures the degree to which a species assemblage is dominated by a few species. If a cell contains high densities of a few species and low densities of all others, the value of H' will be low, indicating low diversity. Alternatively, if many species are present at similar densities, the value will be high, indicating high diversity.

Diversity index values were based on the combined data of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas. Cells are colored based on the value of H' computed for a particular ocean season, or for map d, all seasons. Red indicates high diversity, blue indicates low diversity. Cells that were surveyed but in which no birds were observed have a diversity of zero. Areas not surveyed appear white; no information was available for these areas. 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 m and 2,000 m isobaths are shown in light blue.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

The Shannon Index was selected as the diversity metric; see the Data and Analyses section of this chapter for information on the at-sea survey data sets, data synthesis, and analysis methods used. Species diversity was estimated for the three oceanographic seasons and all seasons using CDAS data from 1980-2001.

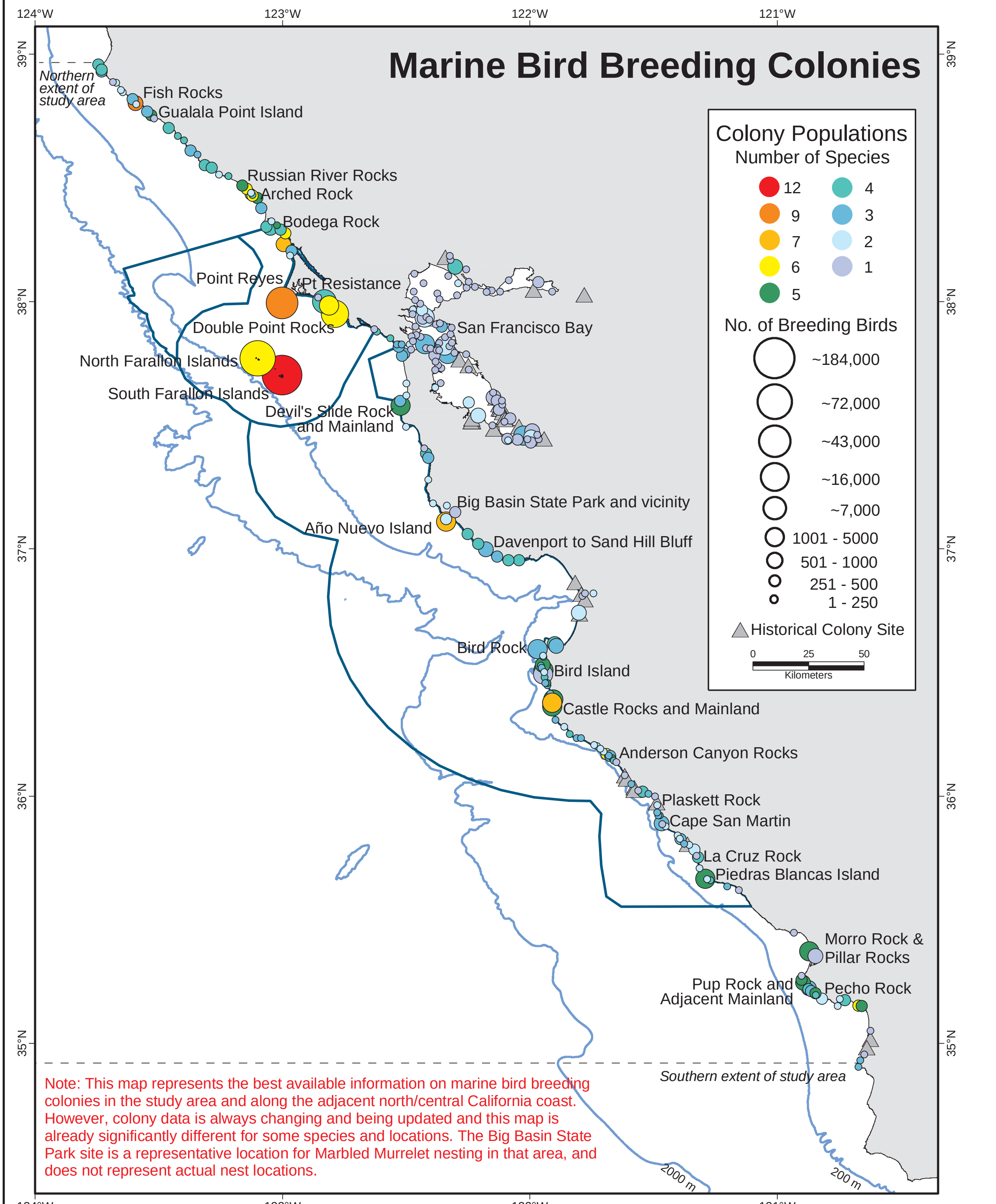
RESULTS AND DISCUSSION

In the summary of all seasons from 1980-2001 (map d), the marine avifauna was most diverse in areas largely outside of National Marine Sanctuary boundaries, especially in areas over the continental slope and particularly the Farallon Escarpment. Localized areas of high diversity occurred within sanctuary boundaries, and included: Pioneer, Ascension/Cabrillo, and Carmel canyons, as well as the continental slope off Point Sur.

During the Upwelling Season (spring/summer), the avifauna was the least diverse; areas of highest diversity in this season included waters over the Farallon Escarpment, and Pioneer, Ascension, and Carmel canyons. This is the season when the avifauna is dominated by locally breeding species and Sooty and Pink-footed Shearwater, with many wintering species gone to their more northern breeding locations.

During the Oceanic Season (fall), diversity was comparable to that of the Upwelling Season in general. Areas of high diversity continued to include the Farallon Escarpment area, Pioneer Canyon and inner Monterey Bay Canyon. During this season, some breeding species or major portions of their populations have departed (e.g., various alcids), while other species have come to the region from locations elsewhere (e.g., Elegant Tern, California Brown Pelican).

During the Davidson Current Season (winter), marine bird diversity, in general, was the highest of the year. Areas of high diversity were all localized, and most occurred over the continental slope (e.g., Farallon Escarpment, and Pioneer, Ascension, Monterey Bay and Carmel canyons) but some also occurred over the shelf (e.g., the inner San Francisco Bay tidal plume and inner portions of Monterey Bay). Many species of birds, breeding elsewhere, have come to the region at this time of the year. Here, food is abundant and weather is more benign than farther north. See related Tables 3.5 and 3.6.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Sources: Most data are from Carter et al. 1992, with updates from Capitolo et al. 2004, 2006, McChesney et al. 2005, Whitworth et al. 2002, Sydeman et al. 1998, and personal communcations from Harry Carter, Steve Hampton, Bill Sydeman and Gerry McChesney. Map developed by Janet Casey, Wendy Williams and Tracy Gill.

Figure 3.42. Marine bird breeding colonies along the coast of north/central California.

ABOUT THIS MAP

This map shows the locations and relative sizes of all known marine bird breeding colonies within the study area, based on best available information. The total number of breeding birds of all marine bird species is indicated by the size of the circle, while the number of species using a particular colony is indicated by the circle color. Table 3.7 shows the top 50 largest colonies of breeding marine birds in the study area, and Appendix 1A and 1B contains information on all breeding bird colonies in the study area.

DATA SOURCES

Data on marine bird colonies were derived primarily from "Breeding Populations of Seabirds in California, 1989-1991" (Carter *et al.,* 1992, unpublished data). Colony data were updated where more current information was available. Data citations are provided in Appendix 1A and the full references are at the end of the bird chapter, and include the following references: Capitolo *et al.,* (2006); McChesney *et al.,* (2005); Capitolo *et al.,* (2004a, b); Thayer and Sydeman (2002 a, b); Warzybok *et al.,* (2002); Whitworth *et al.,* (2002) and Sydeman *et al*., (1998). Personal communications were provided by Steve Hampton (CDFG), Gerry McChesney (USFWS), and Bill Sydeman (PRBO Conservation Science).

METHODS

Colony locations were plotted using latitude and longitude. Colonies were surveyed using a variety of methods, including boat, ground, and aerial photographic surveys. Data collected by Carter *et al*., (1992) were part of a broad-scale survey of all seabird colonies in California. Colonies on the outer coast were surveyed in 1989 and San Francisco Bay colonies were surveyed in 1990. For the South Farallon Islands, data for all species except Brandt's Cormorant, Double-crested Cormorant, and Common Murre were provided by Point Reyes Bird Observatory or other published sources. Data for most tern colonies and certain other colonies in San Francisco were provided by San Francisco Bay Bird Observatory or other sources.

In Carter *et al*., (1992), population estimates for most species were derived from raw nest or bird counts adjusted with a correction factor. Some colony estimates include correction factors; these factors are used to improve estimates for nests or breeding birds that are present during the season, but not present on the day or time of the survey. Correction factors are also used to estimate certain colony sizes for species that nest in burrows and crevices (e.g., storm-petrels, auklets and puffins). These correction factors adjust counts based on typical occupancy rates of burrows or crevices, since not all available sites are used each season. More recent population estimates are based on a variety of methods. Recent estimates for most colonies of Brandt's Cormorants, Double-crested Cormorants, and Common Murres are from annual photographic surveys conducted by the U.S. Fish and Wildlife Service (USFWS), in cooperation with Humboldt State University (HSU), California Department of Fish and Game, and others (Capitolo *et al*., 2004a, b, 2006; McChesney *et al.,* 2005). For the cormorants, raw nest counts were multiplied by two to account for both members of each breeding pair. For Common Murre, raw bird counts were adjusted by a k correction factor of 1.67 to account for pair members not present and nonbreeders present during the survey. Estimates for other species at the South Farallon Islands and Año Nuevo Island are from annual seabird monitoring by PRBO Conservation Science. More recent data from Devil's Slide Rock and Mainland are from annual monitoring conducted by USFWS and HSU. Other estimates are from various other studies and monitoring programs.

RESULTS AND DISCUSSION

The study area is in a geologic subduction zone of the eastern Pacific and adjacent continental margin. Therefore, as with analogous regions elsewhere on the globe (e.g., west coasts of South America and Africa), large islands are not common. Obvious in this map is the importance of the Gulf of the Farallones to breeding marine birds. The Gulf of the Farallones is defined as the broad shelf from Point Reyes/Tomales Point to Año Nuevo and out to the Farallon Islands. The largest colonies and majority of the breeding seabirds within the study area nest in this region.

See Appendix 1A for a numerical summary of each species' and colony's contribution to the breeding marine (and some estuarine) avifauna of the study area, composed of 16 species 12 of which breed within the Gulf of the Farallones. Appendices 1A and 1B contain all available information for all breeding bird colonies in the study area. Available colony data for the following 16 bird species were mapped: Leach's Storm-Petrel, Ashy Storm-Petrel, Brandt's Cormorant, Double-crested Cormorant, Pelagic Cormorant, Black Oystercatcher, California Gull, Western Gull, Caspian Tern, Forster's Tern, Least tern, Common Murre, Pigeon Guillemot, Cassin's Auklet, Rhinoceros Auklet and Tufted Puffin. Table 3.7 shows the top 50 marine bird colonies based on size. In this analysis, the following three colonies accounted for approximately 77% of the total number of breeding marine birds estimated in the study area: South Farallon Islands (~48%), North Farallon Islands (~19%) and Point Reyes (~11%). These colonies are large and relatively diverse owing to the high productivity of surrounding waters and large amount of "land-predator free" breeding habitat available. Several other colonies, or colony complexes (collection of "colonies" within close association to one another), on the outer coast are important overall and on a local basis. These colonies are important numerically and, in many cases, for the diversity of seabird species they harbor. Examples include: Fish Rocks, Gualala Point Island, Russian River Rocks, Arched Rock-Gull Rock complex, Bodega Rock, Point Resistance-Double Point complex (including Point Resistance, Miller's Point Rocks and Double Point Rocks), Devil's Slide Rock and Mainland, Año Nuevo Island, colonies within and near Point Lobos State Reserve (Bird Rock [Monterey County]), Guillemot Island, Pinnacle Point, Bird Island, Yankee Point), Castle-Hurricane complex (Bench Mark-227X, Castle Rocks and Mainland, Hurricane Point Rocks), Cape San Martin, Piedras Blancas Island, Morro and Pillar Rocks, and the Point Buchon/Diablo Canyon area (Point Buchon, Unnamed Rocks, Lion Rock, Pup Rock and Adjacent Mainland, Diablo Rock and Adjacent Mainland, Diablo Canyon Nuclear Power Plant South).

Based on the number of marine bird species (species richness) at each colony, the top six colonies in the study area are: South Farallon Islands (12 species), Fish Rocks and Point Reyes (9 species each), Bird Rock (Marin County), Año Nuevo Island, Castle Rocks and Mainland (with seven species each). Species richness at these colonies is a function of: size and diversity of nesting habitats, proximity to a good food supply, site disturbance, and predation.

For both numbers of breeding birds (184,442) and diversity (12 species), the South Farallon Islands is the most important seabird breeding colony in the study area and one of the largest in the 48 contiguous United States. Because of their importance to seabirds and marine mammals, the Farallon Islands are protected by the USFWS as a national wildlife refuge.

The South Farallon Islands' importance stems from: their size (ca. 100 acres), a variety of breeding habitats, a diversity of nearby, marine foraging areas with abundant prey resources, lack of land-based predators, and protection from human disturbance. The world's largest known colonies of three species occur at South Farallon Islands: Ashy Storm-Petrel, Brandt's Cormorant, and Western Gull. In addition, the South Farallon colonies of Leach's Storm-Petrel, Common Murre, Cassin's Auklet, Rhinoceros Auklet and Tufted Puffin are the largest in the study area for each of those species.

Beyond the Gulf of the Farallones, most colonies contain fewer than 3,000 breeding birds and fewer than five species. However, nearly the entire coastal zone is dotted with these small colonies, making the whole study area important for breeding seabirds.

The Common Murre is the most abundant breeding seabird in the study area, with an estimated population of 269,720 birds. However, 98% of the population occurs within the Gulf of the Farallones. Other species that are numerically dominant include Brandt's Cormorant, Western Gull, Pigeon Guillemot and Cassin's Auklet.

Within the study area but outside the Gulf of the Farallones, Brandt's Cormorant is the most abundant breeding seabird. Many of the largest seabird colonies within the study area are comprised mainly of this species. However, annual aerial surveys for this species have shown some "colonies" to be highly mobile, with birds switching between nearby colony sites over annual and possibly decadal scales (i.e., some colonies decrease in size and neighboring ones increase in size). Because of this, single year surveys do not necessarily portray all important colonies.

Within the San Francisco Bay estuary, species composition is different from the outer coast. Within the Bay, the predominant species are Double-crested Cormorant, California Gull, Western Gull, Caspian Tern, and Forster's Tern. Among these, only the Double-crested Cormorant, Western Gull and Caspian Tern breed on the outer coast. Habitats within San Francisco Bay are highly altered. Most colonies are on such habitats as salt pond levees and islands, bridges, breakwaters, and old buildings. The colonies of Double-crested Cormorant, Caspian Tern, and Forster's Tern are among the largest in California. The colony of endangered Least Terns at the former Alameda Naval Air Station is the largest for that species in the study area.

For species or colonies other than those surveyed regularly, most colonies have not been surveyed systematically since 1989 or 1990. Although species composition has likely remained mostly the same at most locations, changes in numbers of birds have almost certainly occurred; these changes can be discerned from colonies where surveys have continued and data are available. For example, Common Murres in central California have increased dramatically since 1989, recovering from drastic declines in the early 1800s and again in the early 1980s (Ainley and Lewis, 1974; Carter *et al*., 2001; USFWS, unpubl. data). Brandt's Cormorants within the nearshore zone of the Gulf of the Farallones have increased dramatically since the mid-1990s (USFWS, unpubl. data). Alternatively, Cassin's Auklets declined through the 1980s and 1990s, likely due to interdecadal climate changes that reduced availability of their favorite prey, euphausiids (Pyle, 2001; Abraham and Sydeman, 2004). The decline may also be influenced by local increases in trophic competitors, such as the blue and humpback whales. Other bird species, such as Pelagic Cormorant, also may be in decline due to climate and prey changes.

In San Francisco Bay, changes have been dramatic for certain species; colonies have come and gone. For example, Caspian Terns have abandoned some colony sites, such as the formerly large Alameda Naval Air Station, and moved to others. California Gulls have vastly increased since 1989 (Strong *et al*., 2004). An additional species, the Black Skimmer (*Rynchops niger*), recently extended it's breeding range north into San Francisco Bay (Ainley and Divoky, 2001).

Seabirds are sensitive to disturbance and predation, and have evolved the strategy to breed on islands and steep mainland cliffs for protection. Current threats to seabirds include human disturbance, such as from low-flying aircraft, boats, and humans approaching colonies too closely. Low-flying aircraft and fishing boats have been the primary source of human disturbance to Common Murres and Brandt's Cormorants at monitored central California colonies (USFWS, unpubl. data). Colonies of burrow-nesting species are susceptible to trampling of this unstable habitat. Certain fisheries interactions have resulted in high mortality for seabirds. Diving seabirds are particularly susceptible, as they get captured and drowned in nets or hooks of long-lines. Oil spills also have killed thousands of seabirds in this area in recent years. In central California, Common Murres tend to be impacted from oil spills and fisheries interactions more than any other species. The central California murre population declined about 50% in the early 1980s from mortality in set gill-nets and oil spills (Takekawa *et al*., 1990, Carter *et al*., 2001). Seabirds may also be susceptible to overfishing of important prey resources, such as anchovy, sardine, rockfish, squid and krill. Bright artificial lights that illuminate colonies, such as from boats and cities, may cause distress and abandonment of nests. Like moths, nocturnal seabirds (e.g., storm-petrels, Cassin's Auklet) are notorious for their attraction to artificial lights, which can cause disorientation and collisions with boats or other structures.

Increasing numbers of predators is also a concern. In recent years, Common Ravens (*Corvus corax*) have increased and expanded their range dramatically along the central California coast (Kelly and Etienne, 2002; USFWS, unpubl. data). These nest predators have been observed causing many disturbances and nest predation in coastal Common Murre colonies; this has led to abandonment of some murre nesting areas (USFWS, unpubl. data.). In San Francisco Bay, rapidly increasing numbers of California Gulls may be cause for concern, as these birds may out-compete the small tern species and raise predation levels of several waterbirds (Strong *et al.,* 2004). Increases of both ravens and California Gulls are believed to be anthropogenic in origin, as these birds feed extensively on human refuse.

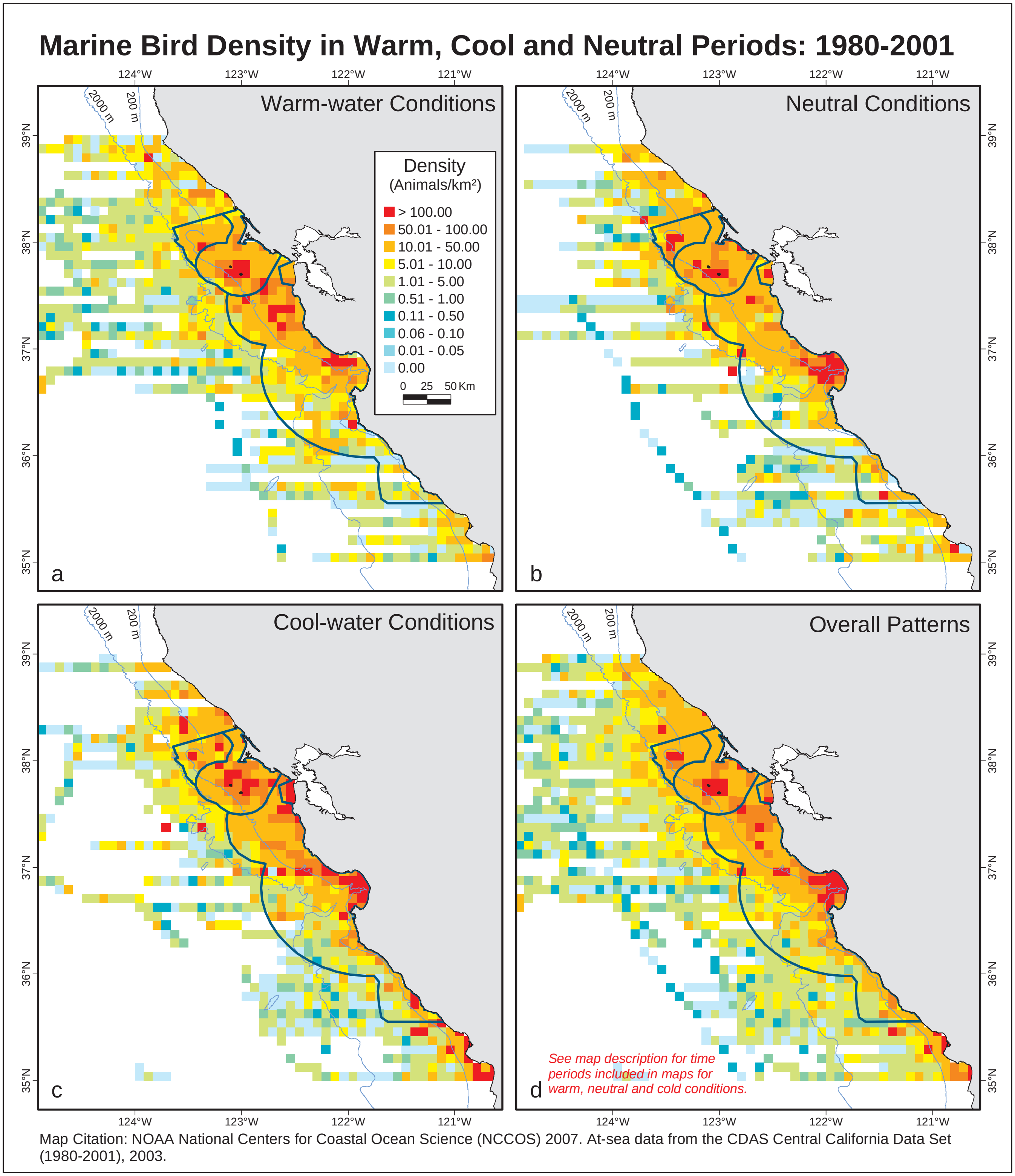


Figure 3.43. Marine bird density in warm, cold and neutral periods: 1980-2001.

ABOUT THESE MAPS

These four maps show a comparison of density of marine birds at sea during: warm-water periods (e.g., El Niño, map a); typical or neutral temperature periods (map b); cold-water periods (e.g., La Niña, map c); and overall density, (all seasons, all years, map d) from 1980-2001. The information was analyzed and mapped into 5' latitude by 5' longitude cells. This analysis provide an example of how marine birds may respond to short-term excursions from the usual (or neutral) marine climate. For a description of how these periods were chosen, see the following topic in the introduction and summaries sections of the bird chapter: "Response to Variation in Marine Climate".

In this analysis density is used, a measure that treats all species equally regardless of body size. Therefore, the patterns demonstrated by tiny, more abundant species, such as storm-petrels and phalaropes, are more greatly expressed than they would be if the analysis was based on biomass.

Densities are based on combined data of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas. Cells that were surveyed but in which no birds were observed have a density of zero; areas not surveyed are shown in white. 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

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

<u>Calculating Marine Bird Density for Different Temperature Periods</u>. Marine bird density data was organized into periods where surface ocean conditions were warm (including El Niño), cold (including La Niñas) or neither ("neutral"). The density of all species seen within respective cells was summed for that cell.

To illustrate these temperature conditions, a comparison of marine bird densities was made by making maps that use selected season/year periods that represented these cold, warm and neutral periods. The data for each "condition" map was grouped as shown below; these groupings were based on the assignments made in Table 3.4. Once the selection of data were made for each analysis period (i.e., warm, neutral or cold), the density of all birds seen within each cell was summed for that cell.

For the warm-water conditions (including El Niño) map, the following seasons and years were used: Davidson Current Season - 1981, 1983, 1984, 1992, 1993, 1994, 1996, and 1998; Upwelling Season - 1985, 1987, 1992, 1993, 1995, and 1998; and Oceanic Season - 1983 and 1997. For the "neutral" conditions map, the following seasons and years were used: Davidson Current Season - 1982, 1986, 1995, and 1997; Upwelling Season - 1980, 1982, 1986, 1988, 1989, 1994, 1996, and 1997; and Oceanic Season - 1982, 1991, and 1995. For the cold-water conditions (including La Niñas) map, the following seasons and years were used: Davidson Current Season - 1985, 1991, 1999, 2000, 2001, and 2002; Upwelling Season - 1981, 1990, 1991, 1999, 2000, and 2001; and the Oceanic Season - 1980, 1981, 1994, 1996, 1998, 1999, 2000, and 2001.

RESULTS AND DISCUSSION

There was not a great deal of difference in density apparent in the exhibited patterns for the different periods. Nevertheless, during warm-water conditions (e.g., El Niño) marine bird populations appear to contract more into the area defined by the boundaries of the central California National Marine Sanctuaries, from Tomales Point south to Monterey. Generally, this area contains most of the shelf habitat of the study area, a habitat that tends to have a greater complexity of microhabitats than deeper waters. The reason not much of a pattern or major difference was apparent in these maps is that individual species respond differently to the three different temperature conditions shown. For instance, some may move out of an area but others may move in, therefore, when species are combined these individual responses are homogenized.

During cold excursions from normal/neutral marine climate, populations seemed to be slightly more widespread, with major concentrations in Monterey Bay. During cold-water conditions (e.g., La Niña), densities appeared to be the highest, especially in waters close to the coast (e.g., see contiguous high-density, red and orange cells along the coast). When warm water is present, the concentrations are further offshore in the mid-outer shelf, and there are fewer highest density (red) cells. This pattern is likely a response to food being more diffusely spread over a wider area.

As noted earlier, overall marine bird density in this analysis is generally dominated by two numerically dominant species, Common Murre and Sooty Shearwater, and to a lesser degree, by the species identified as abundant in the study area (see Table 3.11). See also Figures 3.46 and 3.47, which show how selected individual marine bird species responded to cool and warm-water periods.

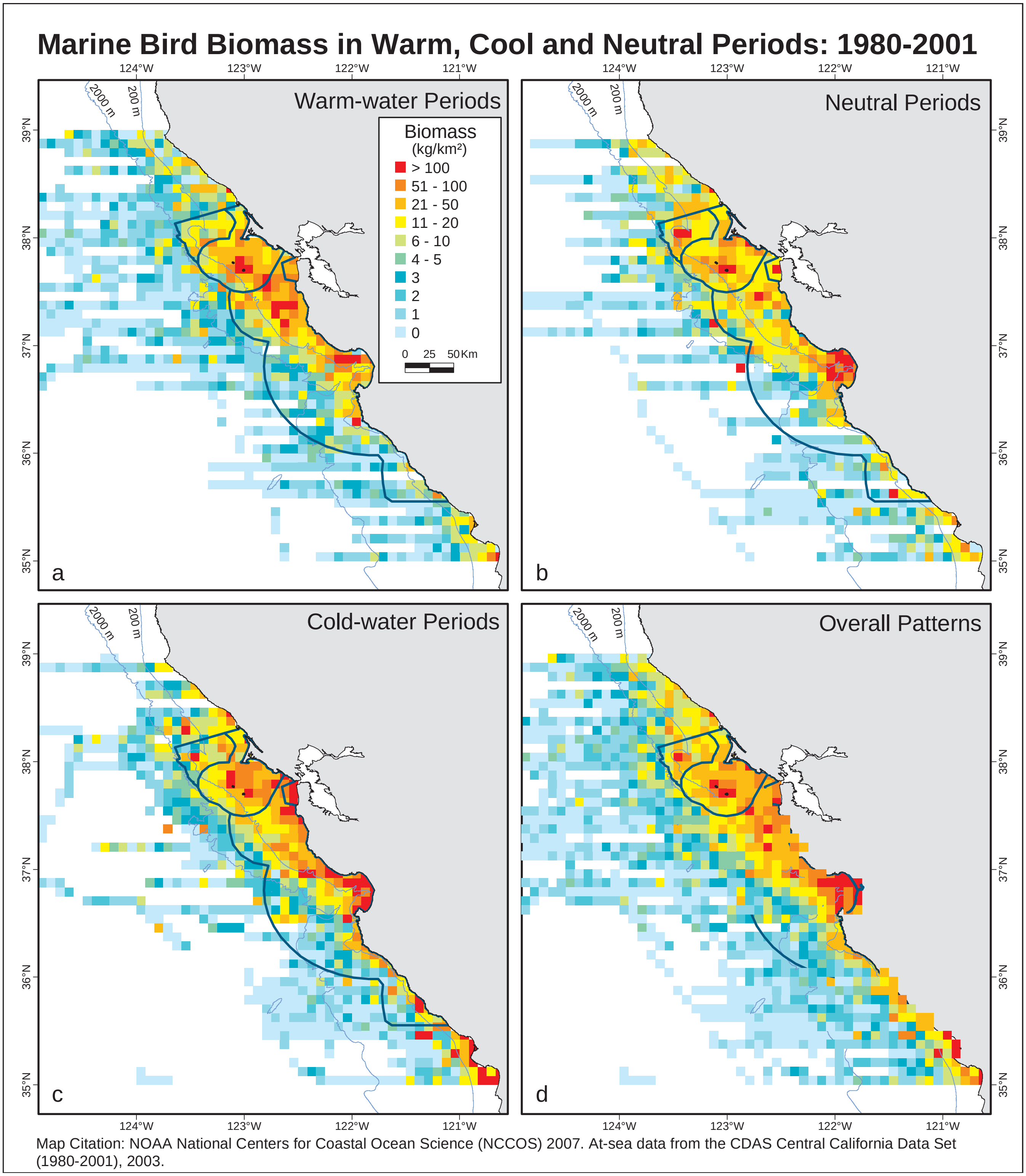


Figure 3.44. Marine bird biomass in warm, cold and neutral periods: 1980-2001.

ABOUT THESE MAPS

These four maps show a comparison of the biomass density (birds/km^2) of 76 species of marine birds at sea during: warm-water periods (e.g., El Niño, map a); typical or neutral temperature periods (map b); cold-water periods (e.g., La Niña, map c); and overall biomass density, from 1980-2001 (map d). The information was analyzed and displayed in 5' latitude by 5' longitude cells. These analyses provide an example of how marine birds may respond to short-term excursions from the usual marine climate. For a description of how these periods were chosen, see the following topic in this chapter: "Response to Variation in Marine Climate".

The color and mapping intervals were selected to show the most structure and highlight significant areas. Cells that were surveyed but in which no birds were observed have a density of zero; areas not surveyed are shown in white. 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

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods used for estimating density and biomass.

<u>Calculating Marine Bird Biomass Density for Different Temperature Periods.</u> For each species that occurred in a cell, the average density was multiplied by a species' body mass (from Dunning, 1993); see Appendix 2. In a few instances, a species was not listed in this reference; in these cases, the mass of a closely-related bird of a similar size was used. This resulted in an estimate of biomass for that species. The biomass of all species in each cell was then summed to give the cell biomass. Once the selection of data were made for each analysis period (i.e., warm, neutral or cold), the density of all species seen within respective cells during those periods was summed for that cell.

Marine bird density data was organized into periods when surface ocean conditions were warm (including El Niño), cold (including La Niña) or neither (neutral). The data for each condition map was grouped as shown below; these groupings were based on the assignments made in Table 3.4.

For the warm-water conditions (including El Niño) map, the following seasons and years were used: Davidson Current Season - 1981, 1983, 1984, 1992, 1993, 1994, 1996, and 1998; Upwelling Season - 1985, 1987, 1992, 1993, 1995, and 1998; and Oceanic Season - 1983 and 1997. For the "neutral" conditions map, the following seasons and years were used: Davidson Current Season - 1982, 1986, 1995, and 1997; Upwelling Season - 1980, 1982, 1986, 1988, 1989, 1994, 1996, and 1997; and Oceanic Season - 1982, 1991, and 1995. For the cold-water conditions (including La Niñas) map, the following seasons and years were used: Davidson Current Season - 1985, 1991, 1999, 2000, 2001, and 2002; Upwelling Season - 1981, 1990, 1991, 1999, 2000, and 2001; and the Oceanic Season - 1980, 1981, 1994, 1996, 1998, 1999, 2000, and 2001.

RESULTS AND DISCUSSION

There was slightly more difference in biomass than was observed for the analogous comparison of density. Biomass was generally more concentrated during warm and cold conditions than during neutral conditions, especially cold-water periods that were mimicked by the overall patterns (all seasons) summary. Many inner-shelf habitat areas exhibited high marine bird biomass during cold-water periods. The Farallon Ridge and Monterey Bay had relatively high biomass under all conditions.

Marine bird biomass in this analysis is generally dominated by two relatively heavy-bodied, numerically dominant species - Common Murre and Sooty Shearwater, and to a lesser degree by the species identified as abundant in the study area (see Table 3.11). The National Marine Sanctuaries in the study area encompass a major portion of the biomass density of marine birds in the study area.

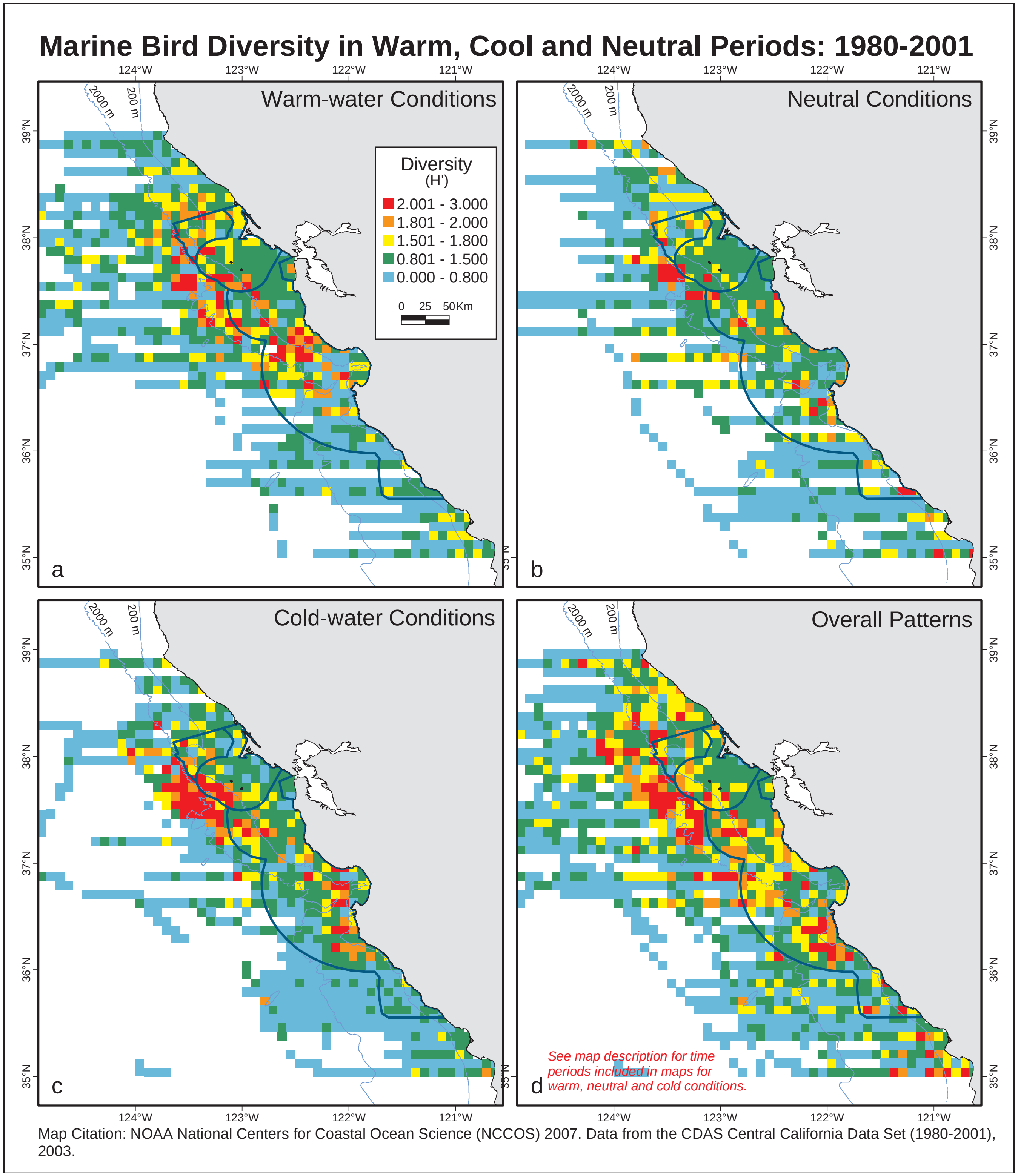


Figure 3.45. Marine bird diversity in warm, cold and neutral periods: 1980-2001.

ABOUT THESE MAPS

These four maps show a comparison of diversity of marine birds during: warm-water periods (e.g., El Niño, map a); typical or neutral temperature periods (map b); cold-water periods (e.g., La Niña, map c); and overall diversity, (all seasons, all years, map d) from 1980-2001. These analyses provide an example of how marine birds may respond to short-term excursions from the usual marine climate. For a description of how these periods were chosen, see the "Response to Variation in Marine Climate" section in the introduction to this chapter.

These maps show species diversity (H'), calculated for each 5' latitude by 5' longitude cell, using density as the variable in the Shannon Diversity Index (Shannon and Weaver, 1949). All 76 marine bird species that had been recorded in the data set and study area were included in the analysis. This diversity index measures the degree to which a species assemblage is dominated by one or more species. If one or more species dominates the numbers of all other species seen within a cell, then diversity is low; diversity is greatest when all species in the community are represented in equal numbers.

Diversity index values were based on the combined data of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were selected to show the most structure and highlight significant areas. Cells are colored based on the value of H' computed for a particular ocean season, or for map d, all seasons. Red indicates high diversity, blue indicates low diversity. Cells that were surveyed but in which no birds were observed have a diversity of zero. Areas not surveyed appear white; no information was available for these areas.

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 m and 2,000 m isobaths are shown in light blue.

DATA SOURCES AND METHODS

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

<u>Calculating Marine Bird Diversity during Different Temperature Conditions.</u> The Shannon Index (Shannon and Weaver, 1949) was used to estimate species diversity. See the Data and Analyses section of this chapter for methods used to estimate diversity.

Data was organized into periods where surface ocean conditions were warm (including El Niño), cold (including La Niña) or neither (neutral). The data for each condition map was grouped as shown below; these groupings were based on the assignments made in Table 3.4. For the warm-water conditions (including El Niño) map, the following seasons and years were used: Davidson Current Season - 1981, 1983, 1984, 1992, 1993, 1994, 1996, and 1998; Upwelling Season - 1985, 1987, 1992, 1993, 1995, and 1998; and Oceanic Season - 1983 and 1997. For the "neutral" conditions map, the following seasons and years were used: Davidson Current Season - 1982, 1986, 1995, and 1997; Upwelling Season - 1980, 1982, 1986, 1988, 1989, 1994, 1996, and 1997; and Oceanic Season - 1982, 1991, and 1995. For the cold-water conditions (including La Niñas) map, the following seasons and years were used: Davidson Current Season - 1985, 1991, 1999, 2000, 2001, and 2002; Upwelling Season - 1981, 1990, 1991, 1999, 2000, and 2001; and the Oceanic Season - 1980, 1981, 1994, 1996, 1998, 1999, 2000, and 2001.

RESULTS AND DISCUSSION

Under all variations of climate, marine bird diversity was highest over the continental slope, with the Farallon Escarpment and Pioneer Canyon, in particular, standing out. Of lesser importance was outer Monterey Bay Canyon and the continental slope off Point Sur.

Areas of high diversity were more spread out along the slope when ocean temperatures were warm. Adding to the latter hot spots noted above was the area around Ascension Canyon. During neutral conditions, diversity everywhere was relatively low, when compared with higher diversities during the warm-water and cold-water periods. Diversity was high when the ocean was cold and productive, perhaps because a higher number of birds, originating from different regions, were attracted to stay longer in the California Current. During warm- water periods with lower productivity, more individuals are likely spending more time at sea looking for food than during cooler water periods; this is an educated guess and other factors could be involved as well.

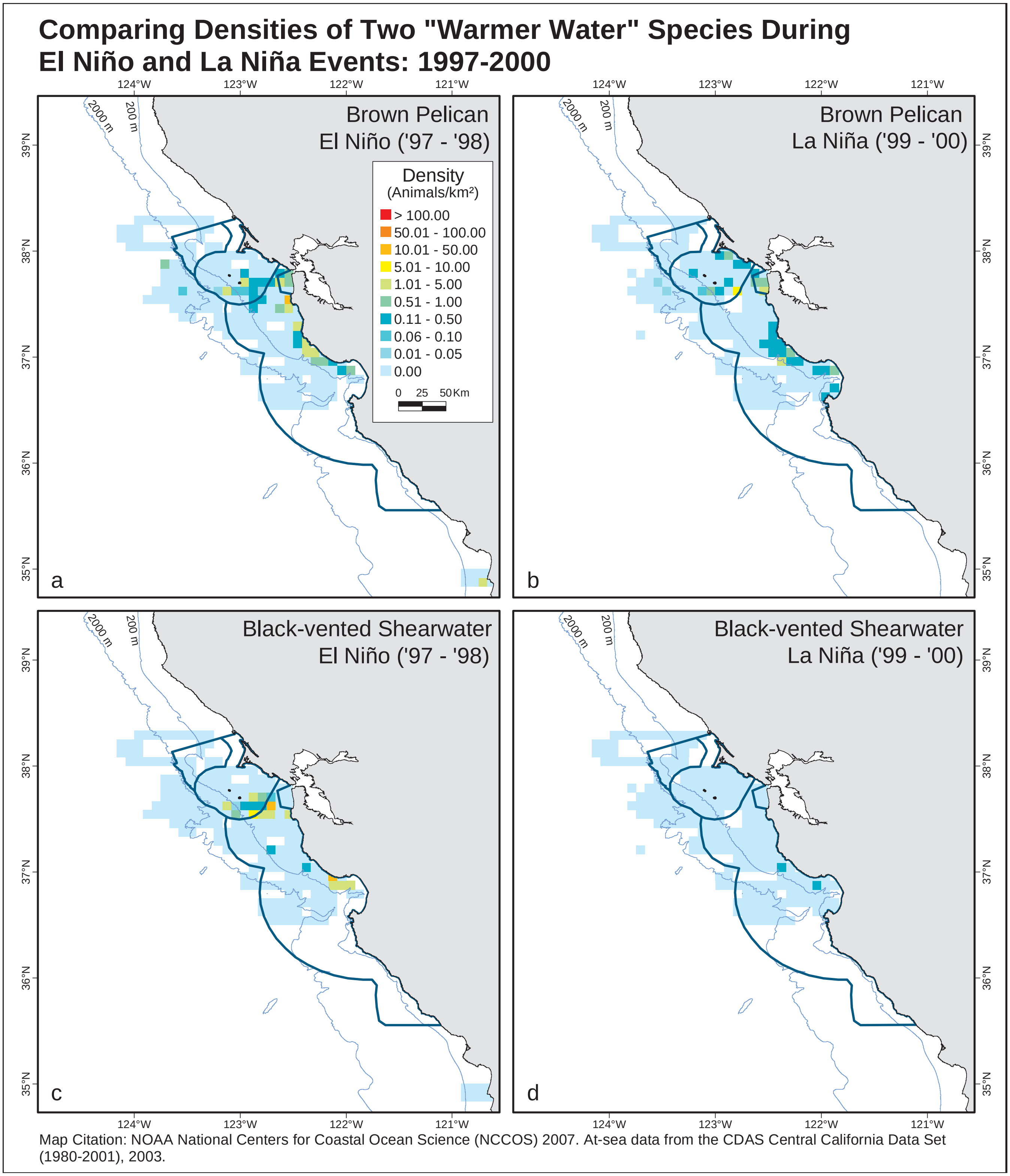


Figure 3.46. Comparing densities of two "warmer water" marine bird species during El Niño and La Niña events: 1997-2000.

ABOUT THESE MAPS

These maps provide a comparison of the density and spatial patterns for two marine bird species, California Brown Pelican and Black-vented Shearwater, during an intense El Niño warm-water event (1997-98) and an adjacent and intense La Niña cool-water event (1999-2000); the distributions for these two species is centered in warmer-water areas, south of the study area. This comparison provides an example of how two marine bird species that prefer warmer waters may respond to short-term anomalies from the usual marine climate. Also see also Figure 3.47, which has the same time periods of data as this comparison, but with two species that generally occur in relatively cooler waters than the species described here. See Methods below for time periods used.

Densities are based on combined data of several studies (see “Data Sources and Methods” below). The color and mapping intervals were customized to show the most structure and highlight significant areas. Cells that were surveyed but in which no birds were observed have a density of zero; areas not surveyed are shown in white. 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

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

<u>Estimating Density for the Two Temperature Periods.</u> Two criteria were used to select the cool and warm periods within the CDAS data set: 1) intensity (looking for an intense warm or cool); and 2) adjacent time periods (so long-terms changes in populations were not involved in the species occurrence patterns). Densities for each of the two species were mapped for the following time periods: for the El Niño condition, the period of the Oceanic Season 1997 through the Upwelling Season 1998 was used; for the La Niña condition, the Oceanic Season 1998 through the Upwelling Season 2000 was used. For a description of how these warm and cool periods were chosen, see Table 3.4 and the “Response to Variation in Marine Climate” in the introduction of this chapter.

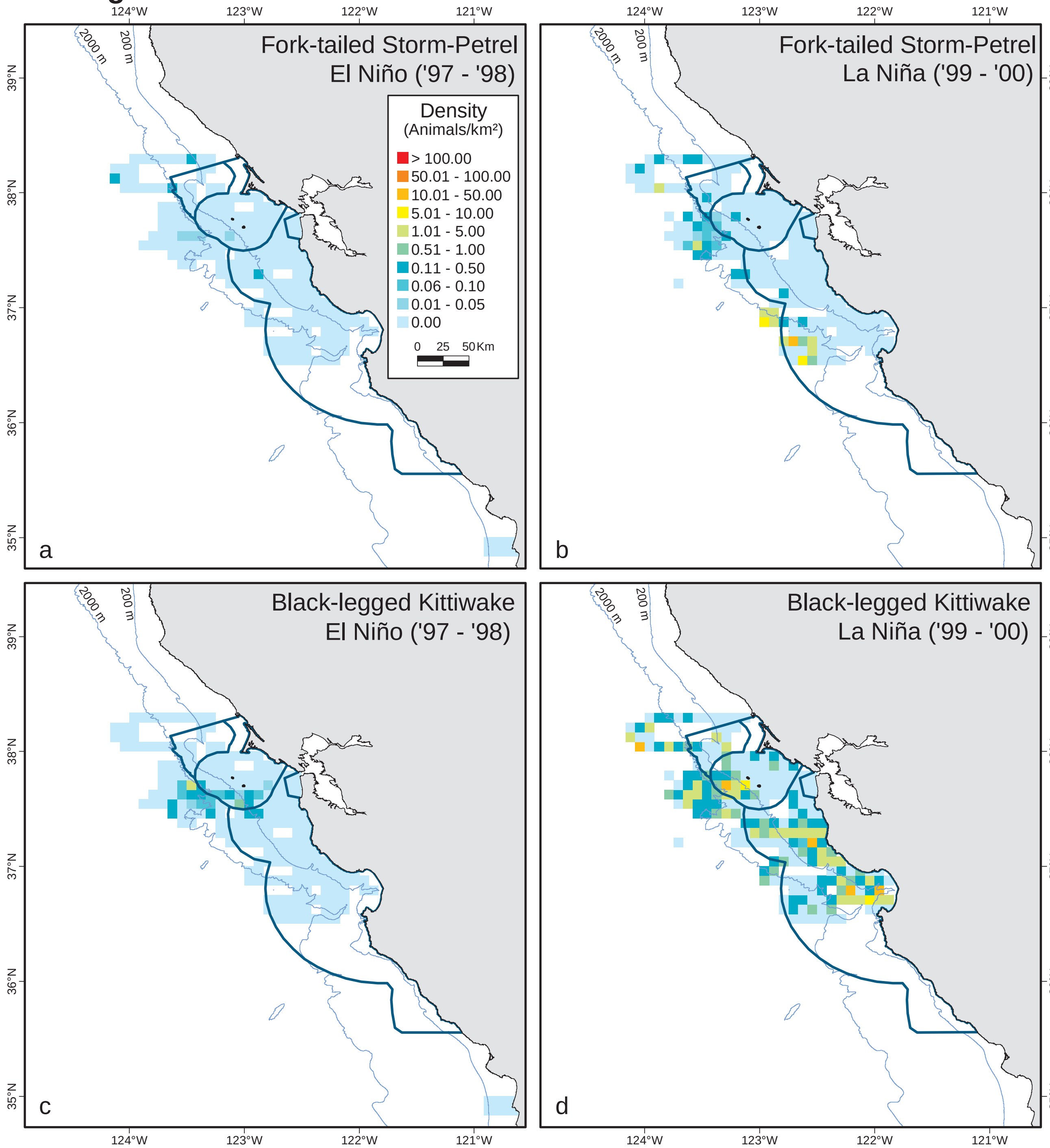
RESULTS AND DISCUSSION

Species such as California Brown Pelican, Black-vented Shearwater and Black Storm-Petrel are zoogeographically centered to the south of central California, where waters are normally warmer and food availability is relatively low. These species move north into central California waters when warmer ocean temperatures expand northward. Many of these individuals have foregone breeding owing to depleted food availability, which is often more extreme in areas to the south, where these species breed.

Shown here are comparisons of spatial patterns in density for California Brown Pelican and Black-vented Shearwater during the short-term, warm-water period. In both cases, densities were higher in central California during the El Niño. And although not reflected in this data, during warm-water conditions the range of California Brown Pelican expands as far north as the Columbia River and sometimes farther; Black-vented Shearwaters, however, do not go much farther north than central California waters.

The response of these species to short-term, cold-water conditions (e.g, La Niña) is less dramatic, but a difference was evident in the Black-vented Shearwater maps; this species density and overall occurrence was lower during cool-water conditions.

Comparing Densities of Two "Cooler Water" Marine Bird Species During El Niño and La Niña Events: 1997-2000



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.47. Comparing densities of two "cooler water" marine bird species during El Niño and La Niña events: 1997-2000.

ABOUT THESE MAPS

These maps provide a second comparison of the density and spatial patterns of two marine bird species, Fork-tailed Storm-Petrel (maps a and b) and Black-legged Kittiwake (maps c and d), during an intense El Niño (~1997-1998) and an adjacent La Niña (1999-2000). See Methods below for explanation of time periods used. This comparison provides an example of how two marine birds that prefer cooler waters may respond to short-term excursions from the usual marine climate. See also Figure 3.46, which has the same time periods of data as this comparison, but with two species that occur in relatively warmer waters than the species described here.

Densities are based on combined data of several studies; see the Data and Analyses section of this chapter. The color and mapping intervals were customized to show the most structure and highlight significant areas. Cells that were surveyed but in which no birds were observed have a density of zero; areas not surveyed are shown in white. 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

The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys used were conducted between 1980 and 2001. See the Data and Analyses section of this chapter for more information on the at-sea survey data sets and methods.

<u>Estimating Density for the Two Temperature Periods.</u> Two criteria were used to select the cool and warm periods within the CDAS data set: 1) intensity (looking for an intense warm or cool); and 2) adjacent time periods (so long-terms changes in populations were not involved in the species occurrence patterns). Densities for each of the two species were mapped for the following time periods: for El Niño, the period of the Oceanic Season 1997 through the Upwelling Season 1998 was used; for La Niña, the Oceanic Season 1998 through the Upwelling Season 2000 was used. See Table 3.4 for information on how ocean seasons were classified in terms of warm, cool or neutral.

RESULTS AND DISCUSSION

Fork-tailed Storm-Petrels and Black-legged Kittiwakes are more northern species and prefer cooler waters. In response to the water temperature change from relatively warm to cool in 1998 to 1999, these two species apparently preferred the cooler, central California waters of the 1999-2000 La Niña over the waters of the El Niño event in 1997-1998 (compare maps a and b for Fork-tailed Storm-Petrel and maps c and d for Black-legged Kittiwake). During the cooler conditions, both species were more numerous off central California.

3.4 CHAPTER SUMMARY

The following is a summary of the spatial and temporal patterns observed for marine birds in the study area and the three National Marine Sanctuaries off north/central California. Also included is relevant life history and management information.

Summary of Spatial and Temporal Patterns

Table 3.5 is a summary of the temporal and spatial patterns of selected marine bird species occurring in the CDAS Central California data set. This summary was developed in Phase I through a visual inspection of species' density data and maps and provides a simple assessment of species' co-occurrence with selected physiographic features. Maps of these physiographic features are in the Environmental Setting Chapter. It is important to note that while CDAS is a robust data set, it does not capture the entire distribution of species and so there are likely species associations with physiographic features that are not captured in Table 3.5.

It is obvious that large numbers of marine birds occur in the study area year-round. The species composition, however, changes greatly due to: 1) the presence of southern hemisphere-breeding species that are 'wintering' in large numbers in the study area during the Upwelling Season (boreal spring/summer); and 2) the subarctic-breeding species 'wintering' in large numbers during the Davidson Current Season (boreal winter). Additionally, many migrants pass through the region, foraging as they go, during the early Upwelling and Oceanic (Fall) seasons. Species breeding within the study area do so primarily during the Upwelling Season.

In the study area, the highest concentrations and the greatest variety of marine birds occur over the continental shelf and slope, where there are more microhabitats defined by ocean complexity (depth, currents, upwelling, etc.). A number of smaller, more discrete areas attract marine birds because more food is available owing to oceanographic factors. Based on this analysis (see Table 3.5), the hot spots for marine birds are listed in Table 3.6 and include the following: Farallon Escarpment; San Francisco Bay tidal plume; Ascension, Cabrillo and Año canyons; inner Monterey Bay; Pioneer Canyon; Farallon Ridge; and Estero/San Luis Obispo bays. Highest diversity occurs near the shelf break, as this is where shallow- and deep-water communities overlap.

Observations on Density, Biomass and Diversity across Marine Bird Species

Another way to summarize occurrence patterns of marine birds in the study area is to analyze for the biological community metrics of species diversity, biomass and density. Analyses for overall density, biomass and diversity were done with respect to ocean season and periods of unusual ocean climate (i.e., warm-water, cold-water and neutral periods). For these summary analyses, we used the data for 76 marine bird species that were contained in the combined data set.

Overall Density and Biomass. The distribution of marine birds across all taxa is similar for density (Figure 3.39) and biomass density (Figure 3.40). This is because the avifauna is dominated by the Common Murre and Sooty Shearwater (in terms of both number of individuals and their body mass). Therefore, the patterns in sum are close to what is evident individually for these two dominant species. Accordingly, the major areas of biomass and density, i.e., the inner and outer shelf, are biased toward these two species.

Phalaropes can also be very abundant but don't contribute much biomass; they are also most abundant over the shelf. Smaller-scale biomass and density hot spots for marine birds are also the same, e.g., inner Monterey Bay, San Francisco Bay tidal plume, the area around the Farallon Islands, Pioneer and Ascension Canyons, and Cordell Bank. Moreover, as will be noted below, birds are more spread out during warm-water than during cold-water or neutral periods, thus, "diluting" density and biomass measurements. This is because the ocean processes that concentrate food are weaker, especially when there is an absence of upwelling features (plumes, eddies, etc.).

Diversity. Highest diversity indices are about the same in all three seasons. In all cases, at the smaller, less detailed spatial scale, species diversity was greatest along the continental slope. This is expected given that the slope constitutes the boundary as well as the overlap between the shelf and oceanic habitats. At a larger, more detailed scale, in all seasons there was an area of notable diversity seaward of the Farallon Islands (Farallon Escarpment) and to some degree outside of the sanctuary boundaries. Likely the diversity here resulted from a coincident occurrence of: 1) oceanic

Table 3.5. A summary of temporal and spatial associations of selected marine birds off north/central California.

Family Name/ Species Common Name	Seasonal Occurrence			Associations with Large Bathymetrically-Defined Areas					Occurs Mostly Outside Sanctuaries	Associations with Discrete Physiographic/Oceanic Features																		
	Upwelling Season (3/15-8/14)	Ocean Season (8/15-11/14)	Davidson Current Season (11/15-3/14)	Coast & Inner Shelf (~0-100m)	Outer Shelf (~100-200m)	Upper Slope (~200-1000m)	Lower Slope (~1000-2000m)	Deep Ocean (beyond 2000m)		Cordell Bank	Bodega Canyon	Fanny Shoal	Farallon Escarpment	Farallon Ridge	San Francisco Bay Plume	Pioneer Seamount	Pioneer Canyon	Ascencion, Cabrillo, & Año Canyons	Pt. Ano Nuevo	Monterey Canyon	Monterey Bay Inshore	Carmel Canyon	Pt. Sur Slope	Pt. Sur Shelf	Davidson Seamount	Estero Bay/San Luis Obispo Bay
Podicipedidae																												
Western and Clark's grebes	x	x	**X	X											X				x		X					X
Gaviidae																												
Pacific loon	X		***X										x		x				x		X			X		
Diomedeidae																												
Black-footed albatross	***X	x	x		X	X	X	x		X		X	X				x	x		X		x	x			
Laysan albatross	x	o	***X		X	X	X	x	X				X													
Procellariidae																												
Northern fulmar	x	x	***X		X	X	X	x		x	x	x	X	x			x	x		x		x	x			
Sooty shearwater	***X	x	o	X	X	X	x	x		X	x	x	x	x	X		X	X		X	X	x				X
Short-tailed shearwater	o	o	***X		X	X	x	x				X					x									
Pink-footed shearwater	***X	x	o	X	X	X	x	x		x			x	X	x			x		X			x			
Buller's shearwater	o	***X	o		X	X	X	x	X		x		X	x		x	x	x		x					x	
Black-vented shearwater	o	**X	x		X	X								x	X	x		x		x						
Hydrobatidae																												
Leach's storm-petrel	**X	**X	o					X	X				X			x	x	x							x	
Fork-tailed storm-petrel	o	o	X		x	X	X	x	X				X			x		x							x	
Ashy storm-petrel	**X	***X	**X		x	X	X	x	X	x	X		X				x	x		X					x	
Black storm-petrel	o	**X	**X		x	X	X				x		X				x	x		X			x			
Anatidae																												
White-winged scoter	o	x	**X	X											X						X					X
Surf scoter	o	x	**X	X											X						X					X
Pelecanidae																												
Brown pelican	**X	**X	x	X	x					x				x	X				X		X			x		X
Phalacrocoracidae																												
Brandt's cormorant	***X	***X	***X	X	X					x		x	x	X	X				X		X			x		x
Pelagic cormorant	**X	**X	**X	X								x		X	x				x							x
Double-crested cormorant	*X	o	o						X			x		X	X						x					x
Scolopacidae																												
Red phalarope	***X	x	o		X	X	X	x	X		x		X				x	x		x			x		x	
Red-necked phalarope	***X	x	o	X	X	x	x			x	x	x		x			x	x		x			x			x
Laridae																												
Glaucous-winged gull	o	x	***X	X	X	x				x	x	x		x	X		x	x			X					X
Western gull	***X	***X	***X	X	X	X	x			x	x	X	X	X	X				X		X			x		X
California gull	o	x	***X	X	X	x					x				X				x		X			x		X
Ring-billed gull	o	x	**X	X	x										X						X			x		X
Mew gull	o	x	**X	X	x										X						X					
Heermann's gull	o	x	**X	X	x										X						X					
Bonaparte's gull	***X	x	o	x	X	X	x										X	x		X						
Sabines gull	***X	x	o				X	X	X		x		X				x	x		X						
Black-legged kittiwake	x	o	***X		X	X	X	x	X		x	x	X			x	x	x		x		x	x		x	
Caspian/Elegant terns	**X	x	o	X											X						X					x
Arctic tern	***X	***X	o			x	x	X	X		x		X			x	x	x		x						
Forster's tern	**X	x	o	X											X						X					
Alcidae																												
Common murre	***X	***X	***X	X	X	x	x			x		x	x	X	X				x		x			x		x
Pigeon guillemot	**X	x	o	X	X									X					x					X		X
Tufted puffin	*X	x	o		x	X	X	X					X	X			x									
Rhinoceros auklet	***X	***X	x		x	X	X			x		x	x	x			x	x	X	x		x	x			
Cassin's auklet	***X	***X	x		X	X	x			X	x	X	X	X			x					x				
Marbled murrelet	*X	*X	*X	X														x	X		X					
Xantus'/Craveri's murrelets	***X	x	x			X	X	X	X				X													
All Xs	**29**	**35**	**27**	**21**	**28**	**24**	**22**	**16**	**11**	**13**	**14**	**14**	**22**	**17**	**20**	**6**	**18**	**19**	**11**	**15**	**18**	**6**	**8**	**8**	**6**	**16**
Large X's	**25**	**14**	**21**	**20**	**19**	**19**	**13**	**5**	**11**	**3**	**1**	**4**	**16**	**9**	**17**	**0**	**2**	**1**	**5**	**7**	**16**	**0**	**8**	**2**	**0**	**10**

1. A summary of temporal and spatial patterns in the occurrence of 44 marine birds off north/central California, based on visual inspection of the species' seasonal density maps made from CDAS at sea-data (1980-2001).
2. The spatial and temporal patterns summarized here may be affected by the sampling effort in the CDAS data set; this table provides a summary of the use of the various habitat features, as viewed in the CDAS data.
3. In the "seasonal occurrence" columns, the number of asterisks indicate the number of sanctuaries in the study area that are used by the species during the season. A large "X" means a relatively major occurrence in the data sets, a small "x" means a minor occurrence, and a "o" means the species was mostly absent.
4. Under the heading for "large, bathymetrically-defined areas", a large "X" indicates where the species was most abundant, a small "x" means a minor occurrence, and a "o" means the species was mostly absent).
5. Under the heading for "discrete physiographic/oceanic features", large X's refer to 'hot spots'; small x's indicate areas of secondary importance for that species. A blank in the table means a species was not present at the location indicated in the maps/data reviewed.

species, 2) shelf species, 3) Farallon breeding species that would not occur offshore were it not for the Farallones, and 4) the location of a persistent boundary of a coastal upwelling front that extends southwestward from Point Arena. Accordingly, during La Niña, when upwelling features are well developed, this area exhibits much greater diversity than during El Niño.

Although there was a significant correlation between bird diversity and effort, the observed patterns of bird diversity are robust and were largely unchanged by methods designed to correct for effort.

Important Areas for Marine Birds in Study Area

Most, if not all, of the marine habitat off north/central California, especially that of the continental shelf and slope, is fully used by marine birds. Based on the analyses of marine bird maps for overall density, biomass, and diversity, the at-sea areas identified in Table 3.6 are especially important. Areas with more and bigger X's were deemed to be more important, as they show a greater expression of marine bird density, biomass and diversity. These areas are hot spots for seabirds and their prey.

Marine Bird Breeding Colonies in Study Area

Although breeding colonies are on land and technically not part of the study area, they were included in this section because they provide a context for understanding the distributions of locally breeding species. Table 3.7 shows the top 50 largest marine bird breeding colonies in the study area, and Appendices 1A and 1B are two tables with all available colony information for 280 marine bird colonies in the study area, including colonies in San Francisco Bay.

Table 3.6. Important areas at sea for marine birds off north/central California.

Area	Biomass/Density			Diversity		
	Davidson Current Season	Upwelling Season	Oceanic Season	Davidson Current Season	Upwelling Season	Oceanic Season
Cordell Bank	x	**X**				
Farallon Escarpment (slope)	**X**	x	x	**X**	**X**	**X**
Farallon Ridge (includes Farallon Island area)	**X**	**X**	x			
San Francisco Bay Tidal Plume		x	**X**	**X**		
Pioneer Canyon				**X**	x	x
Año Nuevo Shelf	**X**		**X**			
Ascension, Año & Cabrillo Canyons	**X**	x	x	**X**	x	
Monterey Bay Inshore	**X**	x	**X**	**X**		
Monterey Bay Canyon	**X**		x			
Carmel Canyon				**X**		
Point Sur Shelf			x			
Point Sur Slope				**X**	x	
Estero Bay & San Luis Obispo Bay	**X**		x			

Note: Large, bold Xs refer to more important areas, and smaller xs refer to other important areas.

Table 3.7. Top 50 marine bird colonies along the north/central California coast.

Colony Name	No. of Breed-ing Species	Colony Size (No. of Breeding Birds)	Percent of Total	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormo-rant	Double-crested Cormo-rant	Pelagic Cormo-rant	Black Oyster-catcher	Califor-nia Gull	Western Gull	Caspian Tern	Forsters Tern	Least Tern	Common Murre	Pigeon Guille-mot	Cassin's Auklet	Rhino-ceros Auklet	Tufted Puffin	CA Colony Number	USFWS Colony Number
South Farallon Islands	12	184,442	48%	1,400	1,990	17,014	1,122	442	30		15,095				127,399	499	18,807	516	128	SF-FAI-02	429-052
North Farallon Islands	6	72,203	19%			102		62			32				71,929	42	36			SF-FAI-01	429-051
Point Reyes	9	43,061	11%		15	1,160		266	6		178				40,810	616		6	4	MA-374-01	429-001
Double Point Rocks	6	16,235	4%		50	328		9	H		8				15,818	22				MA-374-05	429-003
Point Resistance	4	7,177	2%			28	H	H	H		8				7,091	50				MA-374-03	429-024
Año Nuevo Island	7	5,065	1%			3,278		13	27		1,382					117	24	224		SM-370-04	429-023
Alviso Plant, Pond A6	3	4,526	1%							4,328	4		194							SFB-SR-07	429-020
Castle Rocks and Mainland	7	3,322	<1%		P	342		46	H		12				2,901	19	2			MO-362-19	454-010
Bird Island (Monterey Co.)	5	2,791	<1%			2,690		4	2		90					5				MO-362-09	454-009
Alcatraz Island	3	2,483	<1%			1,578					900					5				SFB-SF-11	429-036
Millers Point Rocks	6	1,951	<1%			296		59	1		30				1,510	55				MA-374-04	429-002
Alameda Naval Air Station	3	1,840	<0.5%								502	1,188		150						SFB-AL-10	429-010
Yankee Point	1	1,744	<0.5%			1,744					H					H				MO-362-11	454-024
Bird Rock (Monterey Co.)	3	1,676	<0.5%			1,658			2		16									MO-362-03	454-006
San Fran-Oakland Bay Bridge E.	2	1,530	<0.5%				1,490				40									SFB-AL-05	429-071
Hurricane Point Rocks	5	1,445	<0.5%		P	68		H	H		14				1,343	20			H	MO-362-20	454-011
Devil's Slide Rock and Mainland	5	1,354	<0.5%			692		114	H		8				380	160				SM-372-03	429-014
Piedras Blancas Island	5	1,291	<0.5%			1,224			1		34					29		3	H	SL-352-01	477-007
Richmond-San Rafael Bridge	2	1,282	<0.5%				1,264				18									SFB-CC-12	429-061
Morro Rock and Pillar Rock	5	1,149	<0.5%			876	82	53	H		114					24				SL-352-07	477-026
Bench Mark-227x	5	1,092	<0.5%			444		35	H		38				539	36				MO-362-18	454-029
Fish Rocks	9	905	<0.5%	100		368		123	6		170					119	P	4	15	ME-384-10	404-003
Bird Rock (Marin Co.)	7	894	<0.5%		15	550		37	6		168					115		3	H	MA-380-04	404-010
Bair Island, Pond B1	2	863	<0.5%									800	63							SFB-SM-06	429-016
Pup Rock and Adjacent Mainland	3	820	<0.5%			774			2		44									SL-350-04	477-028
Baumberg Plant #1, Pond 10	1	814	<0.5%										814							SFB-AL-16	429-015
Fairbank Point	1	812	<0.5%				812													SL-352-08	477-044
Bodega Rock	4	778	<0.5%			722			H		24					30		2		SO-380-02	404-008
Unnamed Rocks	5	757	<0.5%			286		174	6		49					242				SL-350-03	477-010
Knight Island	4	754	<0.5%				400				8	76	270							SFB-SN-01	404-053
Cannery Row	4	682	<0.5%			310		198			86					88				MO-362-02	454-044
Cape San Martin	3	663	<0.5%			296	H	18	H		349					H				MO-354-08	477-003
Plant #2, Ponds 4, 5	1	634	<0.5%									634								SFB-AL-32	429-019
Guillemot Island Area	5	632	<0.5%			554		20	10		30					18				MO-362-06	454-023
Salinas River New Mouth	2	568	<0.5%									568	H	H						MO-364-06	454-060
Monterey Harbor	3	553	<0.5%			494					24					35				MO-362-01	454-043
Alviso Plant, Ponds A9, A10	2	512	<0.5%				78			434										SFB-SR-04	430-005
Davenport to Sand Hill Bluff	3	509	<0.5%					13	1							495				SC-364-01	454-038
Arched Rock	4	481	<0.5%			436		9			34					2			H	SO-382-11	404-006
Alviso Plant, Pond B2	1	480	<0.5%										480							SFB-SR-09	429-020
Lion Rock	4	467	<0.5%			424		H	1		24					18				SL-350-05	477-011
Shell Beach Rocks	6	447	<0.5%			P	260	H	11		18					153		5		SL-350-13	477-035
Diablo Rock & Adjacent Mainland	3	415	<0.5%			384		H	H		26					5				SL-350-06	477-029
Russian River Rocks	6	414	<0.5%			P	238	125	2		44					5				SO-382-09	404-005
El Jarro Point to Davenport	4	408	<0.5%			72		22								313		1		SC-370-02	429-050
Greyhound Rock to El Jarro Point	4	398	<0.5%					66	9		2					321				SC-370-01	429-049
Red Rock	1	384	<0.5%								384									SFB-CC-14	429-039
Russian Gulch	5	376	<0.5%				80	227	7		42					20				SO-382-08	404-033
Point Buchon	5	368	<0.5%			172		48	6		40					102				SL-350-02	477-009
Gualala Point Island	5	324	<0.5%			264		4	1		26					29				SO-384-01	404-004
TOTALS for top 50 colonies	-	374,771	97%	1,500	2,070	39,628	5,826	2,187	137	4,762	20,115	3,266	1,821	150	269,520	3,809	18,869	764	147	-	-

Notes

1. This table reflects ~ 97% of the breeding marine birds in the study area (Pt. Arena to Pt. Sal), and includes colonies in San Francisco Bay. The colonies are ranked largest to smallest; these ranks will likely shift from year to year. The numbers in the species columns are the number of breeding birds. The "Total" in"Percent of Total" refers to 388,070 breeding birds in the 280 colonies that were considered.
2. Key: H = historically-nesting species; P = present and probably breeding. A "blank" in the table indicates no available data, or the species is not present there. Colony names in Italics occur along San Francisco Bay.
3. Most colony data are from Carter et al. (1992). Additional sources include: Sydeman et al.(1998); Capitolo et al. (2006); McChesney et al. (2005); Capitolo et al. (2004); Thayer and Sydeman (2002 a, b); Warzybok et al. (2002); Whitworth et al. (2002). Personal communications were also received from: Steve Hampton (CDFG), Gerry McChesney (USFWS), and Bill Sydeman (PRBO Conservation Science). Complete references are at the end of the bird chapter. Data are mostly from 1989-2005.
4. See Appendix 1A for data at all colonies in the study area and San Francisco Bay. See Appendix 1B for additional colony information. Appendix 1A and 1B contais data on 280 colonies, 17 species, and ~ 388,070 breeding marine birds.
5. Colony counts can vary significantly from year to year; therefore colony sizes, rank order, percent of total and number of species also vary. This table is combination of several studies on marine breeding bird colonies in the study area. Data on bird colonies is constantly being updated; hence, this table is already dated for some species and locations.
6. This table was compiled by Janet Casey (R.G. Ford Consulting Co.), with help from Tracy Gill (NOAA) and Gerry McChesney (USFWS) on data collection, input revisions and formatting, and Jamie Higgins (NOAA) on formatting. - January 2007

Marine birds in this area breed mainly during the Upwelling Season, anticipating that food availability will be greatest from July-October, toward the end of this season and into the Oceanic Season. During this period ample supplies of prey are needed to feed growing chicks and recently-fledged young. Egg laying generally occurs in March-May, depending on species, and different species require different amounts of time to complete the breeding task (petrels longest, gulls shortest). The overall breeding period generally occurs March-September, but can extend into December for some species.

The greatest concentration of colonies in the study area occurs in the Gulf of the Farallones between Point Reyes and Año Nuevo and out to the Farallon Islands. The breeding avifauna is dominated by six alcid species: Common Murre, Pigeon Guillemot, Tufted Puffin, Rhinoceros Auklet, Cassin's Auklet, and Marbled Murrelet. Fifteen species of marine birds breed at sites within or immediately adjacent to the National Marine Sanctuaries in the study area; several other species breed inland or in San Francisco Bay, and to a lesser degree use sanctuary waters.

Seasonal Differences in Marine Bird Occurrence. As seen in the maps for individual species, temporal differences in occurrence patterns are strong for many species in the study area (see Tables 3.5 and 3.6). Below is a brief summary of marine bird activity in the three ocean seasons.

Upwelling Season (Spring/Summer). With the onset of upwelling, when cold, nutrient-rich water is brought to the surface by persistent northwest winds and the Coriolis effect, most of the seasonal winter residents depart and several other species migrate through the region (e.g., Sabine's Gull, Arctic Tern). Arriving are several species that nest in the Southern Hemisphere, thus spending their wintering or nonbreeding period in the study area region. The Sooty Shearwater is one of these species and becomes the most abundant species in the study area; the number of Sooty Shearwaters in the CDAS central California data set increased from 2000-2002.

Owing to the addition of Sooty Shearwaters to the avifauna and the continued abundance of Common Murres, overall density and biomass of marine birds is highest during the Upwelling and Oceanic Seasons and is widely spread from the coast to beyond the shelfbreak. Diversity over the shelf, where the shearwaters and murres mostly reside, is relatively low.

Oceanic Season (Autumn). In this season, when upwelling winds have noticeably relaxed, allowing offshore, warmer oceanic water to flow shoreward, the avifauna begins to diversify. In part, this diversification is also due to the presence of passage migrants (see below). However, as more Sooty Shearwaters and other Southern Hemisphere seasonal residents depart, the avifauna has fewer species. At this time, resident breeding species are also dispersing more widely as they finish breeding duties.

The diversity during this season is due to: 1) several species (e.g., phalaropes, jaegers, Arctic Terns, Sabine's Gulls) migrating through the region during this time, 2) the locally-nesting species are all present, and 3) several species that nest elsewhere are abundant as well (e.g., several shearwaters, California Brown Pelican, and Heermann's Gull).

Biomass remains high but shifts closer to shore than during the Upwelling Season, in large part due to an inshore shift of murres and shearwaters. There are more depth-defined feeding habitats in shallower waters.

Davidson Current Season (Winter). During this season, when ocean temperatures are relatively warm and there is no upwelling (but frequent downwelling due to southerly storms) the area is inundated by such subarctic-nesting species as Black-legged Kittiwake, Northern Fulmar and several larger gulls. Also present are nesting species that reside year-round in the region, such as Ashy Storm-Petrel, Brandt's Cormorant, Western Gull, Common Murre, Rhinoceros Auklet and Cassin's Auklet. In fact, many of the latter species begin to occupy nesting colonies during this season, well before the nesting period.

During this season, the diversity of marine bird species of shelf waters increases, and areas of high diversity are more widespread than in the other seasons.

Table 3.8. Top 3 independent variables (of 9 investigated) that explain the variation in the densities at sea of 25 marine birds.

Species [1]	Number of Birds Recorded During Surveys	Percent Variance Explained by Top Three Variables	Three Most Important Variables of Those Investigated, in Order of Importance [2,3]
Pacific Loon	3,802	10.6	Ocean season, distance to land (-), latitude (-)
Western Grebe	7,080	15.5	Ocean season, distance to land (-), ocean depth (-)
Laysan Albatross	96	6.9	Ocean season, ocean depth (+), distance to land (+)
Black-footed Albatross	3,149	22.2	Ocean depth (+), distance to land (-), year (-)
Northern Fulmar	5,882	21.3	Ocean season, ENSO period, year (+)
Pink-footed Shearwater	4,145	13.1	Ocean depth (-), distance to land (-), ESNO period
Sooty Shearwater	296,065	43.4	Ocean season, year (-), ENSO period
Fork-tailed Storm-Petrel	393	9.2	ENSO period, season, ocean depth (+)
Leach’s Storm-Petrel *	1,414	28.4	Ocean season, distance to 2000m isobath (+), ENSO period
Ashy Storm-Petrel *	4,201	17.3	ENSO period, season, year (+)
California Brown Pelican	2,333	15.2	Distance to land (-), latitude (-), Ocean season
Brandt’s Cormorant *	9,482	28.7	Distance from colony (-), dist. to 200 m isobath, dist. to land (-)
Double-crested Cormorant *	300	9.7	Dist. from colony (-), dist. to 200m isobath (-), dist. to land (-)
Pelagic Cormorant *	396	6.1	Distance to land (-), ocean depth (-), dist. to 200 m isobath (-)
Red & Red-necked Phalaropes	49,195	9.6	ENSO period, distance to land (-), ocean depth (-)
Heermann’s Gull	1,121	6.5	Distance to land (-), ENSO period, latitude (-)
Western Gull *	29,545	44.2	Distance from colony (-), distance to land (-), ENSO period
Glaucous-winged Gull	767	17.1	Ocean season, ocean depth (-), latitude (+)
California Gull *	13,721	24	Ocean season, year (+), latitude (+)
Black-legged Kittiwake	4,565	28.9	Ocean season, ENSO period, year (+)
Common Murre *	131,675	52.3	Distance to colony (-), ocean depth (-), distance to land (-)
Rhinoceros Auklet *	14,679	19.8	Distance to land (-), season, ocean depth (+)
Cassin’s Auklet *	63,465	25.8	Distance to land (-), year (-), ocean depth (-)
Tufted Puffin *	235	10.1	Distance from colony (-), year (-), distance to 200 m iso (+)
Marbled Murrelet *	273	4.7	Distance to land (-), latitude (+), ENSO period

Notes

1. Species that breed in the study area have an asterick (*) after their name.
2. For “continuous” variables, a positive (+) with a variable indicates that density increased with an increase in the magnitude of that variable; (-) denotes the opposite.
3. The nine independent variables used in the regression analysis were: distance to nearest land; ocean season; ocean depth; ENSO period; year; latitude; distance to colony; distance to 200 m isobath; and distance to 2,000 m isobath. Other variables (e.g., availability of prey, thermocline depth) not included here may also have a significant effect.

Analysis of Variance in Species Abundance Patterns

Many factors influence the distribution and abundance of marine birds; in this study, the effects of nine independent variables on species density were investigated for 26 species. The data used for the regression analyses were a subset of the mapped data, and included data from the Davidson Current Season from 1985 through 2002; cells with area surveyed less than 0.25 km^2 were excluded. See Table 3.8.

Among the nine variables presented here, the three most important variables that explained variation in species density were "Distance to Land" (16 of 25 species), "Ocean Season" (13 species), and "Ocean Depth" (11 species, see Table 3.8). The next three variables of importance were "ENSO" (eight species), "Year" (seven species), and "Distance to Colony". In some respects, for species having many small colonies (e.g., Pelagic Cormorant), "Distance to Land" and "Distance to Colony" may have co-varied. The variable "Year" indicated whether there was an increasing or decreasing trend in the species' abundance. An effect of ENSO would indicate an especially complex relationship, probably related to prey availability.

Please note that while the three most important environmental variables of those evaluated are indicated in Table 3.8, for many species, it is likely that other variables are of greater importance or significance (e.g., prey availability and size, distance to upwelled-derived frontal features, chlorophyll concentration, depth of thermocline). These variables, however, have been difficult to measure on a consistent basis among all survey types. On average, only about 20% of the variance was explained with the top three variables presented. To gauge how these other factors might affect results for avifauna from the California Current System (see Ainley *et al.,* 2005). With a full suite of variables, explained variation was much higher, and it became evident that depth and distance to shelf-break as used in the current analysis are mere proxies for variables such as chlorophyll and prey availability.

Species Use of the Water Column. Several marine bird species are capable of exploiting the entire water column of the shelf, e.g., Pacific Loon, Western/Clark's Grebes, and Common Murre, but for unknown reasons (possibly prey selection, or perhaps interference competition from murres and shearwaters) the grebes mainly frequent the innermost portion of the shelf. The very abundant Common Murre is found everywhere on the shelf especially during the breeding/Upwelling Season. Other diving species, such as scoters or Marbled Murrelet, frequent only shallow waters of the inner shelf, while species such as Tufted Puffin, Rhinoceros Auklet and Cassin's Auklet frequent waters much deeper (continental slope) than their diving capabilities allow. The very abundant Sooty Shearwaters are found everywhere from the outer slope to the inner shelf, but they are shallow divers, only venturing down to 20 m.

These differences in patterns of habitat use are likely related to factors such as the occurrence patterns of different prey (species/sizes), interspecific competition, or temporal occurrence of certain prey (species/sizes). The latter would account for why some year-round residents feed over waters of different depths during one season compared to another. Species such as the Sooty Shearwater, which use a wide range of ocean depths and habitats, are likely to be more generalized in prey selection, possibly due to their fast, efficient flight allowing them to forage over much larger areas than many other marine birds, particularly the alcids and cormorants. The latter dive for food, a behavior that compromises their flight ability.

Response to Changes in Ocean Climate. The study area is subjected to frequent shifts in marine climate of different scales and periodicity. This makes management a challenge, because populations are affected by natural environmental factors that cannot be addressed proactively by management. The individual species' text (accompanying each map) often explains how the species has become more or less abundant during periods of warmer- or colder-than-average ocean temperatures. Actually, the shift in temperature is a proxy for many other changes, all of which ultimately affect the food web.

Table 3.9. Effects of ocean season and ENSO (El Niño/ Southern Oscillation) events on the abundance of 26 species off central California from 1985 and 2002, as determined through multiple regression analyses.

Species	Ocean Season(s) of Highest Abundance*	ENSO Event of Highest Abundance*
Pacific Loon	DC	LA
Western Grebe	DC	LA
Black-footed Albatross	UP	NE
Laysan Albatross	DC	LA
Northern Fulmar	DC	LA
Sooty Shearwater	UP	NE
Pink-footed Shearwater	OC	EL
Leach's Storm-Petrel	DC/UP	EL
Ashy Storm-Petrel	OC	LA
Fork-tailed Storm-Petrel	DC	LA/EL
Brown Pelican	OC	LA/EL
Brandt's Cormorant	UP	ns
Pelagic Cormorant	UP	ns
Double-crested Cormorant	UP	ns
Red & Red-necked Phalaropes	OC	LA
Western Gull	UP	EL
Glaucous-winged Gull	DC	EL
Heermann's Gull	ns	EL
California Gull	DC	LA
Black-legged Kittiwake	DC	LA
Common Murre	UP	ns
Cassin's Auklet	UP	NE
Rhinoceros Auklet	DC	LA
Tufted Puffin	UP/DC	NE
Marbled Murrelet	DC/UP	LA

* Notes. Ocean seasons are: Davidson Current (DC), Upwelling (UP), and Oceanic (OC); ENSO periods are El Niño (EL), La Niña (LA), and neutral (NE). For species with significant differences in abundance during respective seasons/periods (Sidak tests, P < 0.01), the season/period in which they were most abundant is given. If densities did not differ between the two seasons/periods in which they were most abundant, then the two are listed (eg. DC/UP, where densities were slightly higher in DC season than the UP season). Species with no significant effect of season or period are noted as "ns".

To illustrate the short-term ocean climate effects using species maps, a comparison was done using selected species for specific El Niño and La Niña periods – see Figures 3.46 and 3.47. For an example El Niño period, the most recent, intense event that occurred from the Oceanic Season of 1997 through the Upwelling Season of 1998 was used; for an example La Niña period, the period covering the Oceanic Season of 1998 through the Oceanic Season of 1999 was used. These two periods were chosen because climate differences during those times were extreme, i.e., among the strongest ENSO events of the past 100 years, and they occurred adjacent to one another. Therefore, a comparison of population response was not confounded by long-term trajectories in base population size. Tables 3.9 and 3.10, as well as Figures 3.46 and 3.47 provide some examples of these changes due to interannual climate events (see Table 3.4).

Short-term Warm-water Periods (e.g., El Niño events). During short-term warm-water events (including El Niño), many species tended to occur closer to shore than during other years (Ainley and Boekelheide, 1990; and Oedekoven *et al.,* 2001). During these periods, five of the predominant species became more abundant in general, and inside the marine sanctuaries. These species included Pink-footed Shearwater; Leach's Storm-Petrel; and Western, Glaucous-winged and Heermann's gulls; see Table 3.9. Also increasing in the study area during warm-water periods were less abundant species including Black and Least storm-petrels and Black-vented Shearwater.

Short-term Cold-water Periods (e.g., La Niña events). During short-term cold-water periods, areas of relatively high avifaunal biomass and density expanded to cover broader portions of the study area; 11 of the predominant species became more abundant. Species whose abundance showed the greatest increases at sea were the Western Grebe, Northern Fulmar, Ashy Storm-Petrel, Red and Red-necked Phalaropes (grouped), and Black-legged Kittiwake; see Table 3.9. Others, whose abundances were also significantly greater during La Niña periods, were Pacific Loon, Laysan Albatross, California Gull, Rhinoceros Auklet, and Marbled Murrelet.

Neutral Periods (i.e., neither unusually warm nor cool water). Four species, Black-footed Albatross, Sooty Shearwater, Tufted Puffin and Cassin's Auklet, were significantly more abundant during the neutral period than during the warm or cold periods.

Other Responses to Short-Term Climatic Change. In regression analyses, the densities of the California Brown Pelican and Fork-tailed Storm-Petrel were not significantly different during warm-water and cold-water periods. Basically, this was because such periods varied greatly in intensity, thus reducing effects especially if other factors (not studied) were more important. However, the densities of both were greater during these periods than during the Neutral period. On the other hand, the Brown Pelican responded strongly to the disparity of conditions between the very strong 1997-1998 El Niño and the very strong 1999-2000 La Niña (Figure 3.46). The Black-vented Shearwater, for which there were insufficient data for long-term trend analysis, responded much more dramatically, with large numbers invading central California waters during the 1997-98 El Niño. Finally, there were no significant differences in the at-sea abundance of Common Murre and the three cormorant species among the three short-term, climate-related periods. This means that these populations remained in the study area regardless of climate. With regard to most locally breeding marine birds (e.g., Brandt's Cormorant), cold-water events (e.g., La Niña) tend to benefit the breeding population sizes, breeding success and probably survival of many marine birds, because there is typically more food available during cold-water periods. Conversely, warm-water years generally reduce the availability of food, which stresses the populations, not only reducing their breeding population sizes and breeding success and causing starvation, but making the

Table 3.10. A summary of changes in marine bird occurrence patterns, as a response to warm- and cold-ocean anomalies, as determined by visual comparison of species' maps during the 1997-1998 El Niño event and the 1999-2000 La Niña event.

	Effect on Spatial Distribution		
Species	**No Change**	**El Niño**	**La Niña**
Pacific Loon	X		
Western Grebe	X		
Black-footed Albatross	X		
Laysan Albatross	X		
Northern Fulmar			More dispersed
Pink-footed Shearwater	X		
Buller's Shearwater	X		
Sooty Shearwater		To Monterey Bay	
Black-vented Shearwater		To Gulf of Farallones	
Fork-tailed Storm-Petrel	X		
Leach's Storm-Petrel	X		
Ashy Storm-Petrel		More dispersed	
Black Storm-Petrel		To Gulf of Farallones	
California Brown Pelican		More dispersed	
Brandt's Cormorant		More dispersed	
Pelagic Cormorant		More dispersed	
Red-necked Phalarope	X		
Red Phalarope	X		
Heermann's Gull			
Western Gull	X		
Glaucous-winged Gull		More confined	
Sabine's Gull	X		
California Gull		More confined	
Bonaparte's Gull		To Monterey Bay	
Black-legged Kittiwake		Confined to slope	More dispersed
Arctic Tern	X		
Caspian Tern	X		
Elegant Tern	X		
Common Murre		More dispersed	
Pigeon Guillemot		More dispersed	
Cassin's Auklet		More dispersed	
Rhinoceros Auklet	X		
Tufted Puffin		More dispersed	
Marbled Murrelet		More offshore	
Xantus/Craveri Murrelets	X		

populations more susceptible to other factors (e.g., disease), because of their poor body condition (G. McChesney, pers. comm.).

Breeding species (e.g., Common Murre, Cassin's Auklet) whose populations are not increased by an influx of visitors from colonies outside the study area during warm-water periods, and the cormorant species, are more dispersed within the study area in the breeding season during warm-water periods (Table 3.10). This spreading is often affected most strongly by Farallon breeding species, which usually concentrate near the Gulf of the Farallones (outer shelf), and which move more to coastal waters.

Trends in Marine Bird Abundance

Based on the at-sea data in the CDAS data set (1980-2001), a number of species exhibited gradual changes in abundance from 1985 to 2001; this may be partially due to longer-term, decadal shifts in marine climate (Hare and Mantua, 2000; Mantua and Hare, 2002). These patterns were revealed using regression analyses, especially in cases where Year was an important explanatory variable to species occurrence (Table 3.8).

Ashy Storm-Petrel and California Gull exhibited a gradual increase in abundance, while Tufted Puffin showed a gradual decrease. The Black-legged Kittiwake increased gradually too, and was especially abundant after 1998 (Figure 3.47).

For other species the pattern was more complex. Black-footed Albatross, Sooty Shearwater, Fork-tailed Storm-Petrel and Cassin's Auklet showed a gradual decrease from 1985 until about 1999, when they began to increase.

In the year 2000, the system shifted temporarily from a 'warm' to a 'cool' ocean phase (Bogard, 2000; Schwing and Moore, 2000). The Northern Fulmar exhibited a variable but 'steady' abundance during the 1980s and early 1990s but then began to increase with the arrival of the cooler climate/sea surface temperatures. The abundance of the Common Murre remained stable through most of the study period following a dramatic decline in 1982 (Ainley and Divoky, 2001; Manuwal and Carter, 2001); recently it has begun to increase (H. Carter, pers. comm.). These responses to longer-term temperature shifts present challenges to resource researchers and managers, even greater than those offered by short-term climate shifts (e.g., ENSO events). It takes many years of monitoring to detect long-term shifts in abundance.

Life History and Management Characteristics

The marine avifauna off north/central California, as represented in the summary CDAS data set and this analysis, is composed of 76 marine bird species, with 40 species occurring regularly enough to assess and map patterns of their occurrence. Table 3.11 is a summary of selected life-history and management information for 39 of the marine bird species.

Food Types. With regard to trophic relationships, the majority of marine bird species are either zooplanktivores (generally smaller-bodied birds, such as Cassin's Auklet and phalaropes), and/or piscivores (fish-eating birds, such as shearwaters and murres). Major prey items for marine birds in the study area include: euphausiids (*Thysanoessa spinifera, Euphausia pacifica*), market squid (*Loligo opalescens*), juvenile rockfish (*Sebastes* species, especially *Sebastes jordani*), anchovy (*Engraulis mordax*), herring (*Clupea harengus*), smelt (*Atherinops californiensis, Spirinchus starksi*), Pacific saury (*Cololabis saira*), sardine (*Sardinops sagax*), midshipman (*Porichthys notatus*), surfperch (several species) and myctophids (several species), with importance of prey type varying by the habitat and time of year in which a particular bird species is foraging (Briggs and Chu, 1987; Ainley and Boekelheide, 1990; Thayer and Sydeman, 2007).

Species Relative Abundance in the Study Area. Among the more regularly occurring marine bird species during the 1980-2001 analysis period (see Table 3.11, below), two were very abundant, seven were abundant, 13 were common, 14 were uncommon, and two were rare. The majority of the species (26) are only seasonally present, but of the 15 species that breed in or adjacent to the study area, 14 are present year round. Relative abundance was estimated based on: 1) analysis of the data sets in CDAS, using a logarithmic scale of number of individuals seen within the study area on surveys during the study period; and 2) expert opinion.

Relevance of Marine Sanctuary Boundaries to Marine Birds

Based on the data and analyses reported herein, the boundaries of the National Marine Sanctuaries off north/central California generally encompass the areas of high concentrations and diversity for marine birds, except for the western edge of the Gulf of Farallones area and the "sanctuary exclusion area" off San Francisco and Pacifica.

Owing perhaps to a response to competition for food by the large numbers of marine birds nesting on the Farallon Islands and Point Reyes Headlands, during the breeding (Upwelling) season high concentrations of several breeding species extend seaward of the western boundary of the Gulf of the Farallones National Marine Sanctuary, over the Farallon Escarpment and beyond. This is especially true of Ashy Storm-Petrel, Western Gull, Com-

Table 3.11. Life history and management information for selected marine birds along the north/central California coast.

		Status in Study Area			Temporal Occurrence in Study Area			Major Food Items[3] / Feeding Type					
Species Common Name	Species Scientific Name	Protection Status[1]	Estimated Trend in Abundance in Study Area[6]	Estimated Relative Abundance at Sea[2]	General Occurrence	Primary Months of Presence[5]	Months When Breeding[5, 10]	Plank-ton	Fish	Cephalo-pods (squid, octopus)	Eu-phau-siids (krill)	Benthic Inverte-brates	General-ist Feeder
Loons/Grebes													
Pacific Loon	*Gavia pacifica*		Unknown	Common	Seasonal	Mar-Apr, Aug-Sep			x				
Common Loon	*Gavia immer*		Unknown	Uncommon	Seasonal	Nov-Apr			x				
Western & Clark's Grebes	*Aechmorphorus occidentalis, A. clarksii*		Unknown	Abundant	Year-round	Nov-Sept			x				
Sea Ducks (Scoters)													
Surf Scoter	*Mellanita perspicillata*		Stable	Abundant	Seasonal	Nov-Apr						x	
Albatrosses/Petrels													
Black-footed Albatross	*Phoebastria nigripes*		Stable	Common	Year-round	Mar-Aug				x			x
Laysan's Albatross	*Phoebastria immutabilis*		Unknown	Rare	Seasonal	Nov-Mar				x			x
Northern Fulmar	*Fulmarus glacialis*		Increasing	Common	Seasonal	Nov-Mar							x
Sooty Shearwater	*Puffinus griseus*		Increasing	V.Abundant	Seasonal	Apr-Nov		x	x	x	x		
Pink-footed Shearwater	*Puffinus creatopus*		Stable?	Common	Seasonal	Apr-Nov			x	x			
Buller's Shearwater	*Puffinus bulleri*		Unknown	Common	Seasonal	Aug-Nov			x				
Black-vented Shearwater	*Puffinus opisthomelas*		Stable?	Uncommon	Seasonal	Aug-Nov			x	x			
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	SSC	Decreasing?	Uncommon	Seasonal	Nov-Mar		x	x		x		x
Leach's Storm-Petrel	*Oceanodroma leucorhoa*		Decreasing	Common	Seasonal	Sept	April-Sept	x		x	x		x
Ashy Storm-Petrel	*Oceanodroma homochroa*	SSC	Decreasing	Uncommon	Year-round	All	Apr-Dec	x	x	x	x		x
Black Storm-Petrel	*Oceanodroma melania*	SSC	Unknown	Uncommon	Seasonal	Apr-Oct		x	x				x
Pelican/Cormorants													
California Brown Pelican	*Pelecanus occidentalis californicus*	FE, SE	Increasing	Common	Year-round	Jun-Nov			x				
Pelagic Cormorant	*Phalacrocorax pelagicus*		Decreasing?	Uncommon	Year-round	All	Apr-Sept	x	x	x		x	
Brandt's Cormorant	*Phalacrocorax penicillatus*		Increasing	Abundant	Year-round	All	Apr-Aug		x				
Double-crested Cormorant	*Phalacrocorax auritus*		Increasing	Common	Year-round	Mar-Sep	Mar-Sep		x				
Phalaropes													
Red Phalarope	*Phalaropus fulicaria*		Stable?	Common	Seasonal	Apr-May; July-aug		x			x		x
Red-necked Phalorope	*Phalaropus lobatus*		Stable?	Common	Seasonal	Mar-Aug		x			x		x
Gulls/Terns													
Western Gull	*Larus occidentalis*		Decreasing	Abundant	Year-round	All	Apr-Aug	x	x	x	x	x	x
California Gull	*Larus californicus*		Increasing	Abundant	Year-round	Nov-Mar	Apr-Aug	x					x
Glaucous-winged Gull	*Larus glaucescens*		Stable	Uncommon	Seasonal	Nov-Mar							x
Heermann's Gull	*Larus heermanni*		Stable?	Common	Year-round	Jul-Nov			x				
Sabine's Gull	*Xerna sabini*		Stable	Common	Seasonal	Mar-Sep		x			x		
Black-legged Kittiwake	*Rissa tridactyla*		Increasing?	Common	Seasonal	Nov-Mar		x	x				
Caspian Tern	*Sterna caspia*		Stable	Uncommon	Seasonal	Mar-Nov	Apr-Aug		x				
Elegant Tern	*Sterna elegans*		Stable	Uncommon	Seasonal	July-Nov			x				
Arctic Tern	*Sterna paradisaea*		Stable?	Common	Seasonal	Mar-Apr; Aug-Sept			x				
Alcids													
Common Murre	*Uria aalge*		Increasing	V.Abundant	Year-round	All	Apr-Aug	x	x	x	x		
Pigeon Guillemot	*Cepphus columba*		Stable	Uncommon	Seasonal	Mar-Aug	Mar-Aug		x	x		x	
Cassin's Auklet	*Ptychoramphus aleuticus*	SSC	Decreasing?	Abundant	Year-round	All	Mar-July	x			x		
Rhinoceros Auklet	*Cerorhinca monocerata*		Stable	Common	Year-round	Nov-Aug	Apr-Aug	x	x	x	x		
Tufted Puffin	*Fratercula cirrhata*	SSC	Decreasing	Uncommon	Seasonal	Mar-Sep	Apr-Aug	x	x				
Marbled Murrelet	*Brachyramphus marmoratus*	FT, SE	Decreasing?	Uncommon	Year-round	All	Apr-Aug	x	x				
Xantus's Murrelet	*Synthliboramphus hypoleucus*	FC, ST	Unknown	Rare	Seasonal	May-Oct			x		x		
Craveri's Murrelet	*Synthliboramphus craveri*		Unknown	Rare	Seasonal	Aug-Oct			x				

Notes

1. Management status categories are as follows: FE–federally endangered; FT–federally threatened; FC–federal candidate; SE–state endangered; ST–state threatened; SSC–state species of special concern. Information on CA Species of special Concern 2006 was from Shuford and Gardali, 2006.
2. Relative abundance estimates at sea were based on: 1) the number of individuals tallied in the CDAS at-sea survey data (190-2001) and 2) expert opinion. The categories from the CDAS data set are defined as follows: Rare – up to 100 birds; Uncommon – up to 1,000; Common – up to 10,000; Abundant – up to 100,000; and Very Abundant – up to 1,000,000.
3. Information on food items are mostly from Ainley & Sanger 1979, Briggs & Chu 1987, and Ainley & Boekelheide 1990.
4. Entries with question marks are best estimates from David Ainley or Gerry McChesney (USFWS).
5. Timing information is mostly from Cogswell, 1977and Ainley and Boekelheide, 1990. Information on Caspian Tern breeding time was from Joelle Buffa, FWS, pers. comm. Updates for several species by Gerry McChesney.
6. Estimates on population status was based on analysis of the CDAS shipboard data sets from 1985-2001, and for birds that breed in the study area, a review of available colony data.
7. Months of presence and breeding in the study area are approximations, because timing is strongly influenced by the interannual variability of environmental conditions in the study area.
8. Information on population status and temporal occurrence refers only to birds and their activities in the study area.
9. Other theatened or endangered marine-related birds that occur in the study area but are not included in this table include: short-tailed albatross (FE), western snowy plover (FT, SSC), and California Least tern (FE, SE)
10. Time period when species breeds in or adjacent to study area (I.e., along the central California coast).
11. This table was developed by David Ainley of H.T. Harvey and Associates and and Tracy Gill of NCCOS, NOAA, for NOAA's National Marine Sanctuary Program.

mon Murre, and Rhinoceros Auklet. For the gull and murre species, these deeper waters are not their preferred foraging habitat, but perhaps they forage there during breeding because more suitable continental shelf habitat to the north and south is too far out of range.

To a lesser degree, a smaller high-density area existed seaward of Año Nuevo Island, where there is a smaller, but important bird colony. These three colonies (Farallon Islands, Point Reyes Headlands and Año Nuevo Island), and the waters between them which comprise the Gulf of the Farallones, possess populations that interact regularly in the shallow waters that lie between; many individuals marked at one colony have been seen at the other two sites. Therefore, in terms of marine birds, the waters of the Gulf of the Farallones, as defined above, constitute a natural management unit.

In addition, it was apparent from visual inspection of the maps, that the "sanctuary exclusion area" (i.e., the ocean area off San Francisco and Pacifica that is excluded from the Monterey Bay National Marine Sanctuary) represents a very important area for marine birds, especially those that breed at localities within the Gulf of the Farallones National Marine Sanctuary (e.g., Point Reyes, Farallon Islands) (Ainley *et al.,* 1996b; David Ainley, pers. comm.). This area is influenced strongly by the San Francisco Bay tidal plume, which provides habitat for many forage fish. This "sanctuary exclusion area" is also one of the main foraging areas of the Devil's Slide murre colony, which is in the process of being restored (David Ainley, pers. comm.).

With regard to the offshore bounds of the sanctuaries, among the 40 species of marine birds mapped, 11 species had significant concentrations seaward of sanctuary boundaries (see Table 3.5). In terms of management, it is important to consider Ashy Storm-petrel and its habitat, because it is listed as a "State Species of Concern". The Xantus' Murrelet, a recently listed species, also deserves consideration, although the proportion of this species' population that visits the central California National Marine Sanctuaries is relatively low.

<u>Human Impacts to Marine Birds in the Study Area</u>. Although this report does not address this topic, it bears mentioning, as a variety of human impacts significantly affect the distribution and abundance of marine species. It is key for coastal resource managers to identify and attempt to minimize the impacts they can, for there are many natural and human impacts that cannot be controlled (e.g., climate change, airplane and military disturbance). Major human impacts to marine birds include: feeding birds getting caught in commercial and recreational fishing gear; birds feeding on plastics; loss and disturbance of nesting habitat; disturbance of feeding and breeding habitat, owing to vessel traffic; depletion of fish populations from overfishing; catastrophic oil spills; and chronic oiling.

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CHAPTER REVIEWERS

The review for Phase II work was conducted in 2006 and early 2007; see next page for reviewers.

Two reviews were done for the Phase I marine bird analyses. The first was a workshop to review draft maps in October 2002, and the second review focused on the overall draft bird report (which contains the maps) and was conducted via email November and December, 2002.

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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 species 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.

<u>Details of Density Calculations for Marine Mammals at Sea.</u> 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) $D = n / (l \bullet w)$

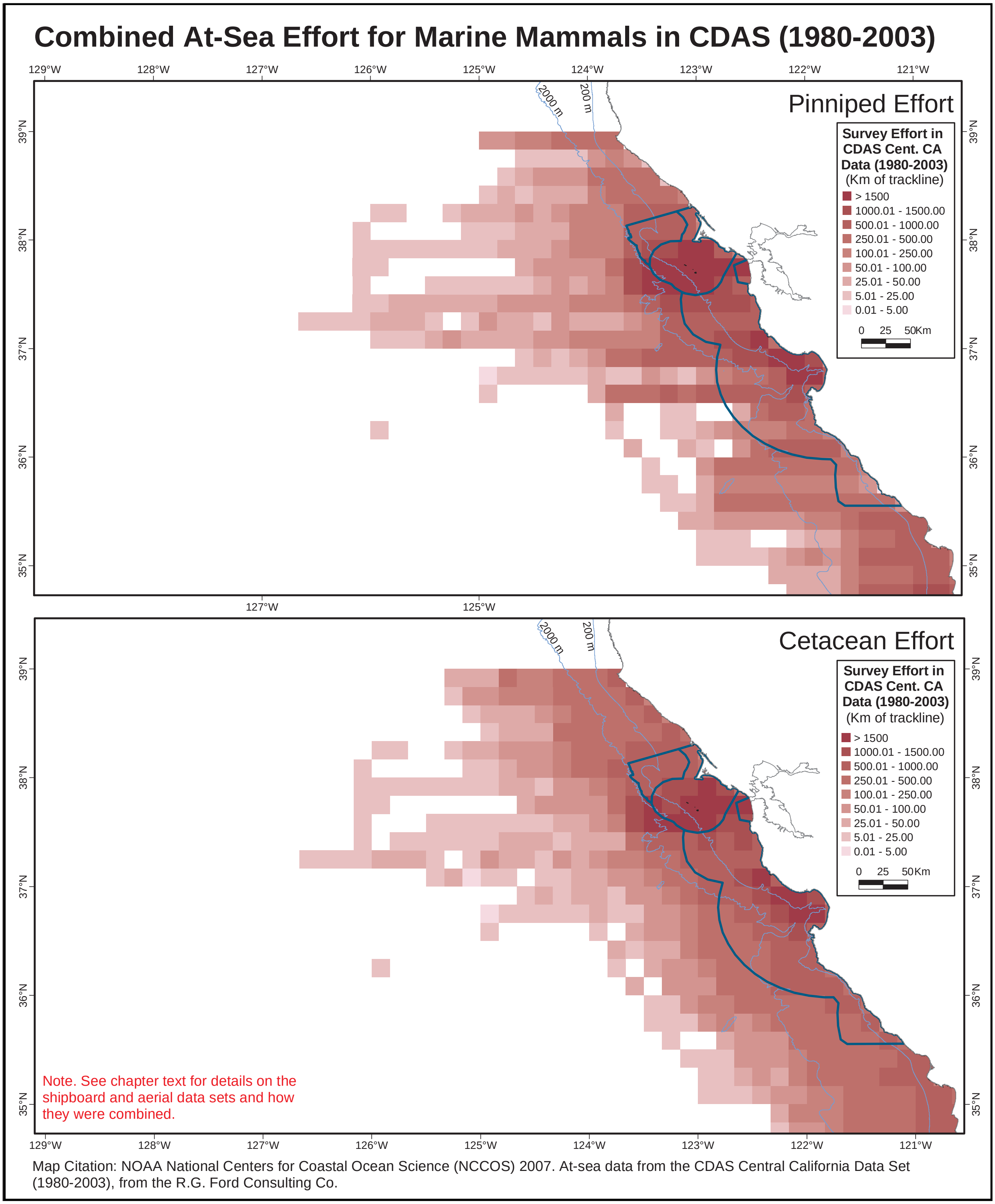
where D is density, n is the number of animals observed, l is the length of the trackline sampled (aircraft or ship), and w is the width of the sampled area. For strip transects, w was the specified strip width. For line transects, the Effective Strip Width (ESW) was calculated from f(0) using methods 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:

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

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

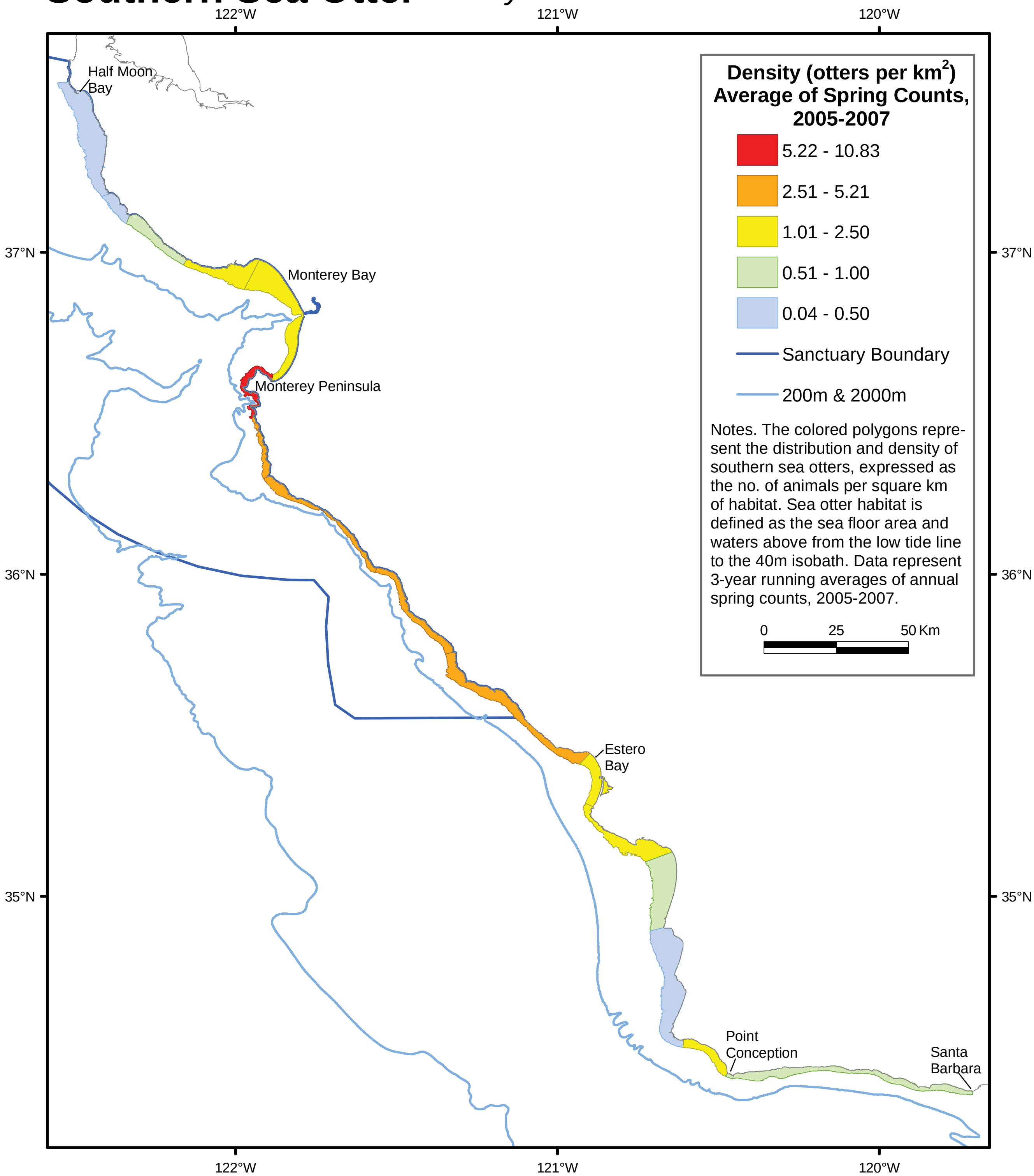
A series of over 65 marine mammal maps and descriptions are presented for 24 marine mammal species. The section contains maps and descriptions for individual species, species groups (e.g., Mesoplodont beaked whales) and community metric maps (e.g., cetacean richness).

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.

Southern Sea Otter *Enhydra lutris nereis*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data & Map Sources: Brian Hatfield, U.S. Geological Survey, M. Tim Tinker and Mike Kenner, University of California at Santa Cruz, and Mike Kenner, Cal. Dept. Fish & Game.

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

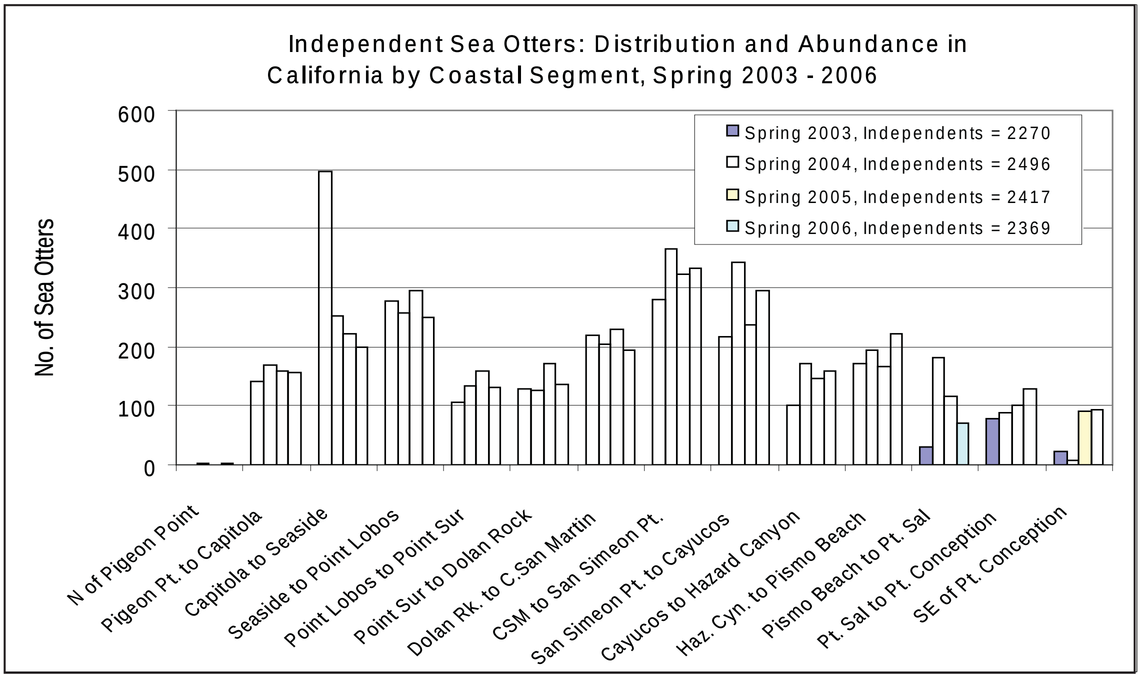


Figure 4.4. Independent southern sea otters: distribution and abundance in California by coastal segment, spring 2003-2006. http://www.werc.usgs.gov/otters/ca-surveyspr2006.htm

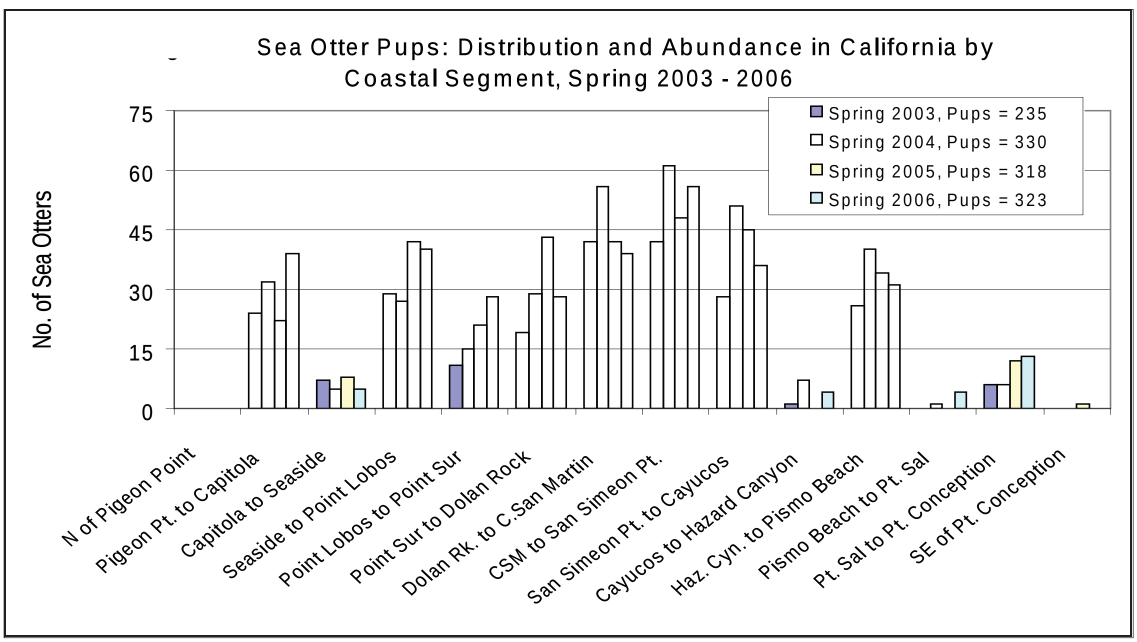


Figure 4.5. Southern sea otter pups: distribution and abundance of in California by coastal segment, spring 2003-2006. http://www.werc.usgs.gov/otters/ca-surveyspr2006.htm

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

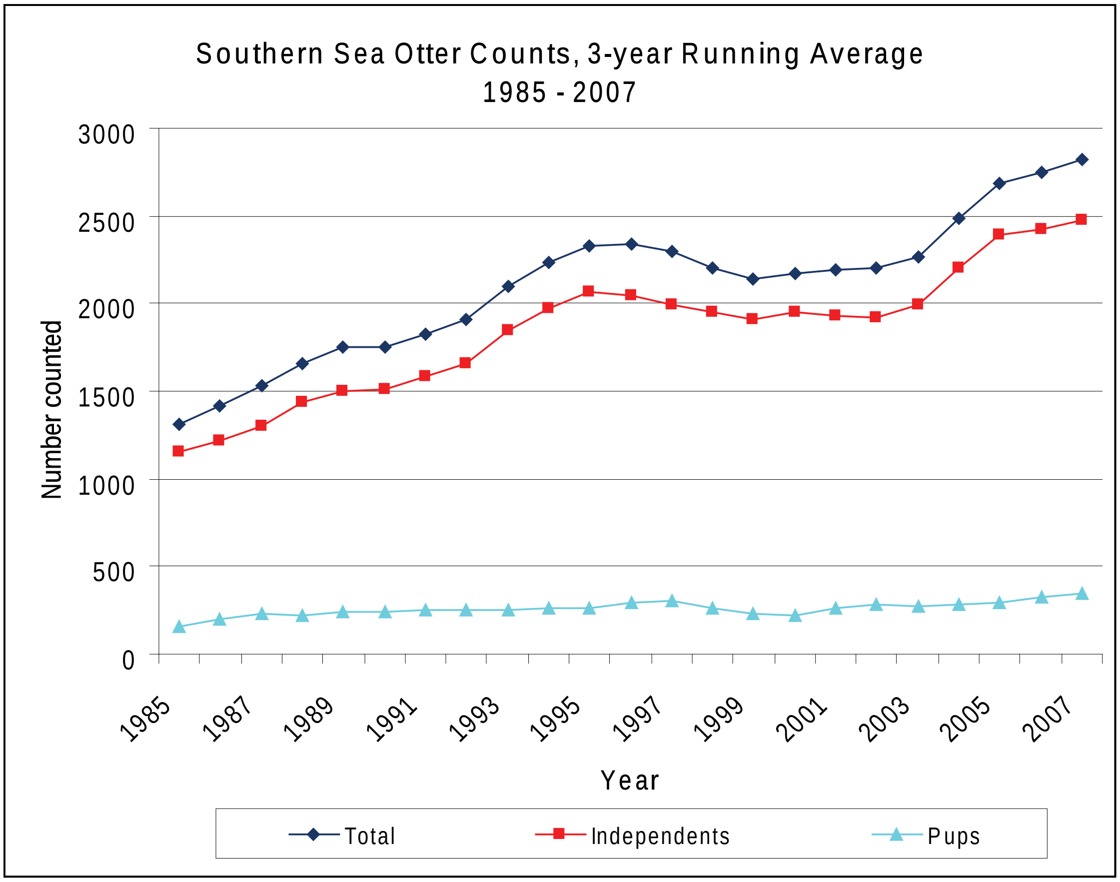


Figure 4.6. Number of southern sea otters counted during spring surveys, plotted as 3-year running averages from 1985-2007. Reprinted with permission from the USGS Western Ecological Research Center. http://www.werc.usgs.gov/otters/ca-survey3yr.html

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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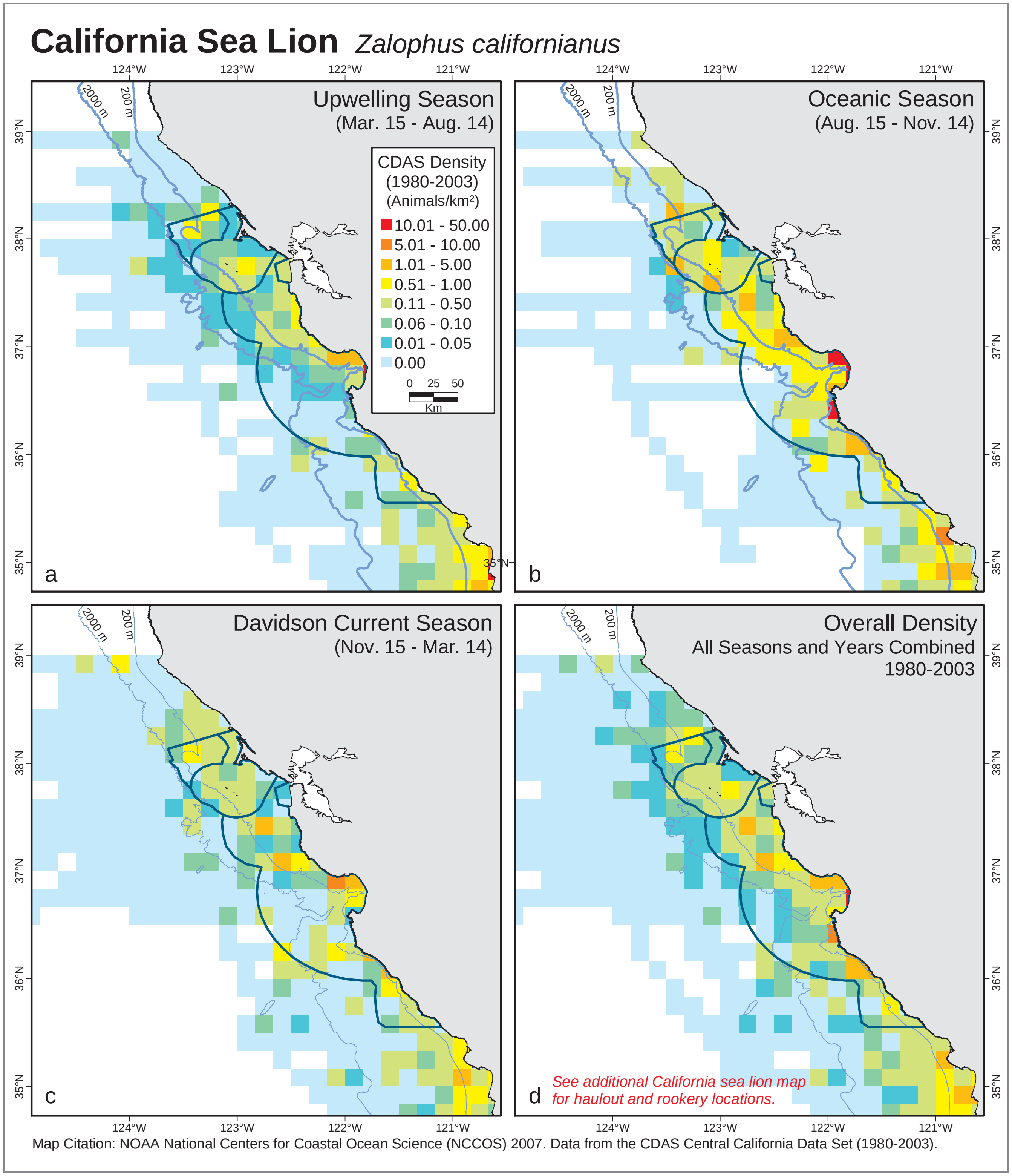


Figure 4.7. Maps for California sea lion: seasonal and overall at-sea densities from the CDAS central California data set **(1980-2003).**

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.

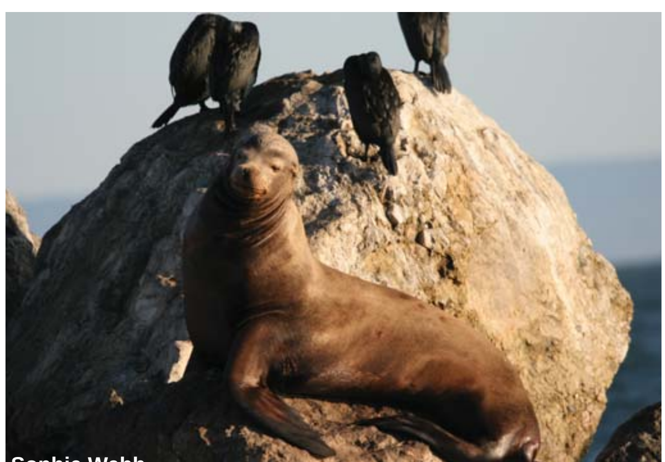
RESULTS AND DISCUSSION

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


Sophie Webb

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).

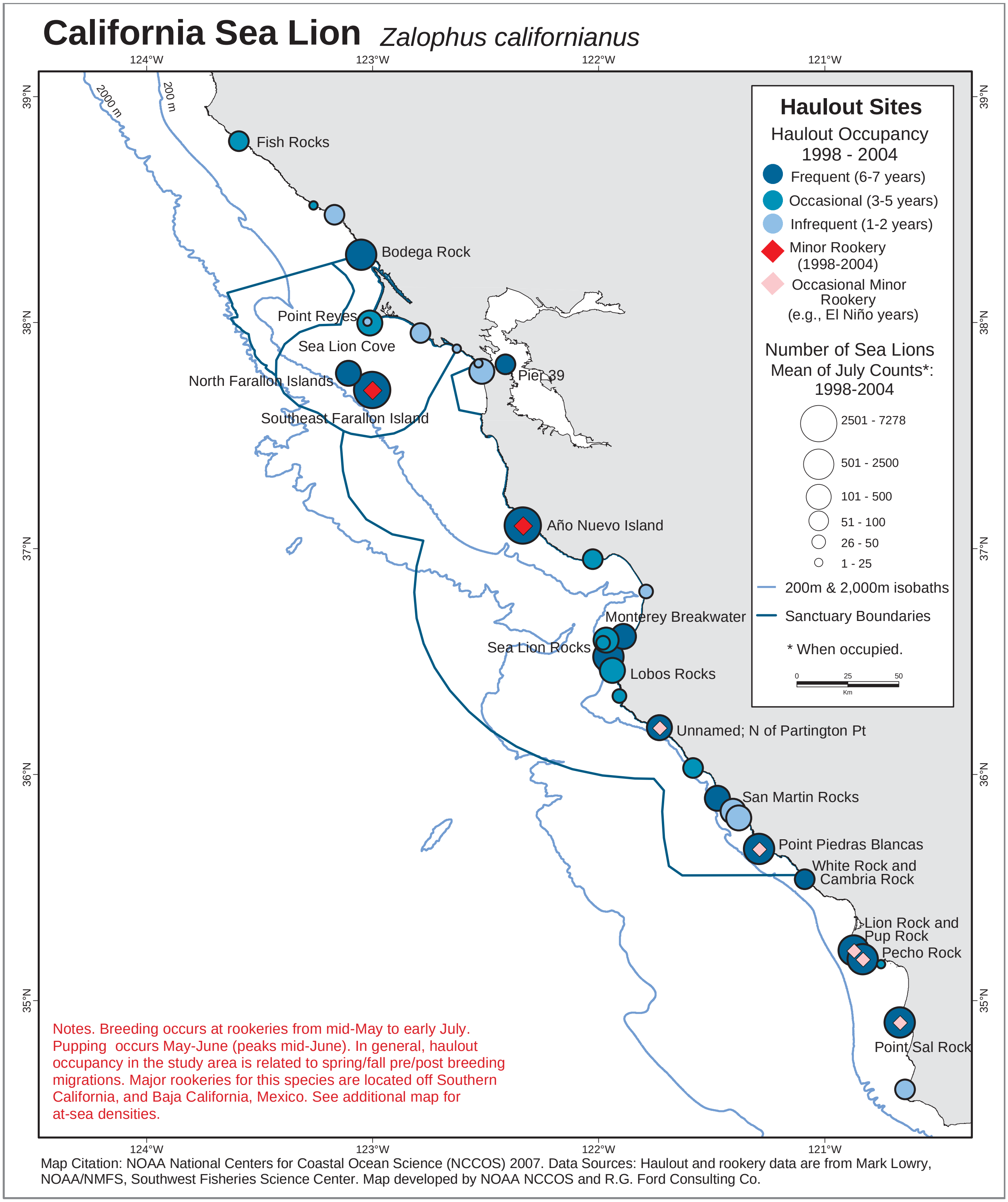


Figure 4.8. Map of California sea lion's haulouts and rookeries, 1998-2004, from NOAA's Southwest Fisheries Science Center.

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.

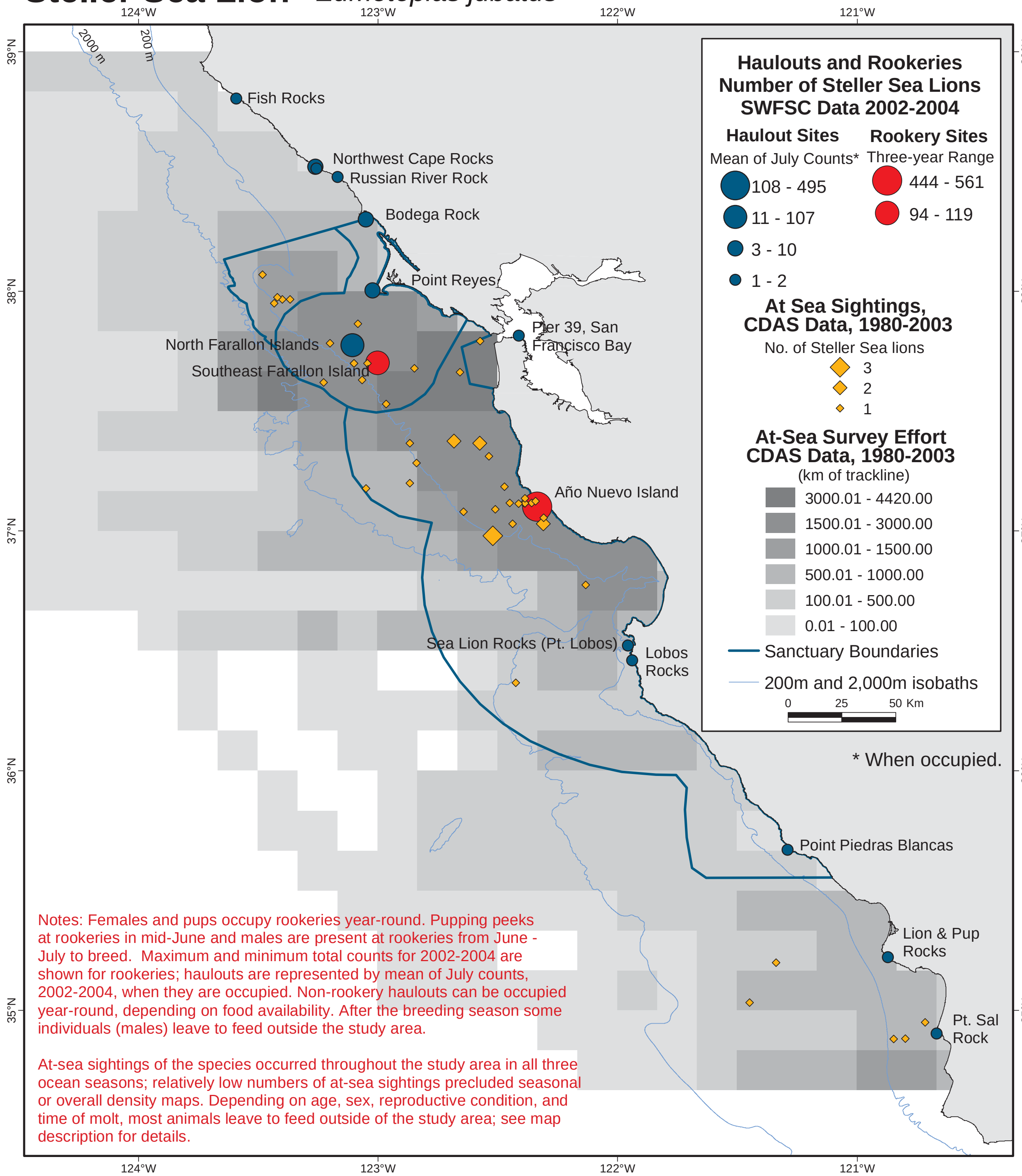
During warm-water periods, some California sea lions move up from south of the study area and temporarily increase production (number of pups born). For example, over the seven-year period from 1998-2004, the number of pups born annually at Año Nuevo Island was often less than 12, except in 1998 and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

Steller Sea Lion *Eumetopias jubatus*



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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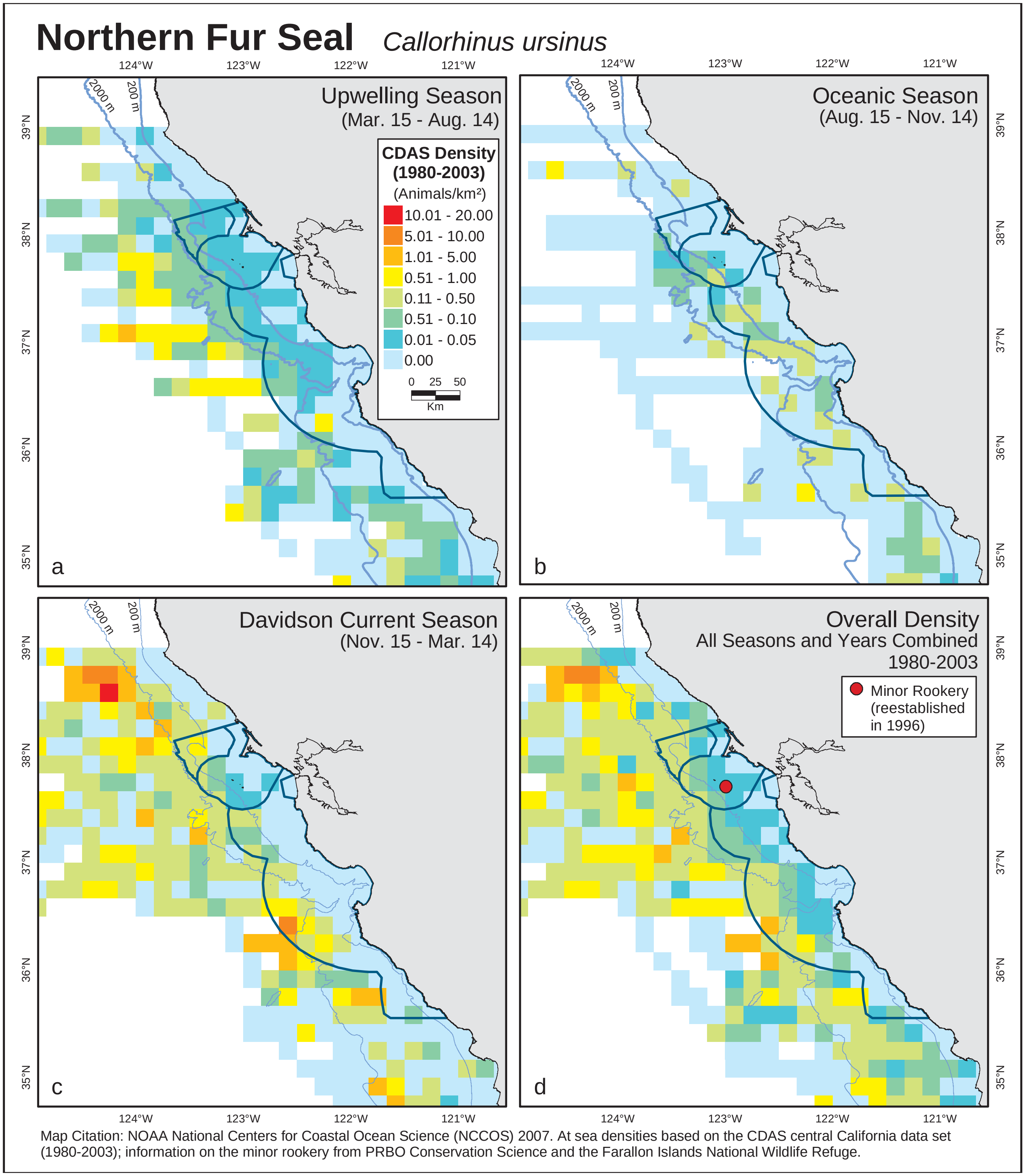

Figure 4.10. Maps for northern fur seal: seasonal and overall densities and rookery location. Densities from the CDAS central California data set (1980-2003) and rookery information from PRBO Conservation Science and the Farallon Islands National Wildlife Refuge.

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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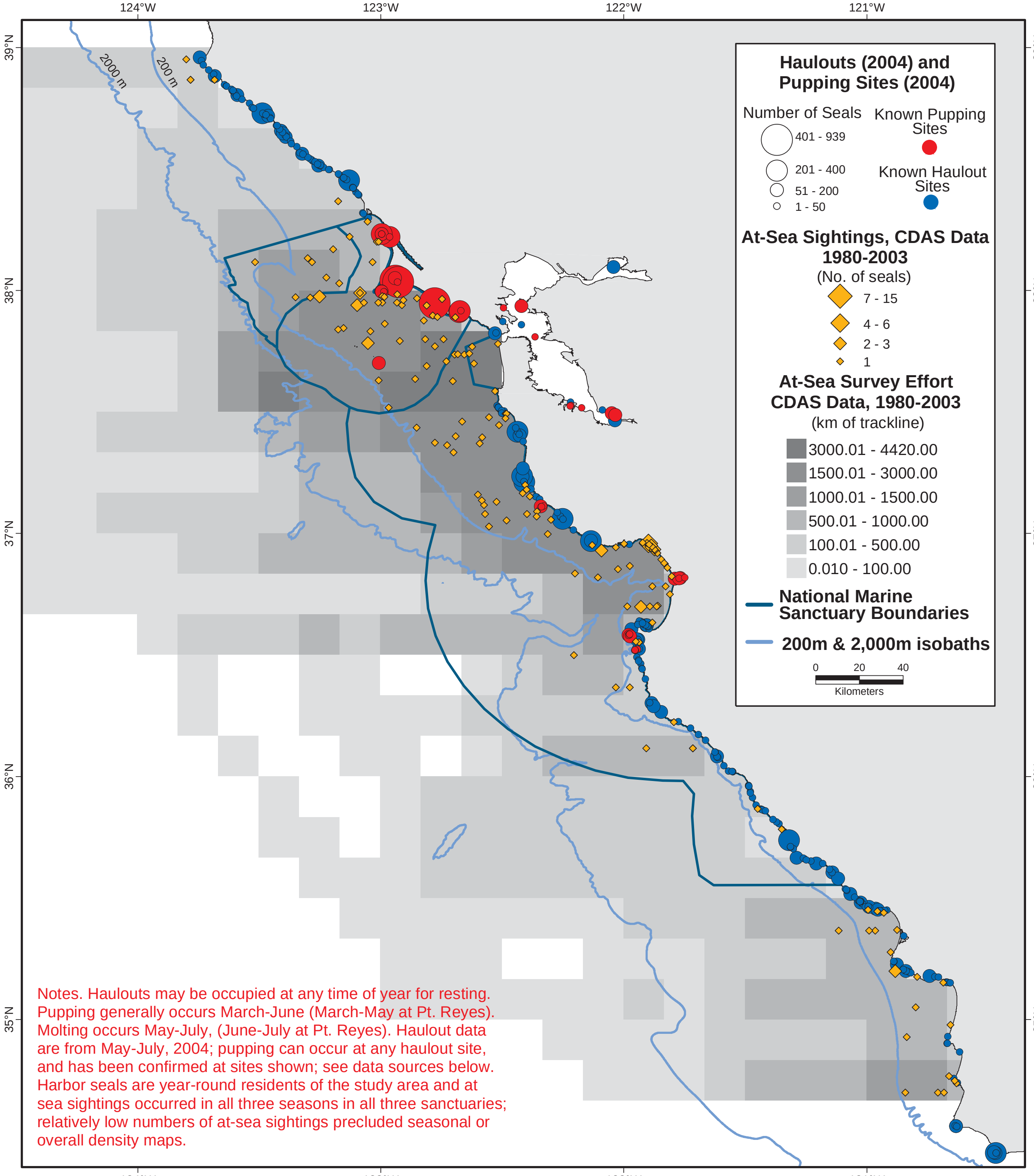
Pacific Harbor Seal *Phoca vitulina richardsii*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Sources: 1) At sea data are from the CDAS Central California Data Set (1980-2003) by R.G. Ford Consulting Co.; 2) Haulout data are from Mark Lowry, NOAA/NMFS, Southwest Fisheries Science Center, and 3) pupping site information is from personal communications with D. Greig, E.Grigg, P. Morris, D.Lee, S. Allen, and M.Lowry.

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.

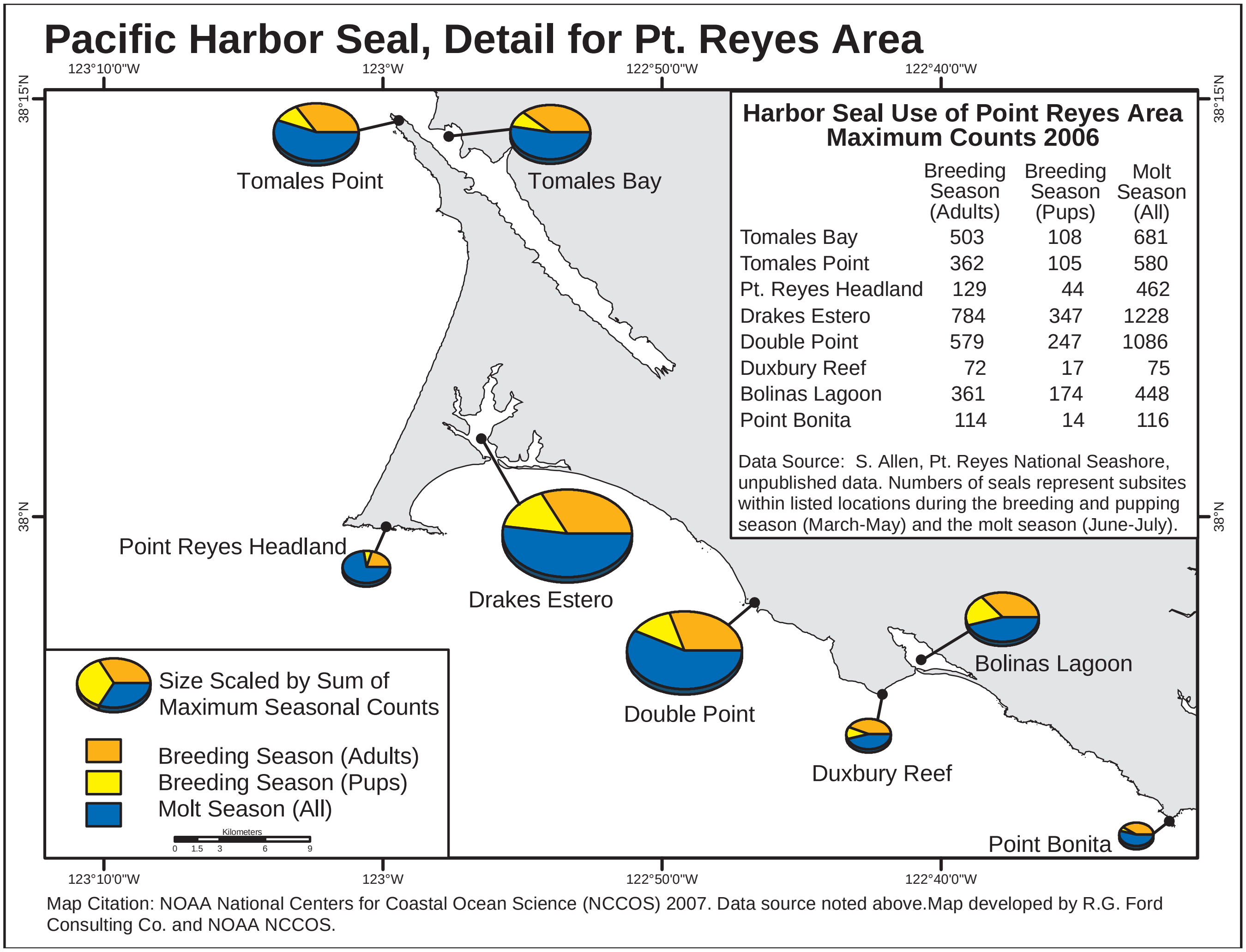
In California, 563 harbor seal haulout sites are widely distributed along the mainland and offshore islands, and include rocky shores, beaches and intertidal sandbars (Lowry *et al.,* 2005). Statewide, the population of Pacific harbor seals appears to be increasing, however the rate of increase is lower 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.

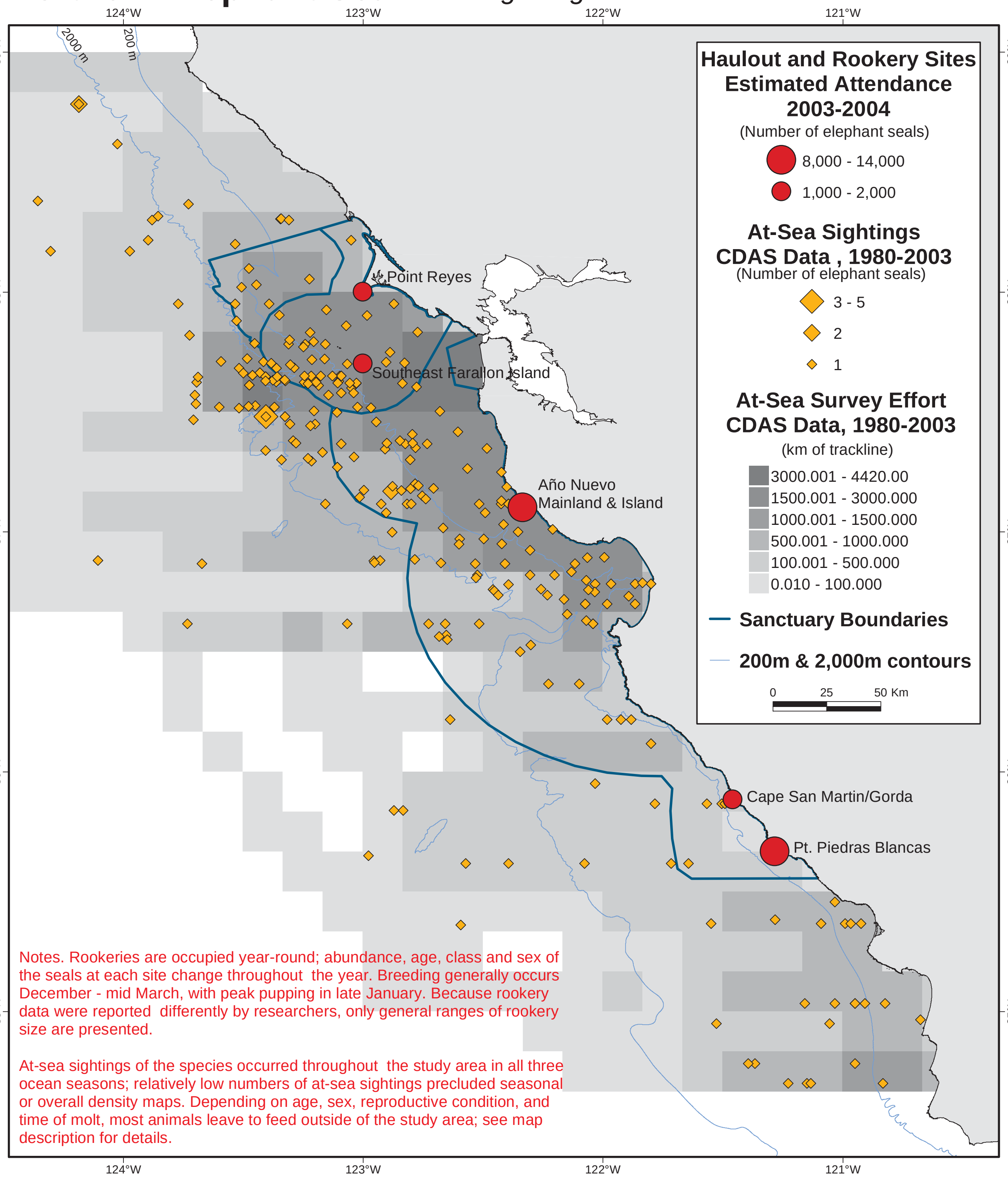
This map also summarizes habitat use (relative importance and pattern of use during breeding, pupping, and molting) of the haulout sites during 2006 at Tomales Point, Tomales Bay, Point Reyes Headland (area of Special Biological Significance), Drakes Estero, Double Point (area of Special Biological Significance), 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.

<u>Monitoring and Trends at Pt. Reyes.</u> 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).

<u>Disturbance.</u> 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).

<u>Education and Outreach.</u> 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.

Northern Elephant Seal *Mirounga angustirostris*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data Sources: Rookery data are from: Brian Hatfield, USGS; Rick Condit, Smithsonian; Bill Sydeman, PRBO; Joelle Buffa, NPS; and Sarah Allen, Pt. Reyes Nat. Seashore, NPS. At-sea data from CDAS data set (1980-2003). Map developed by NOAA NCCOS and R.G. Ford Consulting Co.

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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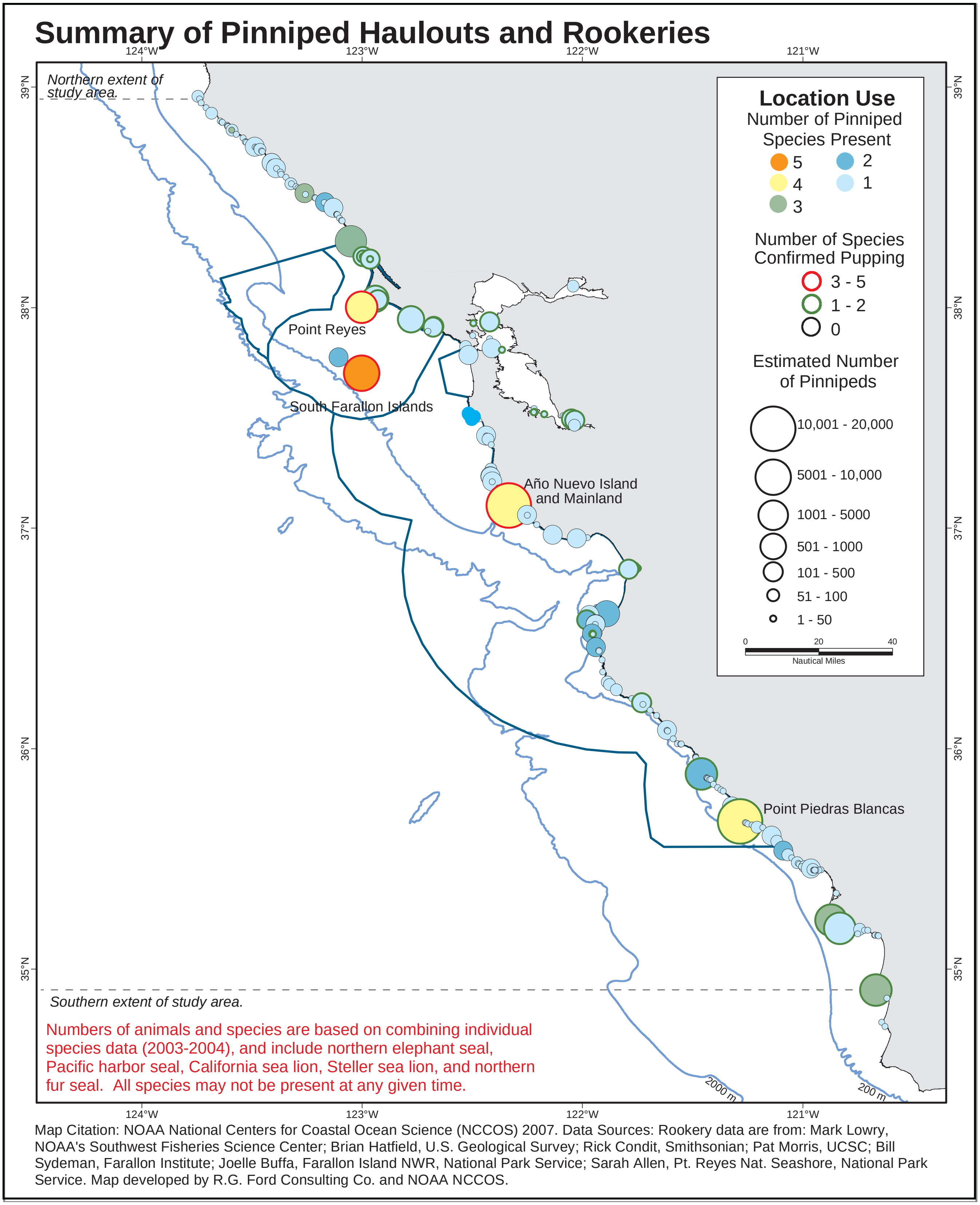

Figure 4.14. Summary of pinniped shore zone use of haulouts and rookeries; see map and description for data sources.

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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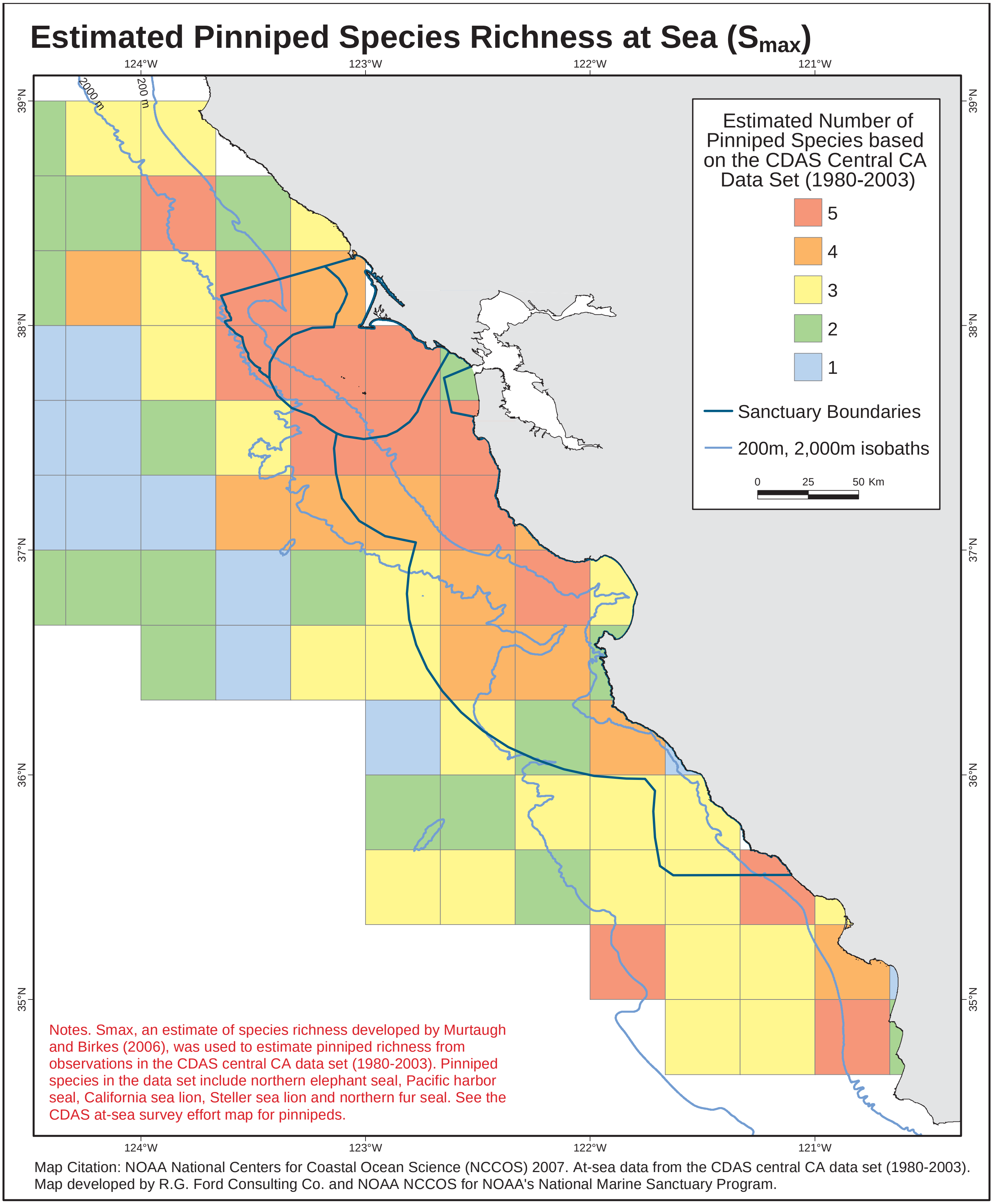


Figure 4.15. Map of estimated species richness for pinnipeds (seals and sea lions), based on the CDAS central California data set (1980-2003).

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.

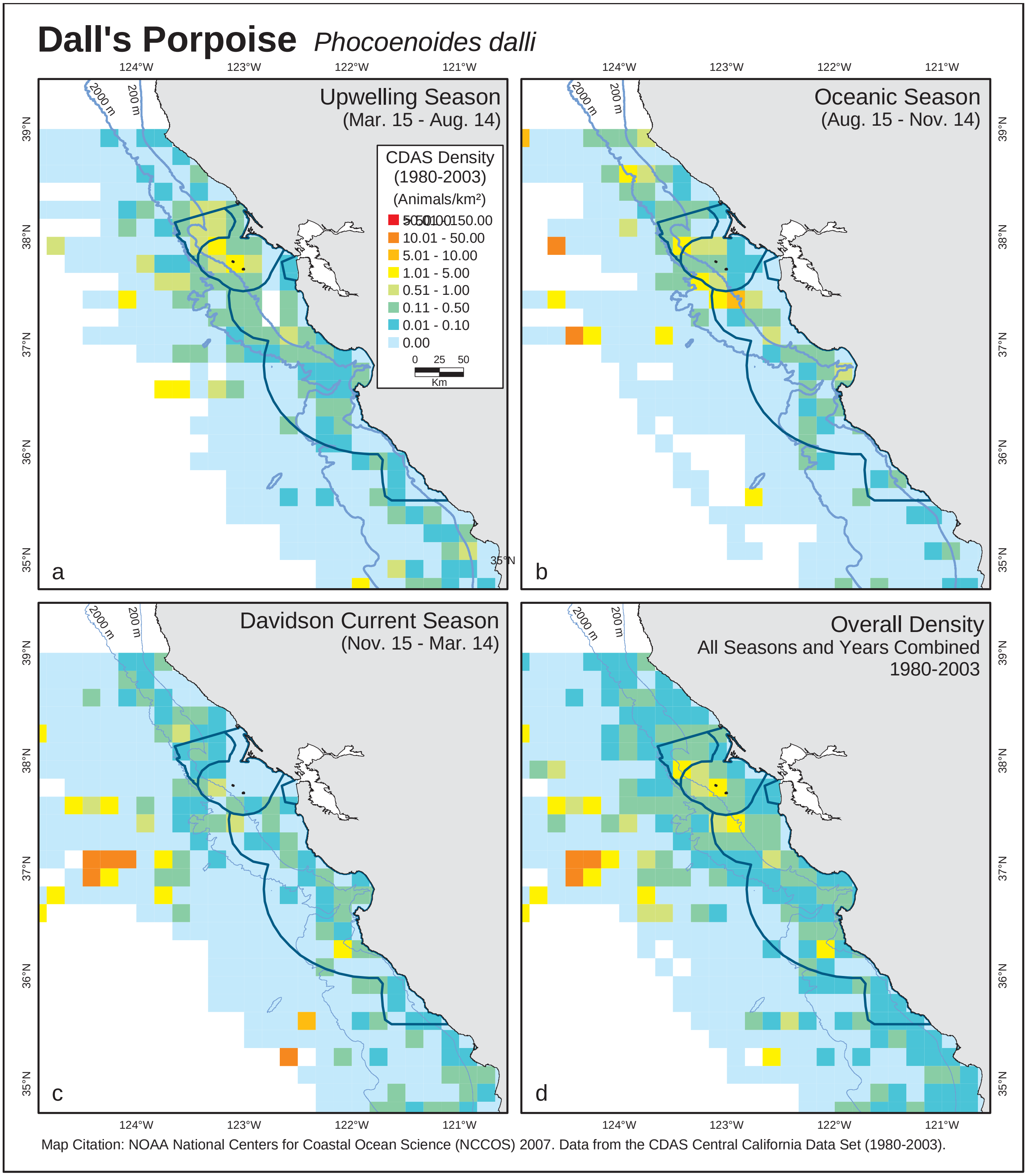


Figure 4.16. Maps for Dall's porpoise: seasonal and overall densities from the CDAS central California data set (1980-2003).

ABOUT THESE MAPS

Figure 4.16a, b and c show the densities (animals/km^2) 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.

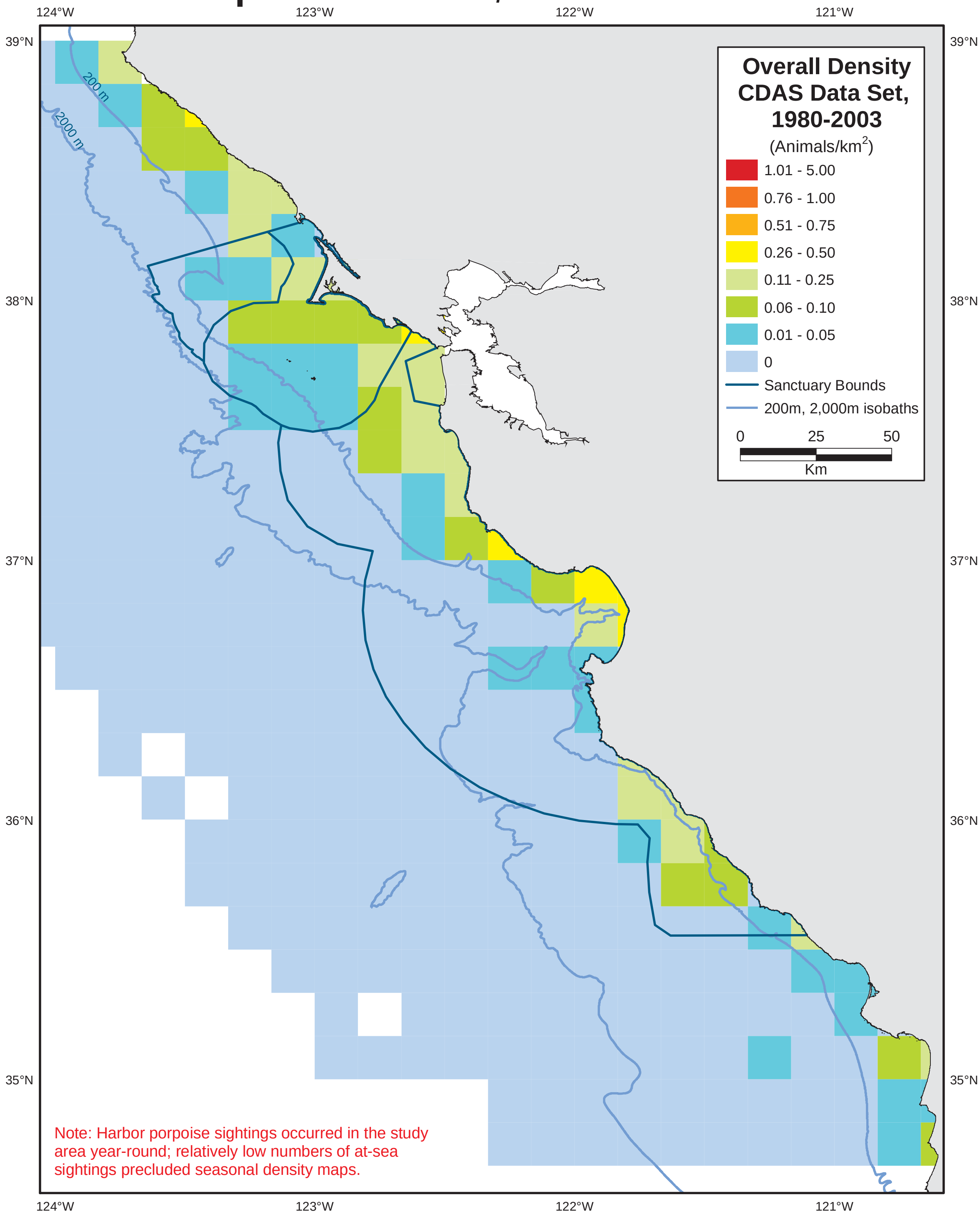
There are no known habitat issues of concern for the Dall's porpoise and the species is not listed as "threatened", "endangered", or "depleted". Insufficient data, however, prohibit evaluation of potential trends in abundance (Carretta *et al.,* 2004).

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

Harbor Porpoise *Phocoena phocoena*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2003).

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.

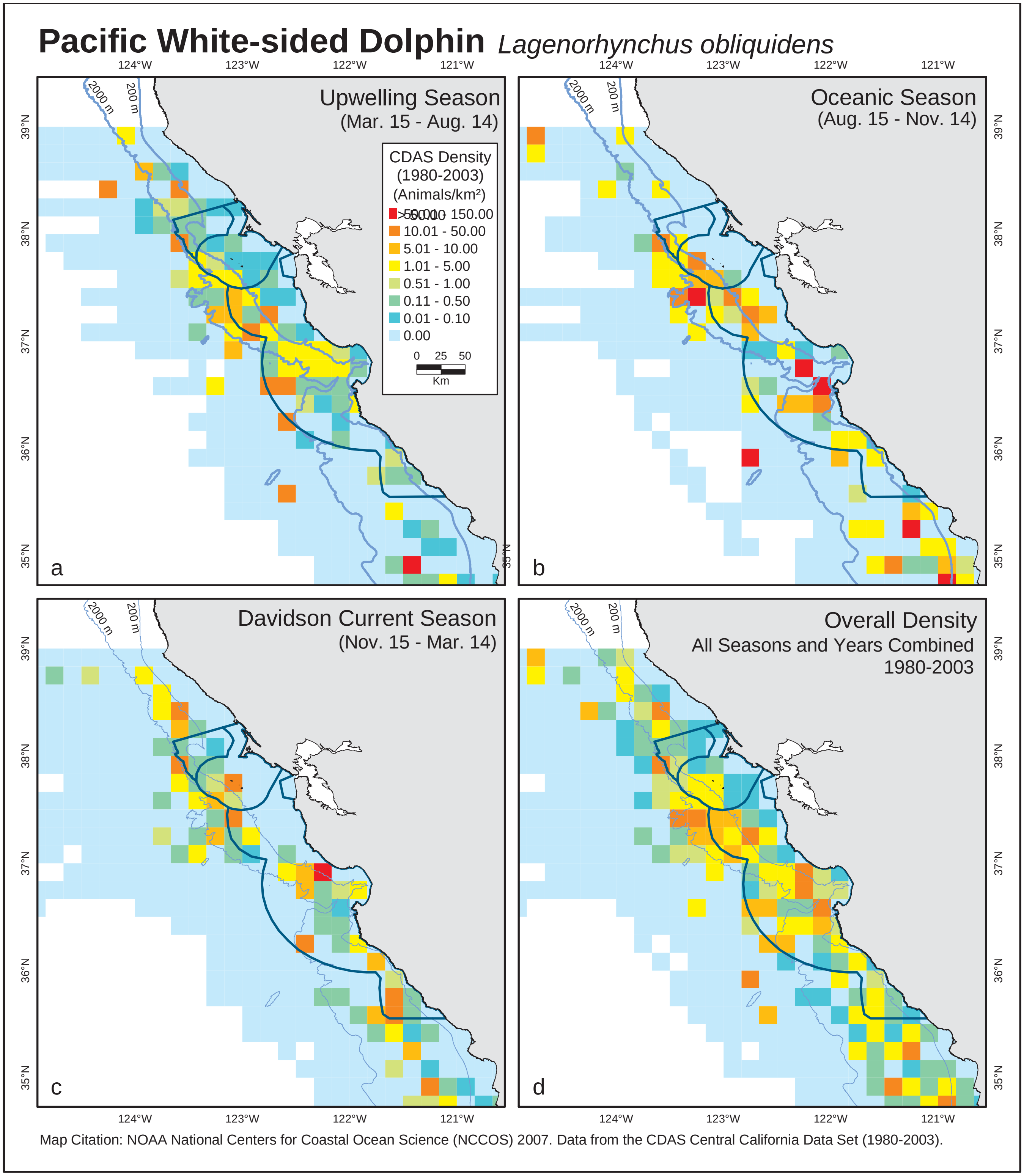


Figure 4.18. Maps for Pacific white-sided dolphin: seasonal and overall densities from the CDAS central California data set (1980-2003).

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).

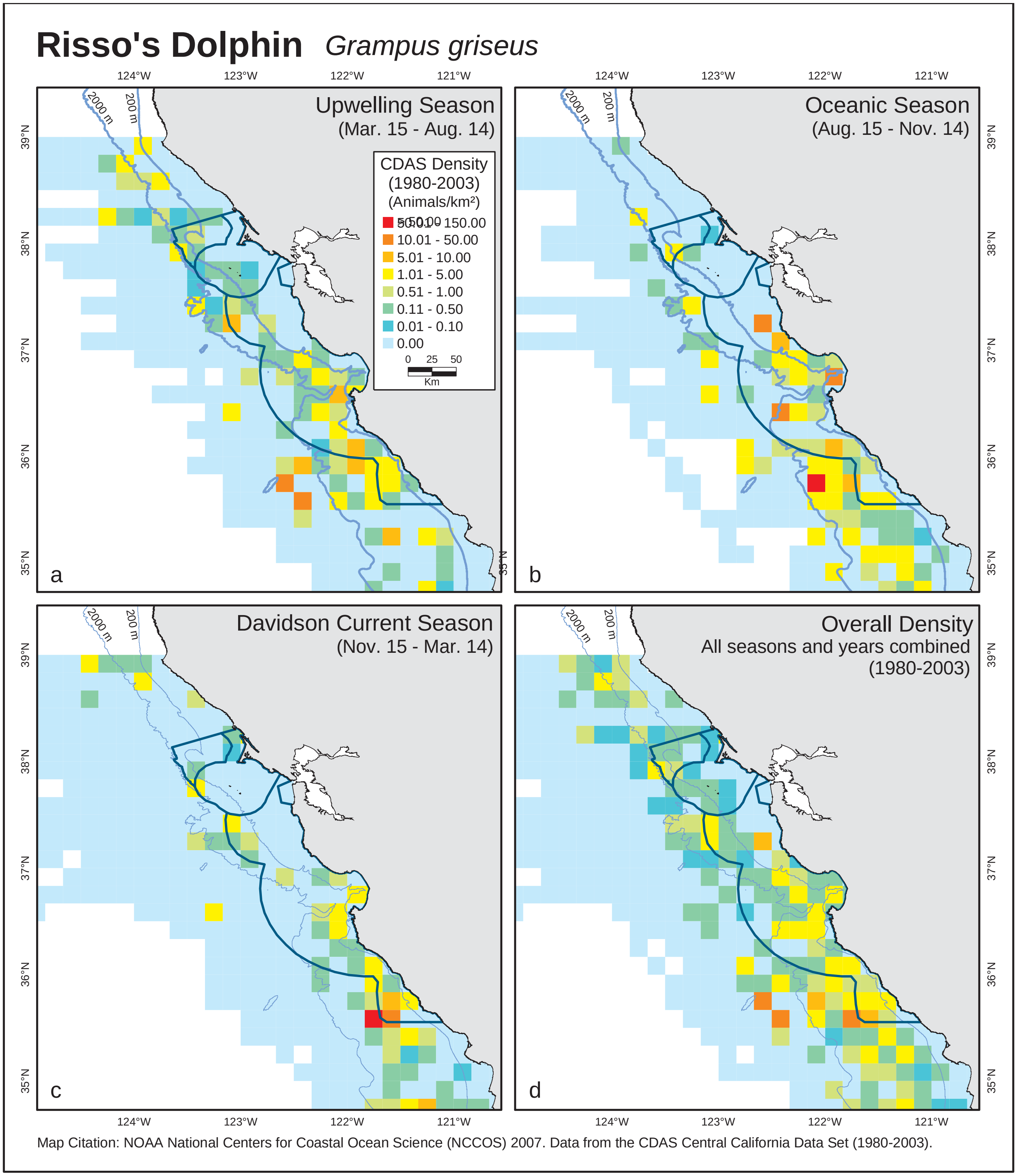


Figure 4.19. Maps for Risso's dolphin: seasonal and overall densities from the CDAS central California data set (1980-2003).

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.

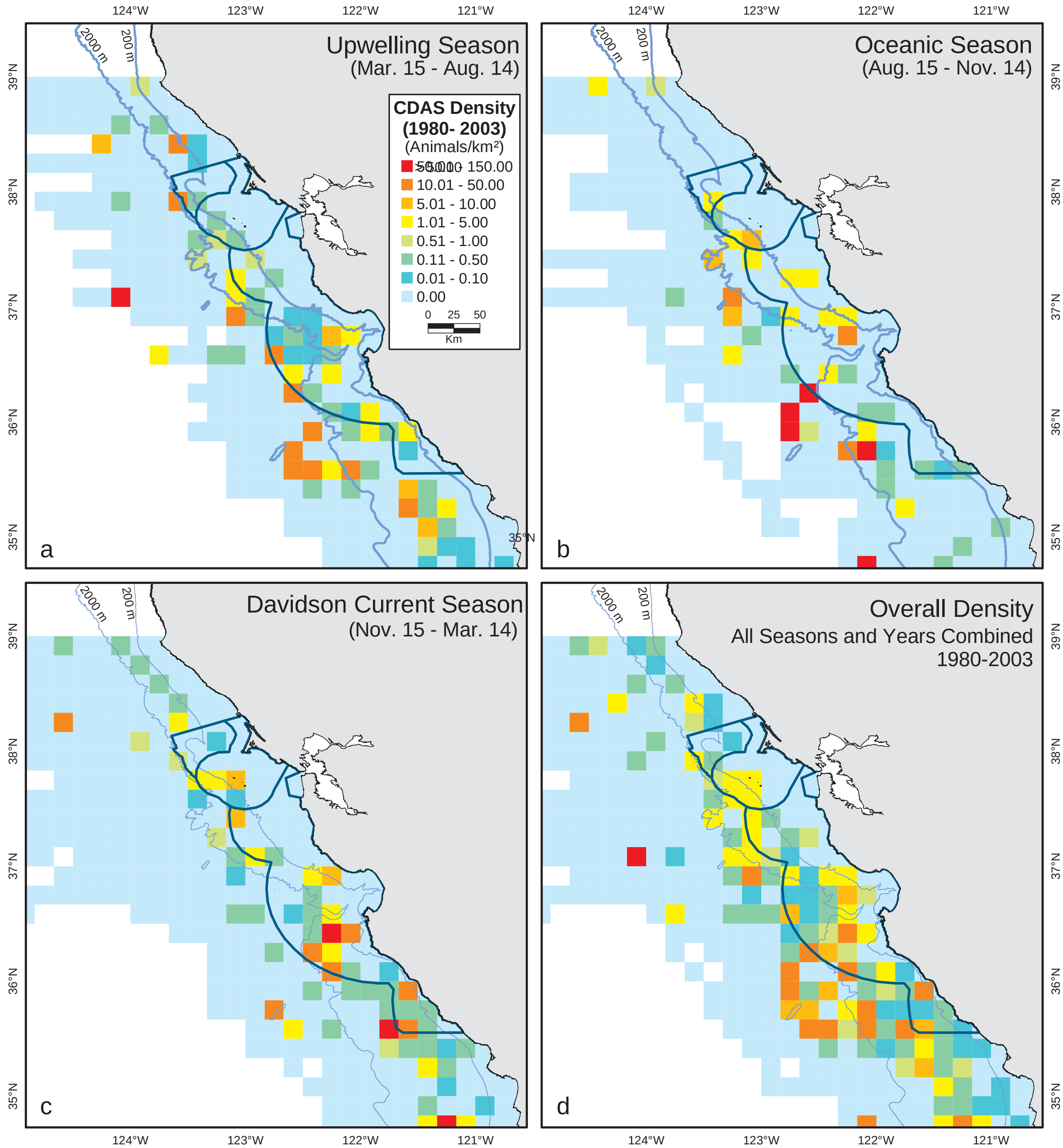
See an additional map for this species in Figure 4.28, from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December of 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

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).

Northern Right-whale Dolphin *Lissodelphis borealis*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data from the CDAS Central California Data Set (1980-2003).

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/km²) 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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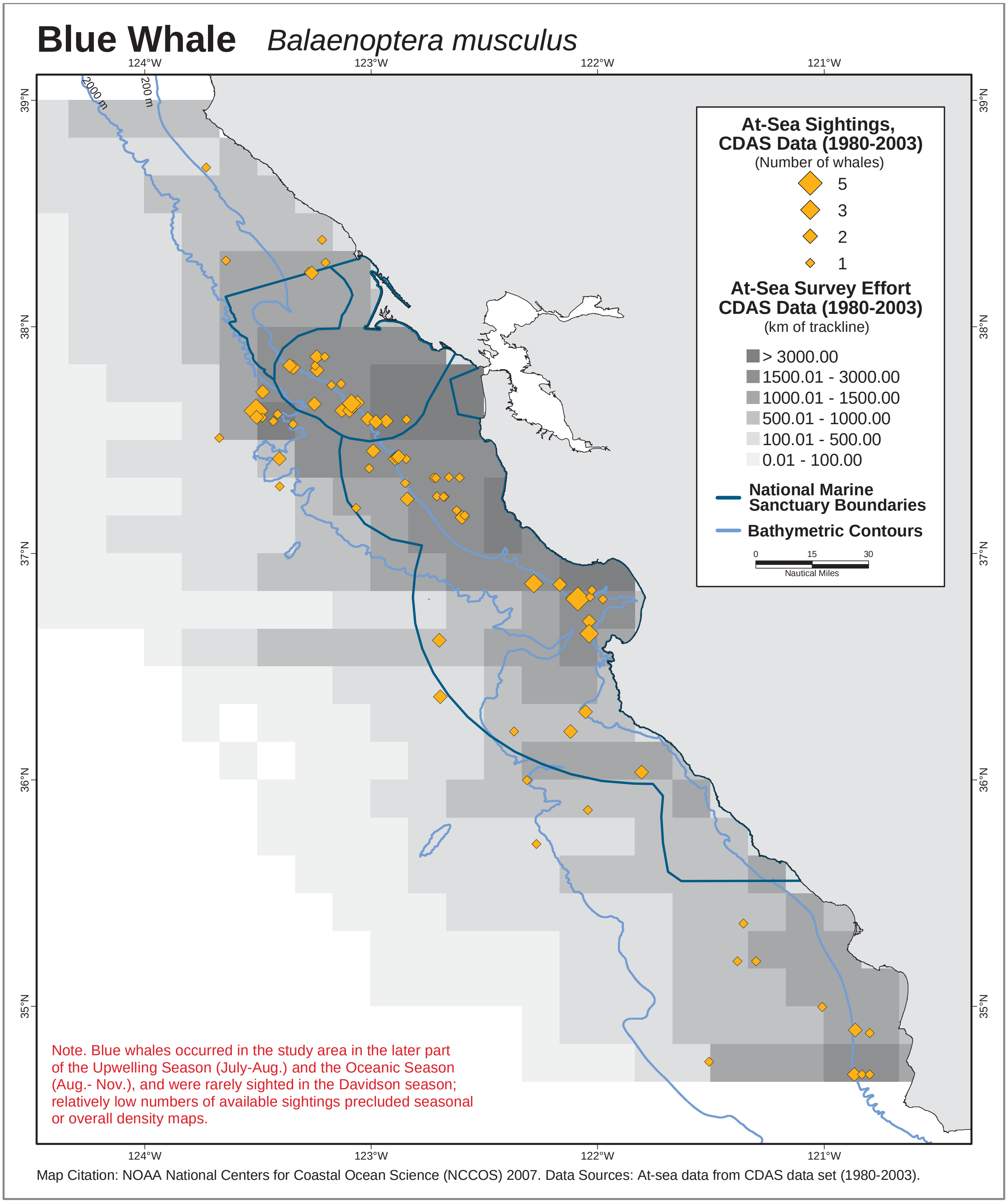

Figure 4.21. Map for blue whale: sightings and survey effort data from the CDAS central California data set (1980-2003).

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).

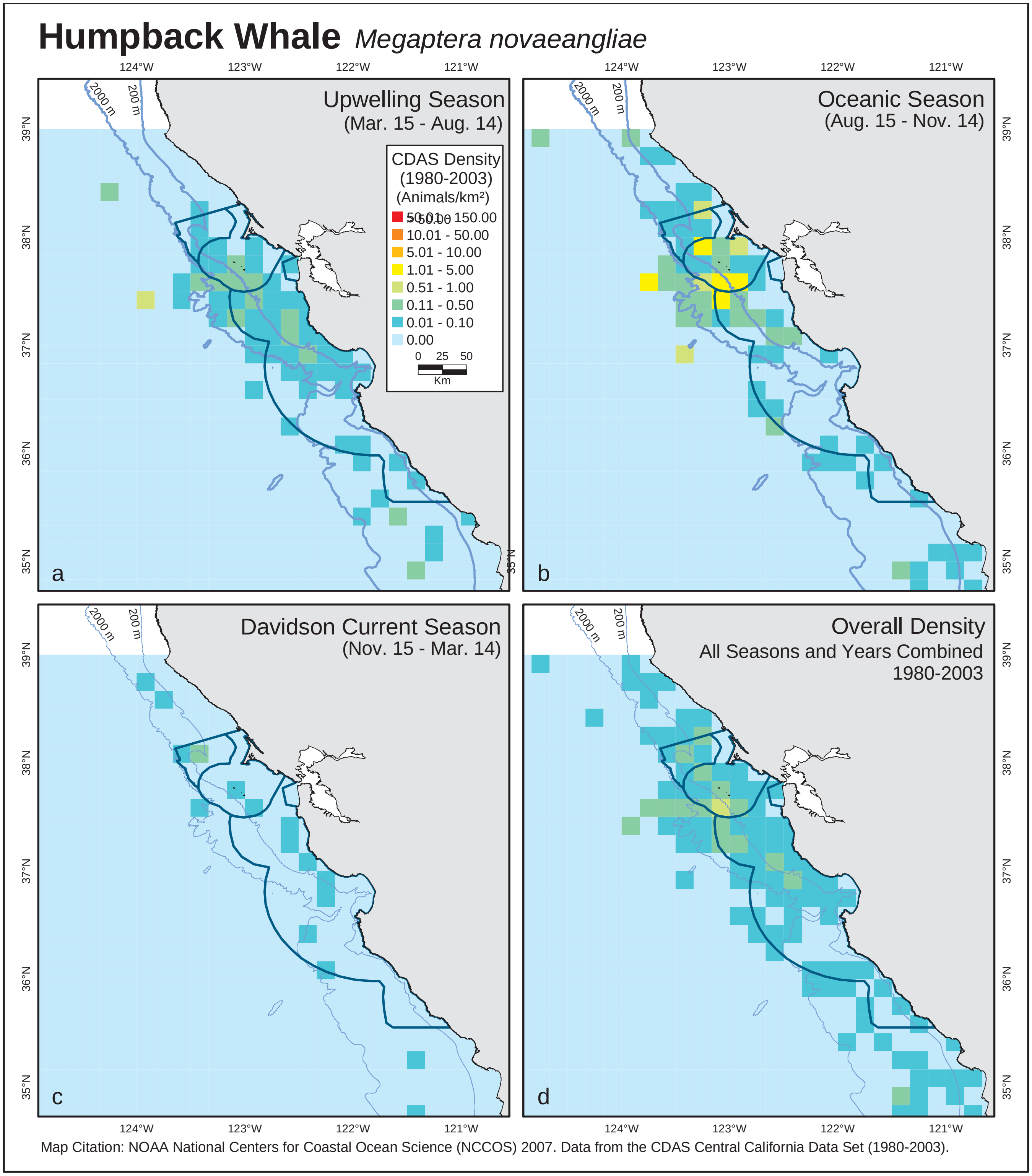

Figure 4.22. Maps for humpback whale: seasonal and overall densities from the CDAS central California data set (1980-2003).

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.

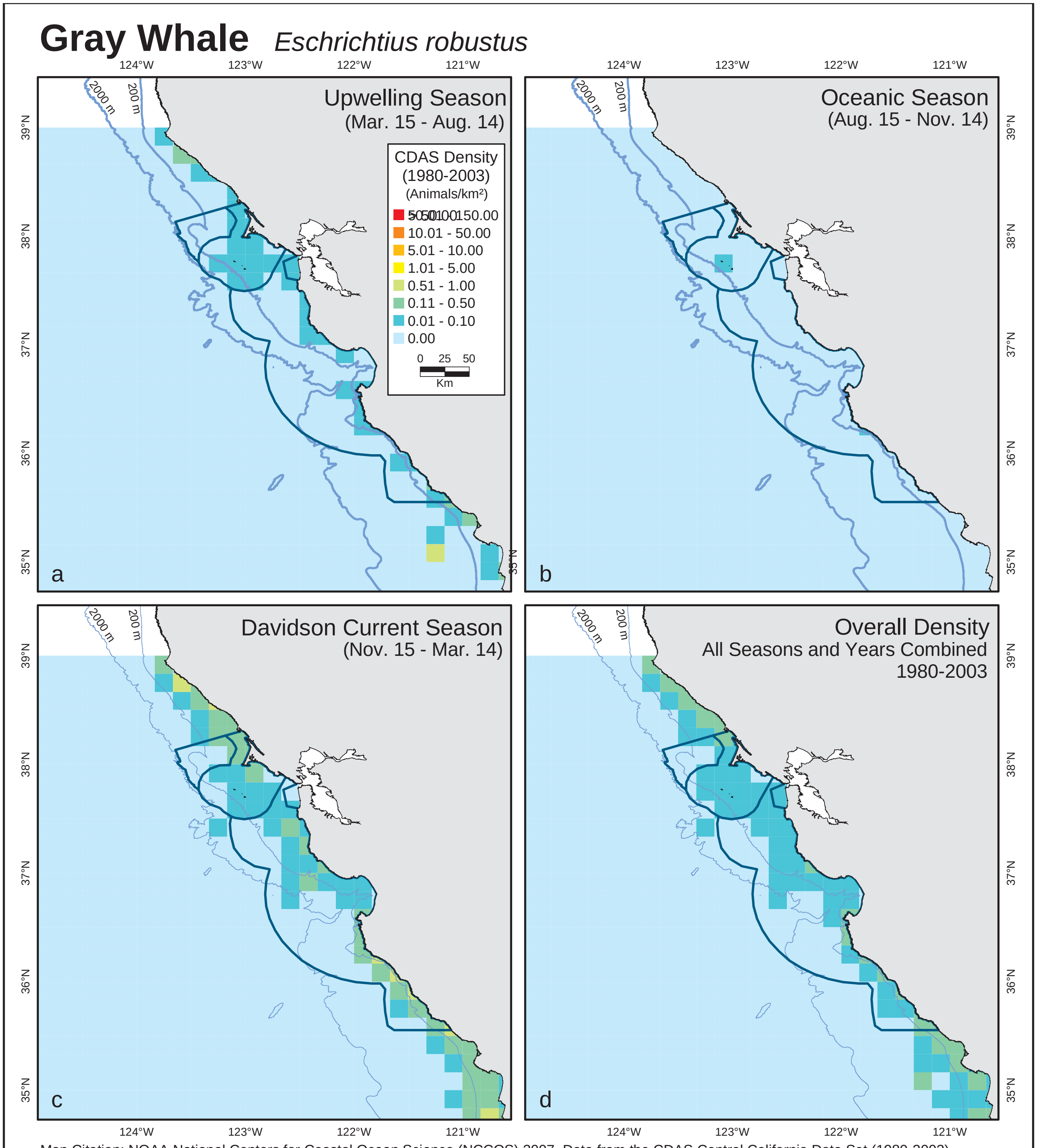
See an additional map for this species in Figure 4.31 from NOAA's Southwest Fisheries Science Center stock assessment surveys (July-December, 1991, 1993, 1996 and 2001). This map provides additional information on the range of the species off the coasts of California, Oregon and Washington.

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).



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data from the CDAS Central California Data Set (1980-2003).

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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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.

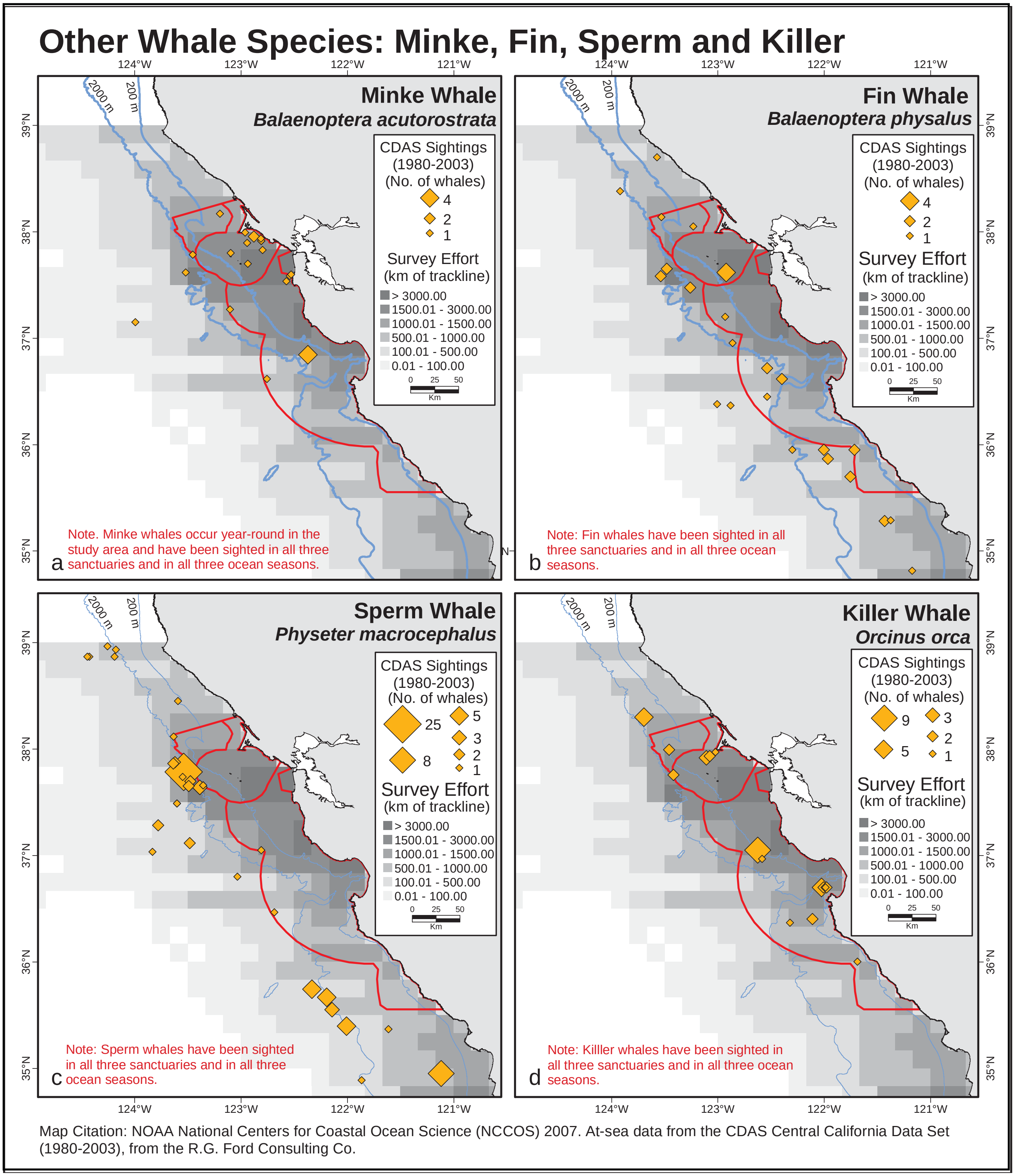

Figure 4.24. Maps for other whales: minke, fin, sperm and killer: sightings and effort data from the CDAS central California data set (1980-2003).

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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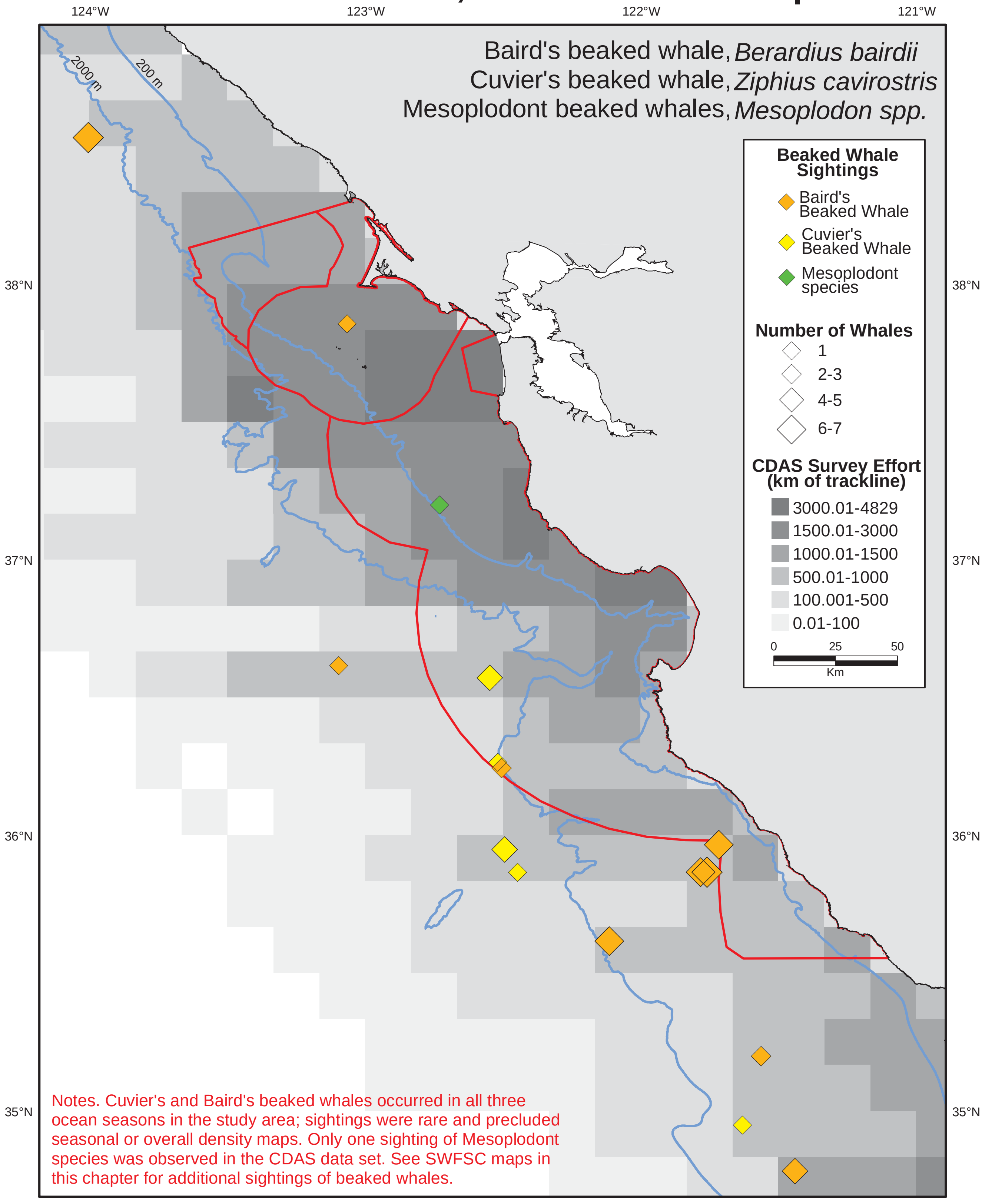
Beaked Whales - Baird's, Cuvier's and Mesoplodonts



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Data from the CDAS Central California Data Set (1980-2003).

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.

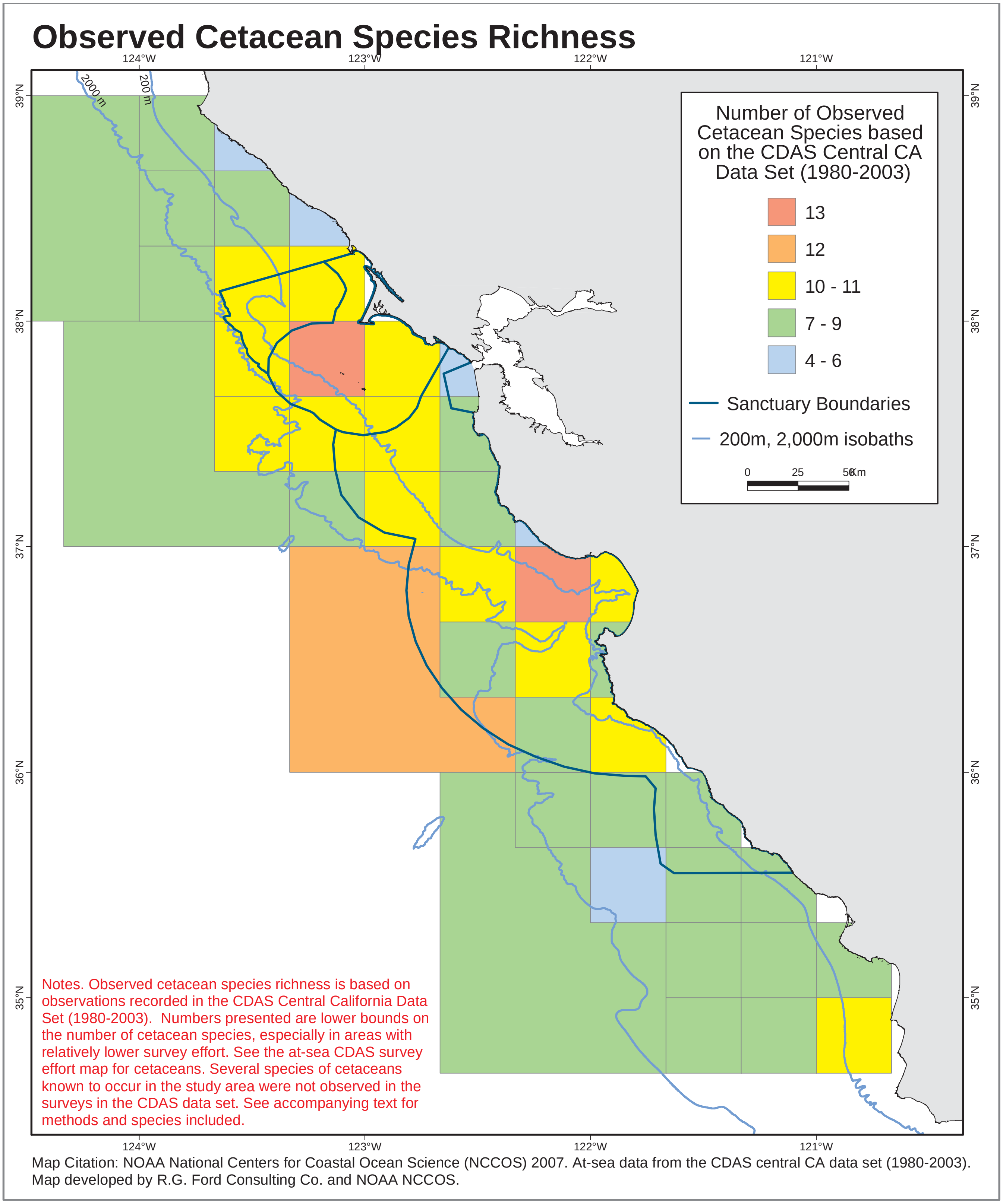


Figure 4.26. Map of observed species richness for cetaceans (whales, dolphins and porpoises) based on the CDAS central California data set (1980-2003).

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.

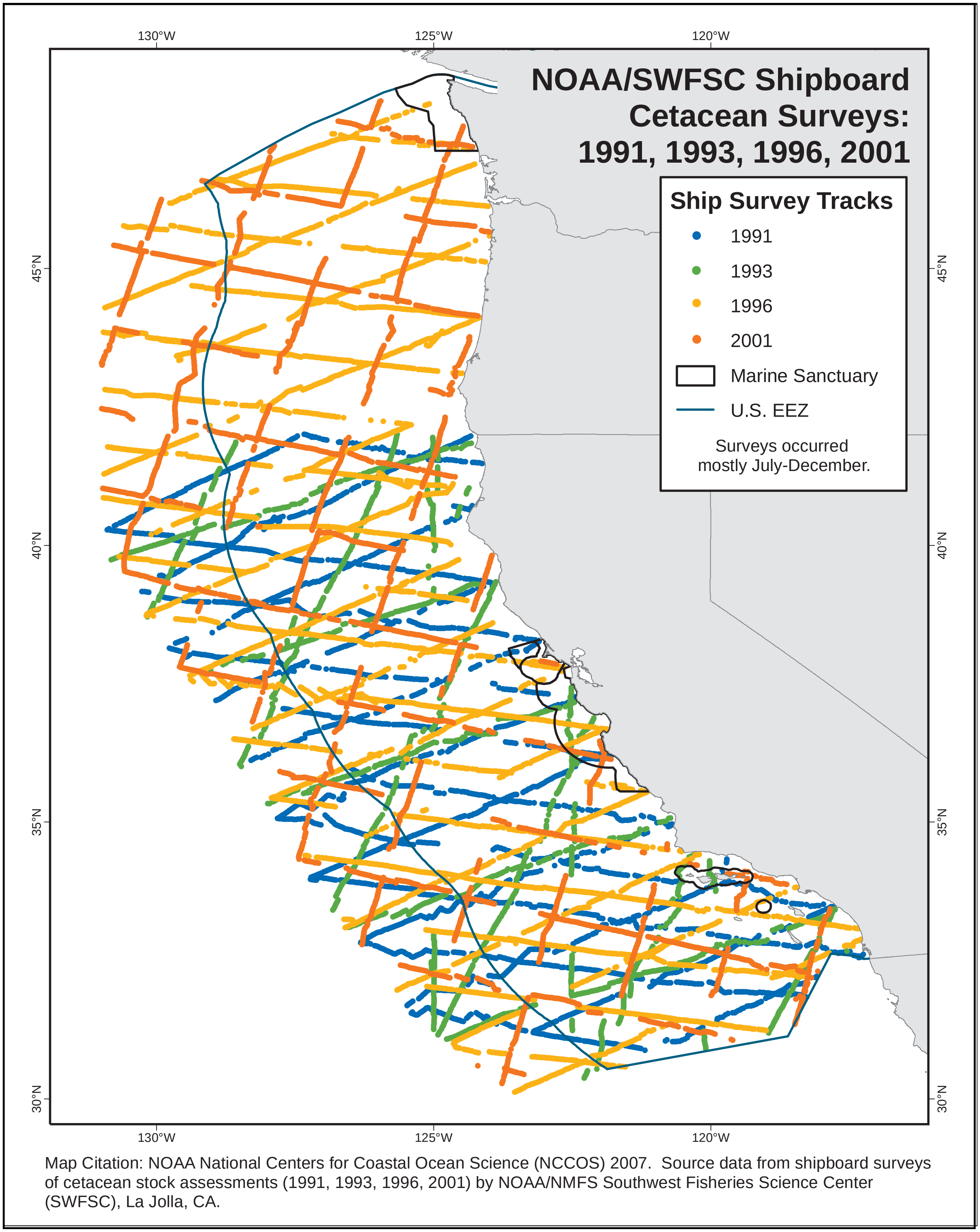
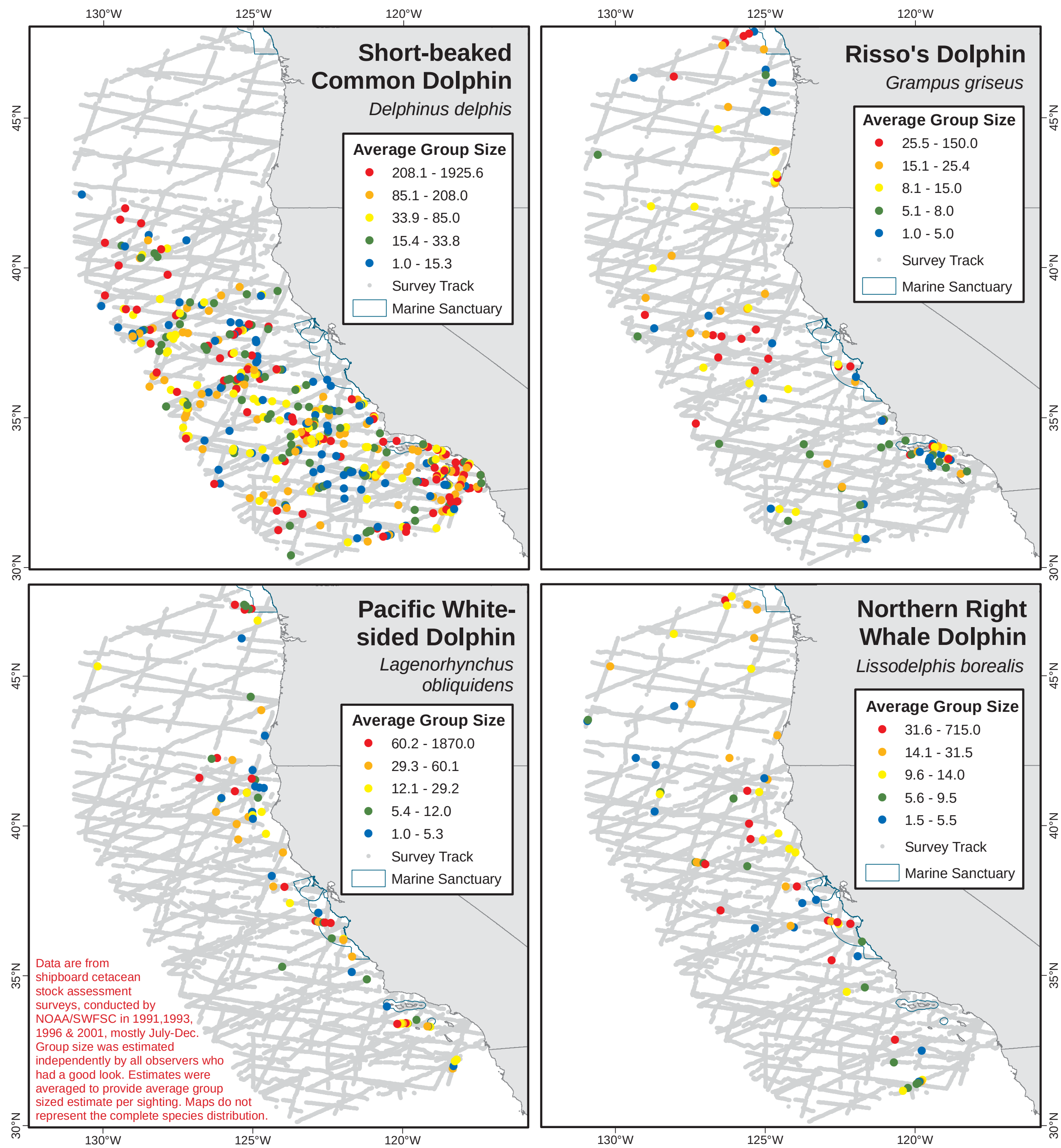
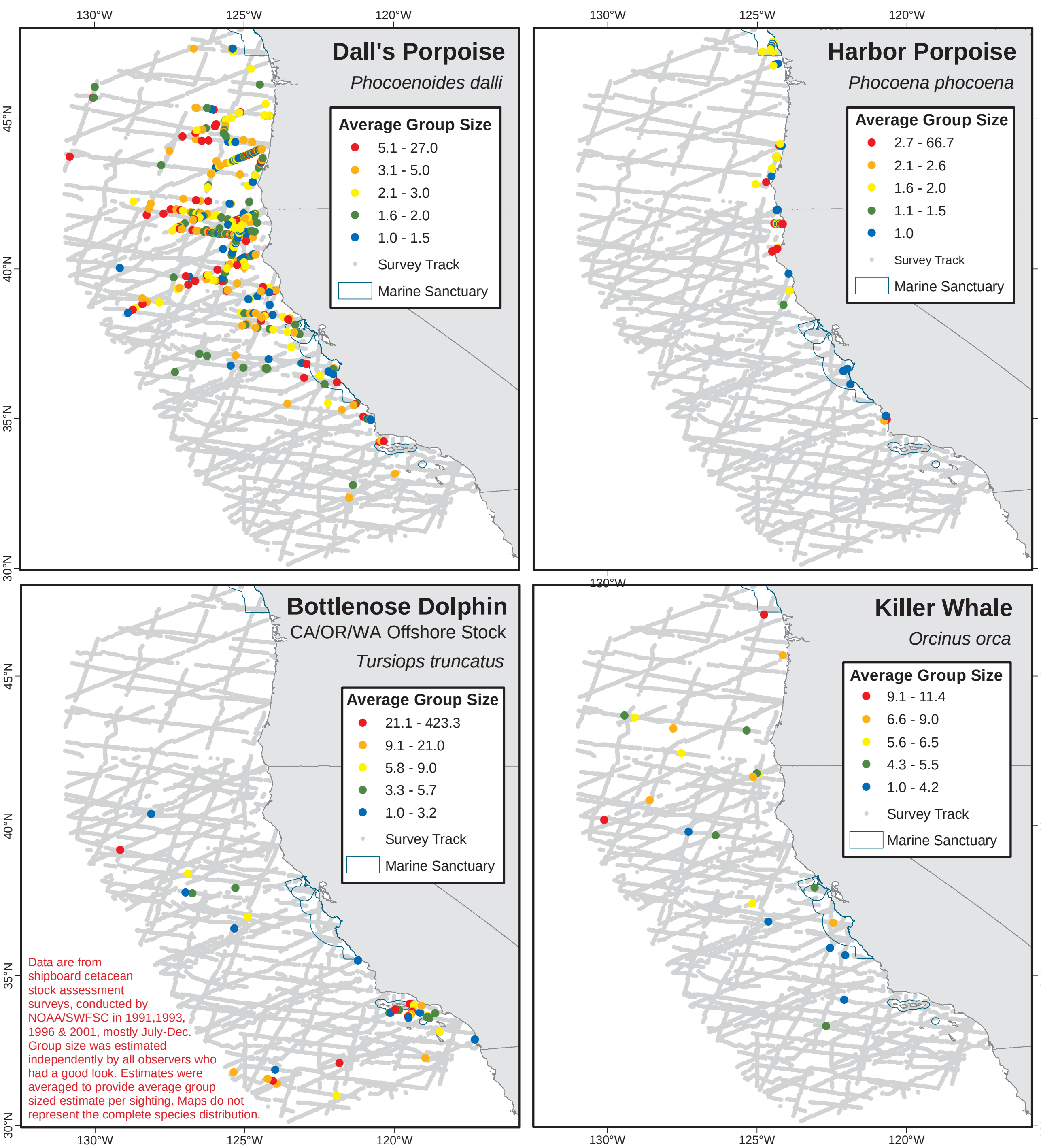


Figure 4.27. Map of survey effort locations for shipboard cetacean surveys conducted in 1991, 1993, 1996 and 2001 by NOAA's Southwest Fisheries Science Center.



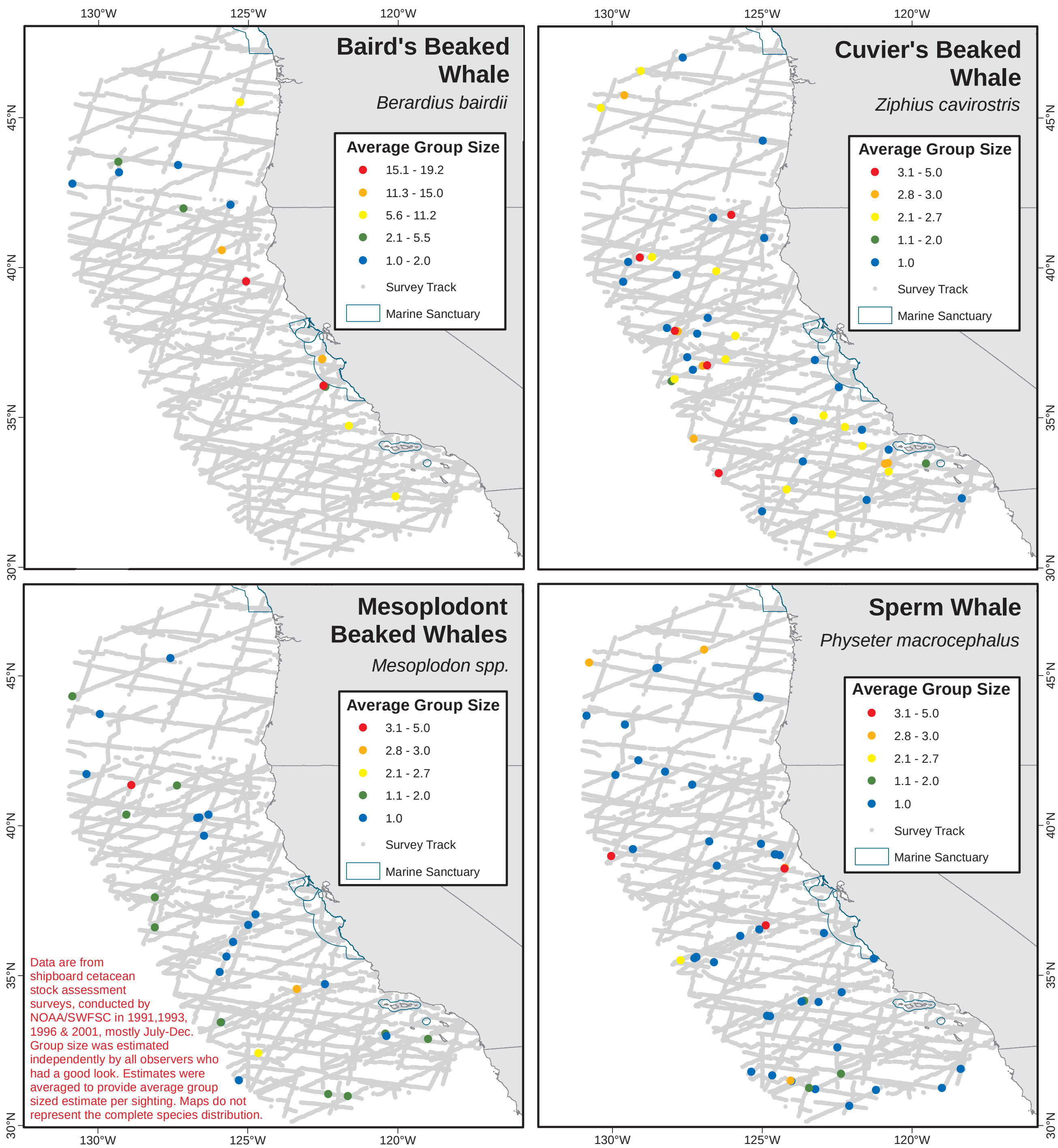
Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from the shipboard cetacean stock assessment surveys (1991, 1993, 1996 and 2001) by NOAA/NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA.

Figure 4.28. 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.



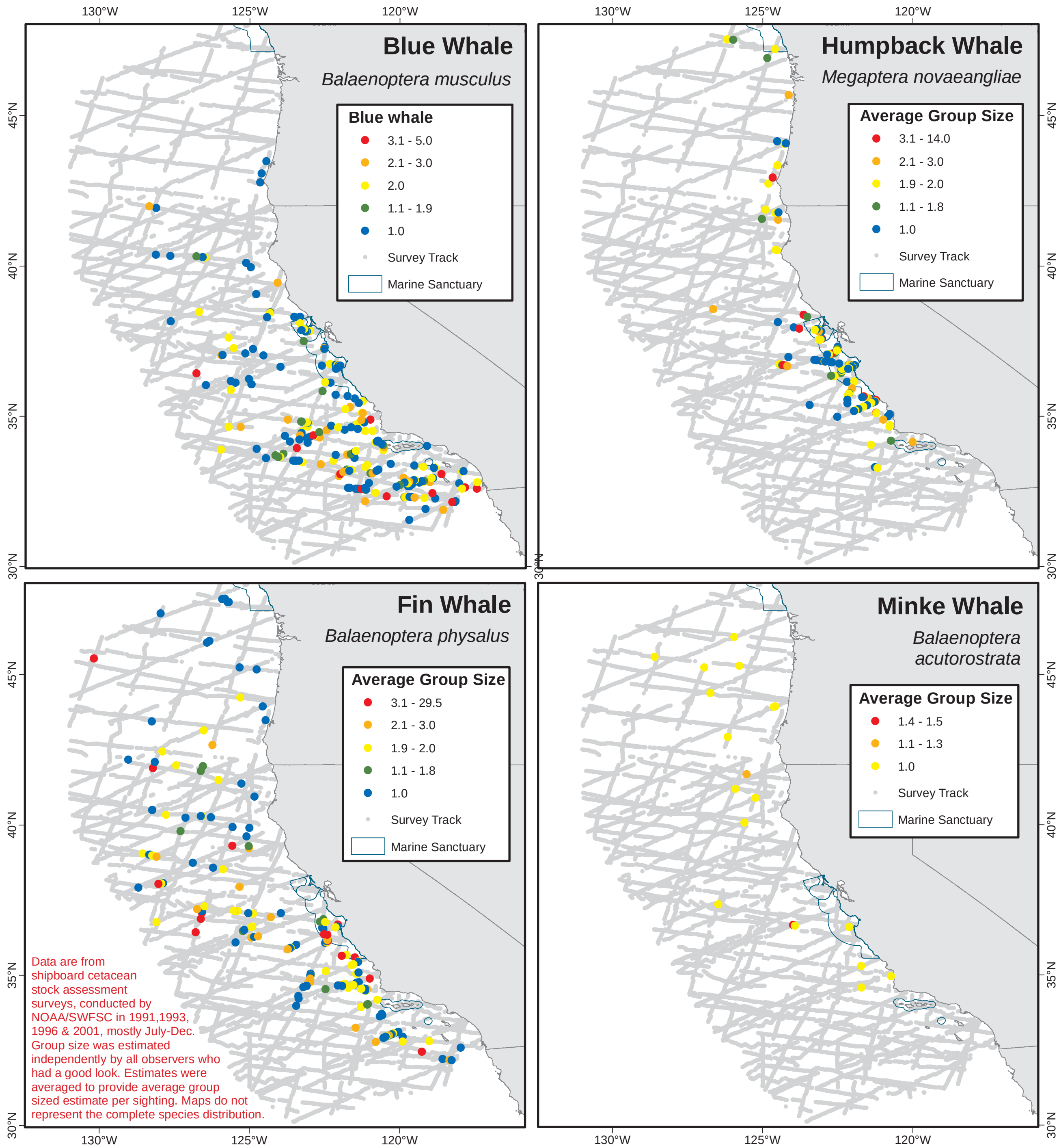
Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from the shipboard cetacean stock assessment surveys (1991, 1993, 1996 and 2001) by NOAA/NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA.

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.



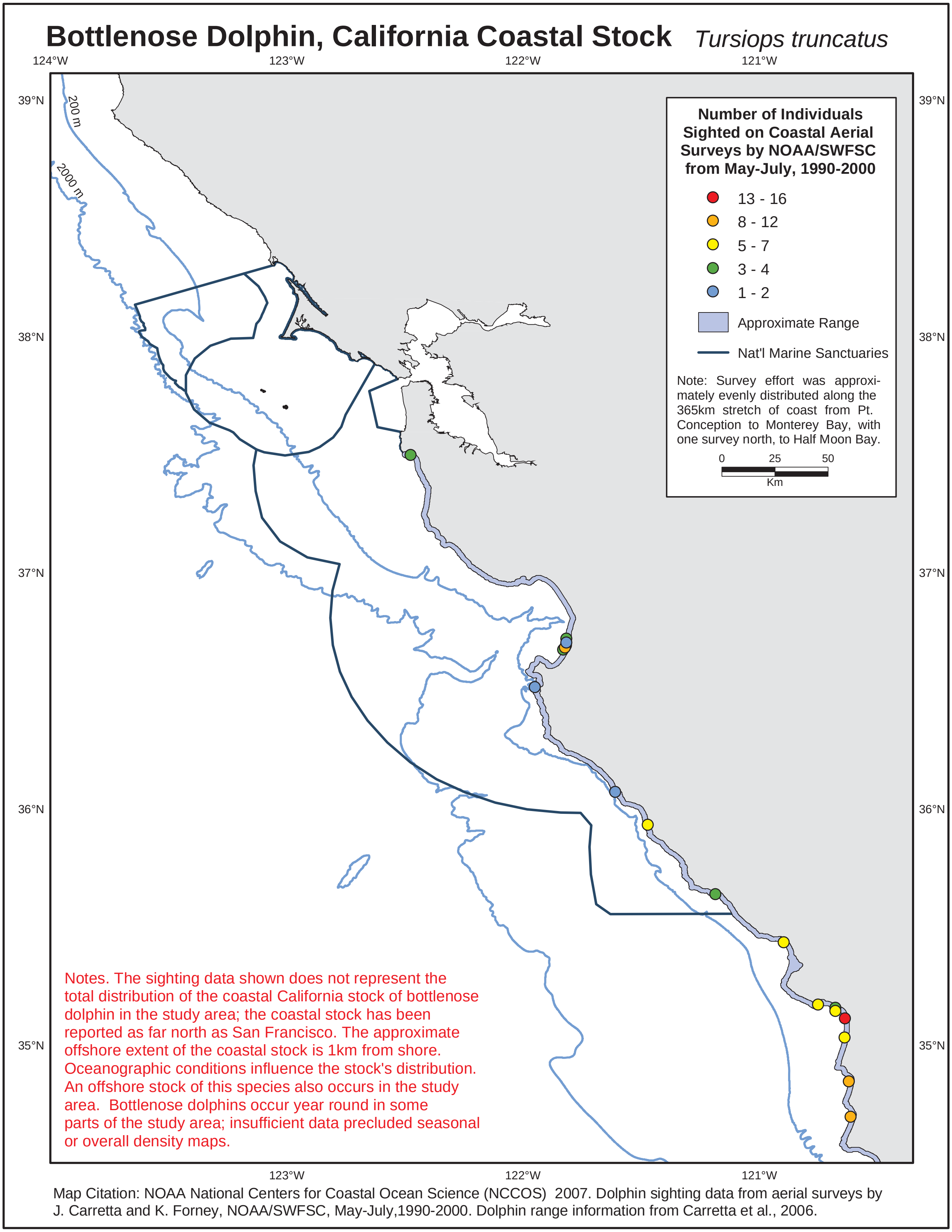
Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Source data from the shipboard cetacean stock assessment surveys (1991, 1993, 1996 and 2001) by NOAA/NMFS Southwest Fisheries Science Center (SWFSC), La Jolla, CA.

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.

Common Name	Scientific Name	Protection & Population Status in the Study Area		Occurrence & Breeding in Study Area			Primary Prey Types					
		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.

	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]		
Species or Species and Stock	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 responsible 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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APPENDICES

Appendix 1A. Available marine bird colony data along coast of north/central California: number of breeding birds by species.

Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormorant	Double-crested Cormorant	Pelagic Cormorant	Black Oyster-catcher	California Gull [9]	Western Gull	Caspian Tern [9]	Forsters Tern [9]	Least Tern	Common Murre	Pigeon Guillemot	Cassin's Auklet	Rhinoceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Point Arena	ME-384-01					154	7		4					52				4	217
Sea Lion Rocks	ME-384-02					106	4		9					12				4	131
Sea Lion Rocks to Arena Cove	ME-384-03					183	4		16									3	203
Moat Cove	ME-384-04					H								10				1	10
Section 30 Cove	ME-384-05					42								8				2	50
Saunders Landing	ME-384-06					20								8				2	28
Iverson Point	ME-384-07					42	H							5				2	47
Triplett Gulch	ME-384-08					119	H		4					55				3	178
Fish Rock Cove	ME-384-09			H		33	1											2	34
Fish Rocks	ME-384-10	100[i]		368[c]		123	6		170					119	P	4	15	9	905
Collins Landing to Gualala River	ME-384-11					187	4		H					90				3	281
Gualala Point Island	SO-384-01			264[c]		4	1		26					29				5	324
Del Mar Point	SO-384-02					9												1	9
Sea Ranch	SO-384-03					84	11		16					42				4	153
Black Point to Stewart's Point	SO-384-04					40	4		6					12				4	62
Stewart's Point to Rocky Point	SO-382-01					66	1		4					15				4	86
Horseshoe Cove	SO-382-02					121			2					2				3	125
Cannon Gulch to Stump Beach	SO-382-03					79	14							2				3	95
Gerstle Cove to Stillwater Cove	SO-382-04					110	6		16					10				4	142
Bench Mark 125 to Timber Cove	SO-382-05					62	2		32					10				4	106
Windermere Point to Jewell Gulch	SO-382-06					40	1		6					2				4	49
Northwest Cape Rocks	SO-382-07					H	1		52									2	53
Russian Gulch	SO-382-08				80[c]	227	7		42					20				5	376
Russian River Rocks	SO-382-09			P[l]	238[c]	125	2		44					5				6	414
Goat Rock to Peaked Hill	SO-382-10						1		6									2	7
Arched Rock	SO-382-11			436[c]		9			34					2			H	4	481
Peaked Hill	SO-382-12					44	1		6					2				4	53
Gull Rock	SO-382-13	10		H	68[c]	44	2		34					2				6	160
Shell-Wright Beach Rocks	SO-382-14				32[c]	55	20		88					5				5	200
Duncan Point to Arched Rock	SO-382-15					136	4		34					H				3	174
Bodega Head	SO-380-01					103	6		10					2				4	121
Bodega Rock	SO-380-02			722[c]			H		24					30		2		4	778
Bodega Harbor	SO-380-03								12					2				2	14
Pinnacle Rock	SO-380-04					51	2		2					27		2		5	84
Sonoma-Marin County Line	MA-380-01			H		84	5		14					25				4	128
Dillon Beach Rocks	MA-380-02			P[l]	32[c]	143	3		32					20				6	230
Tomales Point	MA-380-03					141	3		6					H				3	150
Bird Rock (Marin Co.)	MA-380-04		15[g]	550[c]		37	6		168					115		3	H	7	894
Elephant Rock Complex	MA-380-05					H			8					28				2	36

Appendix 1A cont. Available marine bird colony data along coast of north/central California: number of breeding birds by species.

Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormo-rant	Double-crested Cormo-rant	Pelagic Cormo-rant	Black Oyster-catcher	Cali-fornia Gull[9]	Western Gull	Caspian Tern[9]	Forsters Tern[9]	Least Tern	Common Murre	Pigeon Guille-mot	Cassin's Auklet	Rhino-ceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Point Reyes	MA-374-01		15[g]	1,160[a]		266	6		178				40,810[a]	616		6	4	9	43,061
Coast Campground South	MA-374-02													63				1	63
Point Resistance	MA-374-03			28[a]	H	H	H		8				7,091[a]	50				4	7,177
Millers Point Rocks	MA-374-04			296[a]		59	1		30				1,510[a]	55				6	1,951
Double Point Rocks	MA-374-05		50[g]	328[a]		9	H		8				15,818[a]	22				6	16,235
Stinson Beach to Rocky Point	MA-374-06								6									1	6
Gull Rock Area	MA-374-07					9	1		6					7				4	23
Muir Beach Headlands to Tennessee Cove	MA-374-08					42	1		20					34				4	97
Bird Island (Marin Co.)	MA-374-09			H			1		56					5				3	62
Point Bonita	MA-374-10					95			10					66				3	171
Bonita Cove	MA-374-11					2			6					2				3	10
Point Diablo Bluffs and Needles	MA-374-12					15			34					H				2	49
Yellow Bluff	SFB-MA-01								2									1	2
Sausalito Point Area	SFB-MA-02								4									1	4
Peninsula Point and Cone Rock	SFB-MA-03								6									1	6
Angel Island	SFB-MA-04								6									1	6
Bluff Point to Paradise Cay	SFB-MA-05								4									1	4
Point San Quentin	SFB-MA-06								6									1	6
Marin Islands	SFB-MA-07						2		64									2	66
The Sisters and Point San Pedro	SFB-MA-08								96									1	96
Rat Rock	SFB-MA-09								2									1	2
Southwest San Pablo Bay Duck Blinds	SFB-MA-10								16									1	16
Marin County-West San Pablo Bay Ship Channel	SFB-MA-11								14									1	14
Sonoma Co.-West San Pablo Bay Ship Channel	SFB-SO-01								2									1	2
Little Island	SFB-NA-01									H								0	0
Russ Island	SFB-NA-02				4[c]													1	4
Island No. 2	SFB-NA-03										50							1	50
Knight Island	SFB-SN-01				400[c]				8	76	270							4	754
White Slough	SFB-SN-02										40							1	40
North San Pablo Bay Radar Target	SFB-SN-03				30[c]													1	30
Northeast San Pablo Bay Beacon	SFB-SN-04				8[c]				2									2	10
Mare Island Strait	SFB-SN-05								20									1	20
Commodore Jones Point to Benicia Point	SFB-SN-06								10									1	10
Benicia Point to Army Point	SFB-SN-07								6									1	6
Mothball Fleet	SFB-SN-08								10									1	10
Wheeler Island	SFB-SN-09				252[c]													1	252
Donlon Island	SFB-SA-01				H[c]													0	0
Pittsburgh Pacific Gas & Electric Plant	SFB-CC-01											8						1	8
Port Chicago Allied Chemical Co.	SFB-CC-02											H						0	0

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Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormo-rant	Double-crested Cormo-rant	Pelagic Cormo-rant	Black Oyster-catcher	Cali-fornia Gull [9]	Western Gull	Caspian Tern [9]	Forsters Tern [9]	Least Tern	Common Murre	Pigeon Guille-mot	Cassin's Auklet	Rhino-ceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Suisun Point Area	SFB-CC-03								6									1	6
Nevada Dock	SFB-CC-04								2									1	2
Eckley to Selby	SFB-CC-05								4									1	4
Davis Point Unocal Wharf	SFB-CC-06								22									1	22
Hercules Wharf	SFB-CC-07								2									1	2
Pinole Point	SFB-CC-08								2									1	2
East San Pablo Bay Ship Channel	SFB-CC-09								6									1	6
The Brothers	SFB-CC-10						1		178									2	179
Castro Point Area	SFB-CC-11								8									1	8
Richmond-San Rafael Bridge	SFB-CC-12				1,264[c]				18									2	1,282
Castro Rocks	SFB-CC-13								H									0	0
Red Rock	SFB-CC-14								384									1	384
Standard Oil Long Wharf	SFB-CC-15								6									1	6
Richmond Harbor Entrance Channel	SFB-CC-16								12									1	12
Brooks Island Area	SFB-CC-17						2		98	120								3	220
Richmond Inner Harbor	SFB-CC-18								12									1	12
Albany Hill Cove	SFB-AL-01								2									1	2
Berkeley Yacht Harbor Breakwaters	SFB-AL-02								38									1	38
Berkeley Pier	SFB-AL-03								40									1	40
Bay Bridge "Toll Plaza Point"	SFB-AL-04								2			H						1	2
San Fran-Oakland Bay Bridge E.	SFB-AL-05				1,490[c]				40									2	1,530
Oakland Outer Harbor	SFB-AL-06								8									1	8
Oakland Middle Harbor	SFB-AL-07								10									1	10
Oakland Inner Harbor	SFB-AL-08								6									1	6
Government Island Area	SFB-AL-09								2									1	2
Alameda Naval Air Station	SFB-AL-10								502	1,188		150						3	1,840
Ballena Bay	SFB-AL-11											H						0	0
Bay Farm Island	SFB-AL-12											H						0	0
Oakland International Airport	SFB-AL-13											18						1	18
Mulford Landing Channel	SFB-AL-14								2									1	2
Hayward Marsh, Basin 3A	SFB-AL-15											2						1	2
Baumberg Plant #1, Pond 10	SFB-AL-16									H[k]	814							1	814
Baumberg Plant #1, Ponds 10 &11	SFB-AL-17											H						0	0
Baumberg Plant #1, Pond 8A	SFB-AL-18										313							1	313
Baumberg Plant #1, Pond 6B	SFB-AL-19										85							1	85
Baumberg Plant #1, Ponds 1, 2, 7	SFB-AL-20											H						0	0
Baumberg Plant #2, Ponds 2, 4, 7	SFB-AL-21									H	H							0	0
Baumberg Plant #1, Ponds 4, 5, 7	SFB-AL-22										94	H[k]						1	94
Plant #1, Pond 1A-NW	SFB-AL-23											H						0	0

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Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormorant	Double-crested Cormorant	Pelagic Cormorant	Black Oyster-catcher	California Gull [g]	Western Gull	Caspian Tern [g]	Forsters Tern [g]	Least Tern	Common Murre	Pigeon Guillemot	Cassin's Auklet	Rhinoceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Plant #1, Pond 1A	SFB-AL-24										H							0	0
Plant #1, Pond 2A	SFB-AL-25										125							1	125
Plant #1, Pond 3A	SFB-AL-26										H							0	0
Plant #1, Ponds 4, 5, 6, 7	SFB-AL-27											H						0	0
KGO Radio Towers	SFB-AL-28									H	H							0	0
Plant #1, Pond 3	SFB-AL-29										99							1	99
Plant #1, Pond 1	SFB-AL-30										204							1	204
Plant #2, Ponds 11, 26	SFB-AL-31							H			H							0	0
Plant #2, Ponds 4, 5	SFB-AL-32									634	H[k]							1	634
Alviso Plant, Pond A17	SFB-SR-01										25							1	25
Alviso Plant, Pond A18	SFB-SR-02										H							0	0
Alviso Plant, Pond A16	SFB-SR-03										43							1	43
Alviso Plant, Ponds A9, A10	SFB-SR-04				78[c]			434										2	512
Alviso Plant, Pond A8	SFB-SR-05										158							1	158
Alviso Plant, Pond A7	SFB-SR-06										95							1	95
Alviso Plant, Pond A6	SFB-SR-07							4,328	4		194							3	4,526
Alviso Plant, Pond A5	SFB-SR-08										H							0	0
Alviso Plant, Pond B2	SFB-SR-09										480							1	480
Alviso Plant, Pond A1	SFB-SR-10							2			38							2	40
Charleston Slough	SFB-SR-11										250							1	250
Redwood City Plant, Pond 1	SFB-SM-01										100							1	100
Redwood City Plant, Pond 3	SFB-SM-02										H	H[k]						0	0
Bair Island, Pond A10	SFB-SM-03										H							0	0
Bair Island, Pond A9	SFB-SM-04										H							0	0
Bair Island, Pond B3	SFB-SM-05										H							0	0
Bair Island, Pond B1	SFB-SM-06									800	63	H[k]						2	863
San Mateo Bridge and PG&E Towers	SFB-SM-07				210[c]				6									2	216
San Francisco Ship Channel	SFB-SM-08								8									1	8
Oyster Point Area	SFB-SM-09								2		10							2	12
Double Rock	SFB-SF-01								2									1	2
Hunter's Point	SFB-SF-02								50									1	50
Lash Lighter Basin	SFB-SF-03								40									1	40
Potrero Point	SFB-SF-04								6									1	6
San Francisco Piers South	SFB-SF-05								232									1	232
San Fran.-Oakland Bay Bridge West	SFB-SF-06								48									1	48
Yerba Buena Island	SFB-SF-07			H[c]		4	1		62									3	67
Treasure Island	SFB-SF-08								96									1	96
San Francisco Piers North	SFB-SF-09								62									1	62
Pier 45	SFB-SF-10								66									1	66

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Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormo-rant	Double-crested Cormo-rant	Pelagic Cormo-rant	Black Oyster-catcher	Cali-fornia Gull [9]	Western Gull	Caspian Tern [9]	Forsters Tern [9]	Least Tern	Common Murre	Pigeon Guille-mot	Cassin's Auklet	Rhino-ceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Alcatraz Island	SFB-SF-11			1,578[a]					900					5				3	2,483
Fort Point Rock to Helmut Rock	SF-374-01								6									1	6
Lobos Rock and Land's End	SF-374-02			238[a]					14					18				3	270
Seal Rocks	SF-374-03			184[a]	H		3		46					H				3	233
Eel Rock Cliffs	SF-372-05					9								H				1	9
North Farallon Islands	SF-FAI-01			102[a]		62			32				71,929[a]	42	36[b]			6	72,203
South Farallon Islands	SF-FAI-02	1,400[j]	1,990[f]	17,014[a]	1,122[a]	442[e]	30		15,095[e]				127,399[a]	499[e]	18,807[e]	516	128[e]	12	184,442
Mussel Rock Area	SM-374-01						1							10				2	11
Mori Point	SM-372-01					31								18				2	49
San Pedro Rock	SM-372-02			H		H[d]	2		12[d]				H	128[d]			H	3	142
Devil's Slide Rock and Mainland	SM-372-03			692[a]		114[d]	H		8[d]				380[d]	160[d]				5	1,354
Pillar Point	SM-372-04				H	5								2				2	7
Seal Rock Cliffs	SM-372-06			37		123	H		2					12				4	174
Martin's Beach	SM-372-07			H		108	1							20				3	129
Pomponio Beach to Pescadero Beach	SM-370-01						2							20				2	22
Pigeon Point	SM-370-02						H		2					8				2	10
Gazos Creek North	SM-370-03								4					8				2	12
Año Nuevo Island	SM-370-04			3,278[a]		13	27		1,382					117	24[h]	224[h]		7	5,065
Punta del Año Nuevo	SM-370-05					114								102				2	216
Greyhound Rock to El Jarro Point	SC-370-01					66	9		2					321				4	398
El Jarro Point to Davenport	SC-370-02			72[c]		22								313		1		4	408
Davenport to Sand Hill Bluff	SC-364-01					13	1							495				3	509
Sand Hill Bluff to Needle Rock Point	SC-364-02					2	3							245				3	250
Needle Rock Point to Terrace Point	SC-364-03					31	6		6					232				4	275
Terrace Point to Point Santa Cruz	SC-364-04			108[c]			1		2					205				4	316
Palm Beach	SC-364-05											H						0	0
Salinas River Old Mouth	MO-364-01											H						0	0
Elkhorn Slough Salt Ponds	MO-364-02								10	H	H							1	10
Elkhorn Slough Estuarine Reserve	MO-364-03								16	20								2	36
Moss Landing Harbor	MO-364-04								16									1	16
Moro Cojo Slough	MO-364-05											H						0	0
Salinas River New Mouth	MO-364-06									568[n]	H	H						2	568
Monterey Harbor	MO-362-01			494[c]					24					35				3	553
Cannery Row	MO-362-02			310[c]		198			86					88				4	682
Bird Rock (Monterey Co.)	MO-362-03			1,658[c]			2		16									3	1,676
North Carmel Bay	MO-362-04					9			6									2	15
Pescadero Rocks	MO-362-05						2		20					22			H[k]	3	44
Guillemot Island Area	MO-362-06			554		20	10		30					18			H[k]	5	632
Pinnacle Point Area	MO-362-07			P[l]		33	3		10					H				4	46

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Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormorant	Double-crested Cormorant	Pelagic Cormorant	Black Oystercatcher	California Gull [9]	Western Gull	Caspian Tern [9]	Forsters Tern [9]	Least Tern	Common Murre	Pigeon Guillemot	Cassin's Auklet	Rhinoceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Sand Hill Cove	MO-362-08					18	1		4					H				3	23
Bird Island (Monterey Co.)	MO-362-09			2,690[c]		4	2		90					5				5	2,791
Carmel Highlands	MO-362-10					2	1											2	3
Yankee Point	MO-362-11			1,744[c]					H					H				1	1,744
Yankee Point South	MO-362-12					7	5		18					2				4	32
Soberanes Creek Rocks	MO-362-13					46	1		6					15				5	68
Lobos Rocks	MO-362-14						4		4					8				3	16
Soberanes Point South	MO-362-15			66[c]		7	H		1					7				4	81
Kasler Point North	MO-362-16						1		2					3				3	6
Rocky Point	MO-362-17			54[c]		H	H		6					17				3	77
Bench Mark-227x	MO-362-18		P[o]	444[a]		35	H		38				539[a]	36				6	1,092
Castle Rocks and Mainland	MO-362-19		P[o]	342[a]		46	P[l]		12				2,901[a]	19	2[ob]			8	3,322
Hurricane Point Rocks	MO-362-20		P[o]	68[a]		P[l]	H		14				1,343[a]	20			H	6	1,445
Point Sur	MO-360-01					33	H		H[k]					3				3	36
Molera Rock	MO-360-02					H			8					5				2	13
Cooper Point and Islands	MO-360-03			P[l]		18			1					18				4	37
Pfeiffer Point	MO-360-04			38[c]		9								5				3	52
Wreck Beach South	MO-360-05					11			2					8				3	21
Grimes Point	MO-360-06			30[c]		H	H		4									2	34
Lafler Rock and Mainland	MO-360-07			48[c]		4								H				2	52
Torre Canyon Rocks	MO-360-08			H		15	1											2	16
Partington Point	MO-360-09								14					5				2	19
Partington Ridge North	MO-360-10			276[c]	5	2	1		7					18				6	309
McWay Rocks	MO-360-11			P[l]			H		14					15				3	29
Partington Ridge South	MO-360-12			P[l]		H			8					165				3	173
Anderson Canyon Rocks	MO-360-13			P[l]	5	26			2					32				5	65
Burns Creek Rocks	MO-360-14			P[l]			1		2					12				4	15
Buck Creek	MO-360-15								2									1	2
Dolan Rock	MO-360-16			H														0	0
Bench Mark 223	MO-360-17					11												1	11
Square Black Rock	MO-360-18			H														0	0
Gamboa Point	MO-360-19			56[c]			1		4									3	61
Bench Mark 247	MO-360-20					H												0	0
Lopez Rock	MO-360-21			P[l]														1	0
Lopez Point South	MO-360-22								2									1	2
Rockland Landing North	MO-360-23			114[c]	18[c]	33			7									4	172
Rockland Landing	MO-360-24					2			6					17				3	25
Kirk Creek to Mill Creek	MO-354-01								2									1	2
36 North	MO-354-02					H												0	0

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Larus Rock	MO-354-03					H	H		2					2				2	4
Unnamed Point	MO-354-04					H	H		8[k]									1	8
Gorda Area	MO-354-05						1		8					5				3	14
Small Rocks & Mainland N.E. of Plaskett Rk.	MO-354-06					2	6		26					40				4	74
Plaskett Rock	MO-354-07			26[c]		H	1		5					H				3	32
Cape San Martin	MO-354-08			296[c]	H[c]	18	H		349					H				3	663
Unnamed Rock	MO-354-09			H[c]	H[c]	H	H		4									1	4
Mainland Point across from Bird Rock	MO-354-10					26	H							5				2	31
Point North of Redwood Gulch	MO-354-11					2			2									2	4
Redwood Gulch Rock	MO-354-12			P[l]					2					H				2	2
Seastack South of Redwood Gulch	MO-354-13			134[c]		9	H		6									3	149
Unmapped Island	MO-354-14			22[c]		H			3					5				3	30
Salmon Creek	MO-354-15					H												0	0
Arched Peninsula South of Salmon Creek	MO-354-16					24								28				2	52
Ragged Point Lodge Colony	SL-354-01			136[c]		H	H		H					8				2	144
Ragged Point South	SL-354-02								2									1	2
3 Rocks	SL-354-03			130[c]		48	2		12									4	192
La Cruz Rock	SL-354-04			P[l]			H		18									2	18
Piedras Blancas Island	SL-352-01			1,224[c]			1		34					29		3	H	5	1,291
Point Piedras Blancas	SL-352-02						2		2									2	4
Two Rocks South of Point Piedras Blancas	SL-352-03					7	1		14					5				4	27
Point San Simeon	SL-352-04						1		10					42				3	53
South San Simeon	SL-352-05													22				1	22
Island South of Cayucos Point	SL-352-06						6											1	6
Morro Rock and Pillar Rock	SL-352-07			876[c]	82[c]	53	H		114					24				5	1,149
Fairbank Point	SL-352-08				812[c]													1	812
Morro Bay Spit	SL-352-09											H						0	0
Spooner's Cove	SL-350-01								H					56				1	56
Point Buchon	SL-350-02			172[c]		48	6		40					102				5	368
Unnamed Rocks	SL-350-03			286[c]		174	6		49					242				5	757
Pup Rock and Adjacent Mainland	SL-350-04			774[m]			2		44									3	820
Lion Rock	SL-350-05			424[m]		H	1		24					18				4	467
Diablo Rock & Adjacent Mainland	SL-350-06			384[m]		H	H		26					5				3	415
Diablo Canyon Nuclear Power Plant South	SL-350-07			P[l]		114	1		28					48				5	191
Double Rock Region	SL-350-08					18	3		6					5				4	32
Pecho Rock	SL-350-09			190[m]					14								H	2	204
Smith and Whaler Islands	SL-350-10						1		H					18				2	19
Port San Luis	SL-350-11						1							19				2	20
Fossil Point	SL-350-12					46	7		21					131				4	205

Appendix 1A cont. Available marine bird colony data along coast of north/central California: number of breeding birds by species.

Colony Name	California Colony Code	Leach's Storm-Petrel	Ashy Storm-Petrel	Brandt's Cormorant	Double-crested Cormorant	Pelagic Cormorant	Black Oystercatcher	California Gull [9]	Western Gull	Caspian Tern [9]	Forsters Tern [9]	Least Tern	Common Murre	Pigeon Guillemot	Cassin's Auklet	Rhinoceros Auklet	Tufted Puffin	No. of Breeding Species	Colony Size (No. of Breeding Birds)
Shell Beach Rocks	SL-350-13			P[l]	260[c]	H	11		18					153		5		6	447
North Pismo Beach Rocks	SL-350-14					15	3		10					104		1		5	133
Oso Flako Lake North	SL-350-15											6						1	6
Oso Flako Lake South	SL-350-16											H						0	0
Guadalupe Dunes North	SL-344-01											H						0	0
Guadalupe Dunes South	SB-344-01											40						1	40
Mussel Point	SB-344-02					9			7					5				3	21
Point Sal	SB-344-03								4					45		3		3	52
TOTALS	-	1,510	2,070	41,515	6,490	5,681	330	4,764	22,600	3,406	3,550	224	269,720	6,432	18,869	770	147	-	**388,080**

Notes

1. This table represents the best available information on 281 colonies of 16 breeding marine bird species that in the study area along the central California coast, from Pt. Arena to Pt. Sal, CA and also in San Francisco Bay. The colonies contain approximately 388,080 breeding birds; maximum colony size=184,442; average size=1,386; median=40. Colonies are listed north to south. See #3 below for a reference to this table. Additional data on these colonies are in worksheet 2 of this file. Information on additional colonies and species is available from the U.S. Fish & Wildlife Service & NOAA's National Marine Sanctuary Program. Colony counts are always changing; this is a "snapshot" of best available data from a variety of sources.
2. The numbers of breeding birds is reported here. See species accounts for estimation methods; some are actual counts and some are estimates based on actual counts with corrections.
3. This table is in a report with the following working reference: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. Phase II of a Biogeographic Assessment off North/Central California – In Support of the National Marine Sanctuaries of Cordell Bank, Gulf of the Farallones, and Monterey Bay. Prepared by NOAA NCCOS' Biogeography Branch and Partners. Silver Spring, MD. Please contact tracy.gill@noaa.gov if you have questions.
4. Key to symbols in table: H = historically-nesting species; P = present and breeding or probably breeding. A "blank" in the table indicates no available data, or the species is not present there. The California Colony Code includes a reference to the county or location: for example, SFB indicates the colony is in San Francisco Bay; SO in the code indicates the colony is in Sonoma County.
5. Species reported as present or probably present (P) were included in No. of Breeding Species but not in Colony Size.
6. Species reported as historical (H) were not included in No. of Breeding Species or Colony Size.
7. Although most marine bird species that breed in San Francisco Bay do not significantly use the ocean study area, Bay colonies were included because: 1) some bay breeders do use the ocean; and 2) the data were available.
8. Most data were collected from 1989-1990 and are from Carter et. (1992). Superscript notes in the table reference data other than from Carter et. (1992) and are from the following sources:
   a: Capitolo et al. (2006); updates from 2004 for Common Murre, Brandt's Cormorant, and Double-crested Cormorant at selected colonies. Cormorant numbers are estimates, based on two times the number of nests observed. To estimate the number of breeding birds for Common Murre, the counts at colonies are corrected by multiplying the number of birds counted by 1.67.
   b: Gerry McChesney, personal communication (2006).
   c: Capitolo et al. 2004; updates from 2003 for Brandt's Cormorant and Double-Crested Cormorant.
   d: McChesney et al. 2005; updates from 2004 for San Pedro Rock, Devil's Slide Rock and Mainland.
   e: Warzybok et al. 2002; updates from 2002 are included for the following five species at South Farallon Island: Cassin's Auklet, Tufted Puffin, Pigeon Guillemot, Pelagic Cormorant and Western Gull.
   f: Sydeman et al. 1998; updates from 1992 for Ashy Storm-Petrel for Southeast Farallon Island.
   g: Whitworth et al. 2002; updates from 2001 for Ashy Storm-Petrel at Bird Rock, Point Reyes and Double Point Rocks. Provided are means of reported ranges for population estimates.
   h: Thayer and Sydeman 2002a,b; updates from 2002 for Cassin's Auklet and Rhinoceros Auklet in the vicinity of Año Nuevo; this does not include the small breeding area within the Brandt's Cormorant colony.
   i. Sowls et al. (1980). In 1989, no Leach's Storm-Petrels were detected during one night of surveys, indicating possible decline or loss of colony but survey effort was low (Carter et al. 1992).
   j: Ainley and Lewis, 1974: estimates of breeding birds for Leach's Storm-Petrels. Based on surveys conducted since 1987, this colony appears to have declined substantially (W.J. Sydeman and G.J. McChesney, pers. comm.).
   k: Personal communication from Harry Carter, 2007.
   l: Colonies indicated as Present ("P") were inactive in 2003 (Capitolo et al. 2004) but active and not counted at least one year during 2000-2004 period (G.J. McChesney, pers. comm.).
   m: McChesney et al. 2000b; available data for Brandt's Cormorant colonies in 2000 were used for colonies that were inactive when last assessed in 2003 (Capitolo et al. 2004).
   n: U.S. Fish and Wildlife Service, Salinas River National Wildlife Refuge, unpublished data from 2004.
   o: McChesney et al. (2000a). For Ashy Storm-Petrel, two, one and one nest each were recorded at Bench Mark-227x, Castle Rocks and Mainland, and Hurricane Point Rocks, respectively, and 20-60 breeding birds were estimated for the three colonies combined.
9. Updated numbers for California Gull, Forster's Tern, and Caspian Tern in San Francisco Bay are available in Strong et al. (2004) but were not included in this table.
10. The number of breeding bird species and individuals at a colony can vary significantly from year to year; this table reflects a combination of survey "snapshots". It was the best available information at the time. It is highly likely there are more species and many more birds in each colony than are shown in this table, and some colonies shown here have come and gone.
11. Although they do not breed in the study area, Marbled Murrelets feed in the study area and breed nearby at Big Basin State Park and vicinity, in the Santa Cruz Mountains, along the central CA coast. The Santa Cruz population has about 500 birds, and probably less than 200 are breeding there (S. Hampton, CDFG, pers. comm.). The species forages in the coastal ocean study area, and is listed as state-endangered and federally-threatened. A representative location (37°08'45" N x 122°18'00"W) for Marbled Murrelets breeding at Big Basin State Park was included on the map, but not in this table because it does not represent an actual nesting location for the species.
12. This table was compiled by Janet Casey (R.G. Ford Consulting Co.), with help from Tracy Gill (NOAA) and Gerry MCChesney (USFWS) on data collection and revisions, and Jamie Higgins (NOAA) on revisions. Please contact tracy.gill@noaa.gov if you have questions.
13. See Appendix 1B for additional information on the colonies.
14. An entry for Marbled Murrelet was not included in the table because the data available references a general area for Marbled Murrelet nests and not a specific location. The location referenced here is the Big Basin State Park and vicinity; the approx. position of the Park is 37°08'45"N by 122°18'00"W and the approx. number of breeding Marbled Murrelets for that area is 200 birds.

Appendix 1B. Available marine bird colony data along coast of north/central California: related colony information.

Colony Name	California Colony Code	USFWS Colony Number	Latitude	Longitude	No. of Breeding Species	Colony Size (No. of Breeding Birds)	Percent Total	Downcoast Order (North to South)	Decimal Latitude	Decimal Longitude
Point Arena	ME-384-01	404-017	38°57'20" N	123°44'30" W	4	217	0.056%	1	38.95556	-123.74167
Sea Lion Rocks	ME-384-02	404-001	38°56'07" N	123°43'45" W	4	131	0.034%	2	38.93528	-123.72917
Sea Lion Rocks to Arena Cove	ME-384-03	404-042	38°55'41" N	123°43'45" W	3	203	0.052%	3	38.92806	-123.72917
Moat Cove	ME-384-04	404-018	38°53'10" N	123°41'00" W	1	10	0.003%	4	38.88611	-123.68333
Section 30 Cove	ME-384-05	404-019	38°52'59" N	123°40'10" W	2	50	0.013%	5	38.88306	-123.66944
Saunders Landing	ME-384-06	404-020	38°51'13" N	123°39'05" W	2	28	0.007%	6	38.85361	-123.65139
Iverson Point	ME-384-07	404-002	38°50'39" N	123°38'37" W	2	47	0.012%	7	38.84417	-123.64361
Triplett Gulch	ME-384-08	404-021	38°49'00" N	123°36'15" W	3	178	0.046%	8	38.81667	-123.60417
Fish Rock Cove	ME-384-09	404-022	38°47'45" N	123°35'20" W	2	34	0.009%	9	38.79583	-123.58889
Fish Rocks	ME-384-10	404-003	38°48'00" N	123°35'31" W	9	905	0.233%	10	38.80000	-123.59194
Collins Landing to Gualala River	ME-384-11	404-023	38°46'00" N	123°32'40" W	3	281	0.072%	11	38.76667	-123.54444
Gualala Point Island	SO-384-01	404-004	38°45'04" N	123°31'42" W	5	324	0.083%	12	38.75111	-123.52833
Del Mar Point	SO-384-02	404-024	38°44'15" N	123°31'00" W	1	9	0.002%	13	38.73750	-123.51667
Sea Ranch	SO-384-03	404-025	38°42'00" N	123°27'30" W	4	153	0.039%	14	38.70000	-123.45833
Black Point to Stewart's Point	SO-384-04	404-026	38°40'00" N	123°25'15" W	4	62	0.016%	15	38.66667	-123.42083
Stewart's Point to Rocky Point	SO-382-01	404-027	38°39'00" N	123°23'44" W	4	86	0.022%	16	38.65000	-123.39556
Horseshoe Cove	SO-382-02	404-028	38°36'30" N	123°22'10" W	3	125	0.032%	17	38.60833	-123.36944
Cannon Gulch to Stump Beach	SO-382-03	404-029	38°35'30" N	123°20'30" W	3	95	0.024%	18	38.59167	-123.34167
Gerstle Cove to Stillwater Cove	SO-382-04	404-030	38°33'00" N	123°18'45" W	4	142	0.037%	19	38.55000	-123.31250
Bench Mark 125 to Timber Cove	SO-382-05	404-031	38°32'20" N	123°17'00" W	4	106	0.027%	20	38.53889	-123.28333
Windermere Point to Jewell Gulch	SO-382-06	404-043	38°30'20" N	123°13'00" W	4	49	0.013%	21	38.50556	-123.21667
Northwest Cape Rocks	SO-382-07	404-032	38°30'40" N	123°15'17" W	2	53	0.014%	22	38.51111	-123.25472
Russian Gulch	SO-382-08	404-033	38°28'00" N	123°09'36" W	5	376	0.097%	23	38.46667	-123.16000
Russian River Rocks	SO-382-09	404-005	38°27'14" N	123°08'34" W	6	414	0.107%	24	38.45389	-123.14278
Goat Rock to Peaked Hill	SO-382-10	404-044	38°26'14" N	123°07'30" W	2	7	0.002%	25	38.43722	-123.12500
Arched Rock	SO-382-11	404-006	38°25'53" N	123°07'32" W	4	481	0.124%	26	38.43139	-123.12556
Peaked Hill	SO-382-12	404-034	38°25'45" N	123°07'10" W	4	53	0.014%	27	38.42917	-123.11944
Gull Rock	SO-382-13	404-035	38°25'30" N	123°07'10" W	6	160	0.041%	28	38.42500	-123.11944
Shell-Wright Beach Rocks	SO-382-14	404-036	38°25'00" N	123°06'00" W	5	200	0.052%	29	38.41667	-123.10000
Duncan Point to Arched Rock	SO-382-15	404-037	38°22'30" N	123°05'00" W	3	174	0.045%	30	38.37500	-123.08333
Bodega Head	SO-380-01	404-038	38°18'00" N	123°03'45" W	4	121	0.031%	31	38.30000	-123.06250
Bodega Rock	SO-380-02	404-008	38°17'48" N	123°02'50" W	4	778	0.200%	32	38.29667	-123.04722
Bodega Harbor	SO-380-03	404-045	38°19'21" N	123°02'30" W	2	14	0.004%	33	38.32250	-123.04167
Pinnacle Rock	SO-380-04	404-039	38°18'20" N	123°01'10" W	5	84	0.022%	34	38.30556	-123.01944
Sonoma-Marin County Line	MA-380-01	404-040	38°17'20" N	123°00'20" W	4	128	0.033%	35	38.28889	-123.00556
Dillon Beach Rocks	MA-380-02	404-009	38°16'26" N	122°59'11" W	6	230	0.059%	36	38.27389	-122.98639
Tomales Point	MA-380-03	404-011	38°12'13" N	122°57'39" W	3	150	0.039%	37	38.20361	-122.96083
Bird Rock (Marin Co.)	MA-380-04	404-010	38°13'49" N	122°59'35" W	7	894	0.230%	38	38.23028	-122.99306
Elephant Rock Complex	MA-380-05	404-041	38°11'00" N	122°58'00" W	2	36	0.009%	39	38.18333	-122.96667
Point Reyes	MA-374-01	429-001	37°59'30" N	123°00'00" W	9	43,061	11.096%	40	37.99167	-123.00000
Coast Campground South	MA-374-02	429-042	38°00'52" N	122°51'14" W	1	63	0.016%	41	38.01444	-122.85389
Point Resistance	MA-374-03	429-024	37°59'55" N	122°49'40" W	4	7,177	1.849%	42	37.99861	-122.82778
Millers Point Rocks	MA-374-04	429-002	37°58'53" N	122°48'35" W	6	1,951	0.503%	43	37.98139	-122.80972
Double Point Rocks	MA-374-05	429-003	37°56'51" N	122°47'08" W	6	16,235	4.184%	44	37.94750	-122.78556
Stinson Beach to Rocky Point	MA-374-06	429-043	37°53'08" N	122°37'38" W	1	6	0.002%	45	37.88556	-122.62722
Gull Rock Area	MA-374-07	429-025	37°52'35" N	122°37'00" W	4	23	0.006%	46	37.87639	-122.61667
Muir Beach Headlands to Tennessee Cove	MA-374-08	429-026	37°51'00" N	122°33'45" W	4	97	0.025%	47	37.85000	-122.56250
Bird Island (Marin Co.)	MA-374-09	429-007	37°49'27" N	122°32'09" W	3	62	0.016%	48	37.82417	-122.53583
Point Bonita	MA-374-10	429-008	37°48'55" N	122°31'40" W	3	171	0.044%	49	37.81528	-122.52778
Bonita Cove	MA-374-11	429-027	37°49'30" N	122°31'00" W	3	10	0.003%	50	37.82500	-122.51667
Point Diablo Bluffs and Needles	MA-374-12	429-028	37°49'30" N	122°29'00" W	2	49	0.013%	51	37.82500	-122.48333

Appendix 1B cont. Available marine bird colony data along coast of north/central California: related colony information.

Colony Name	California Colony Code	USFWS Colony Number	Latitude	Longitude	No. of Breeding Species	Colony Size (No. of Breeding Birds)	Percent Total	Downcoast Order (North to South)	Decimal Latitude	Decimal Longitude
Yellow Bluff	SFB-MA-01	429-053	37°50'13" N	122°28'15" W	1	2	0.001%	52	37.83694	-122.47083
Sausalito Point Area	SFB-MA-02	429-054	37°51'22" N	122°28'34" W	1	4	0.001%	53	37.85611	-122.47611
Peninsula Point and Cone Rock	SFB-MA-03	429-055	37°51'44" N	122°27'25" W	1	6	0.002%	54	37.86222	-122.45694
Angel Island	SFB-MA-04	429-056	37°51'18" N	122°26'24" W	1	6	0.002%	55	37.85500	-122.44000
Bluff Point to Paradise Cay	SFB-MA-05	429-057	37°53'47" N	122°27'37" W	1	4	0.001%	56	37.89639	-122.46028
Point San Quentin	SFB-MA-06	429-058	37°56'48" N	122°28'20" W	1	6	0.002%	57	37.94667	-122.47222
Marin Islands	SFB-MA-07	429-059	37°57'57" N	122°28'15" W	2	66	0.017%	58	37.96583	-122.47083
The Sisters and Point San Pedro	SFB-MA-08	429-041	37°59'22" N	122°26'25" W	1	96	0.025%	59	37.98944	-122.44028
Rat Rock	SFB-MA-09	404-046	38°00'16" N	122°27'40" W	1	2	0.001%	60	38.00444	-122.46111
Southwest San Pablo Bay Duck Blinds	SFB-MA-10	404-047	38°02'15" N	122°28'03" W	1	16	0.004%	61	38.03750	-122.46750
Marin County-West San Pablo Bay Ship Channel	SFB-MA-11	404-048	38°04'17" N	122°25'38" W	1	14	0.004%	62	38.07139	-122.42722
Sonoma Co.-West San Pablo Bay Ship Channel	SFB-SO-01	404-049	38°06'35" N	122°27'52" W	1	2	0.001%	63	38.10972	-122.46444
Little Island	SFB-NA-01	404-050	38°10'52" N	122°20'31" W	0	0	0.000%	64	38.18111	-122.34194
Russ Island	SFB-NA-02	404-051	38°10'57" N	122°19'17" W	1	4	0.001%	65	38.18250	-122.32139
Island No. 2	SFB-NA-03	404-052	38°09'56" N	122°19'09" W	1	50	0.013%	66	38.16556	-122.31917
Knight Island	SFB-SN-01	404-053	38°08'16" N	122°17'58" W	4	754	0.194%	67	38.13778	-122.29944
White Slough	SFB-SN-02	404-054	38°07'39" N	122°15'19" W	1	40	0.010%	68	38.12750	-122.25528
North San Pablo Bay Radar Target	SFB-SN-03	404-055	38°06'04" N	122°19'41" W	1	30	0.008%	69	38.10111	-122.32806
Northeast San Pablo Bay Beacon	SFB-SN-04	404-056	38°04'17" N	122°17'17" W	2	10	0.003%	70	38.07139	-122.28806
Mare Island Strait	SFB-SN-05	404-057	38°04'40" N	122°14'43" W	1	20	0.005%	71	38.07778	-122.24528
Commodore Jones Point to Benicia Point	SFB-SN-06	404-058	38°02'37" N	122°09'54" W	1	10	0.003%	72	38.04361	-122.16500
Benicia Point to Army Point	SFB-SN-07	404-059	38°02'32" N	122°09'08" W	1	6	0.002%	73	38.04222	-122.15222
Mothball Fleet	SFB-SN-08	404-060	38°05'00" N	122°05'00" W	1	10	0.003%	74	38.08333	-122.08333
Wheeler Island	SFB-SN-09	405-001	38°04'37" N	121°57'47" W	1	252	0.065%	75	38.07694	-121.96306
Donlon Island	SFB-SA-01	405-002	38°01'45" N	121°46'50" W	0	0	0.000%	76	38.02917	-121.78056
Pittsburgh Pacific Gas & Electric Plant	SFB-CC-01	405-003	38°02'17" N	121°54'29" W	1	8	0.002%	77	38.03806	-121.90806
Port Chicago Allied Chemical Co.	SFB-CC-02	405-004	38°02'56" N	121°59'09" W	0	0	0.000%	78	38.04889	-121.98583
Suisun Point Area	SFB-CC-03	404-061	38°02'15" N	122°07'06" W	1	6	0.002%	79	38.03750	-122.11833
Nevada Dock	SFB-CC-04	404-062	38°02'11" N	122°10'22" W	1	2	0.001%	80	38.03639	-122.17278
Eckley to Selby	SFB-CC-05	404-063	38°03'27" N	122°13'11" W	1	4	0.001%	81	38.05750	-122.21972
Davis Point Unocal Wharf	SFB-CC-06	404-064	38°03'16" N	122°15'15" W	1	22	0.006%	82	38.05444	-122.25417
Hercules Wharf	SFB-CC-07	404-065	38°01'23" N	122°17'29" W	1	2	0.001%	83	38.02306	-122.29139
Pinole Point	SFB-CC-08	404-066	38°00'25" N	122°21'46" W	1	2	0.001%	84	38.00694	-122.36278
East San Pablo Bay Ship Channel	SFB-CC-09	404-067	38°01'48" N	122°22'18" W	1	6	0.002%	85	38.03000	-122.37167
The Brothers	SFB-CC-10	429-040	37°57'47" N	122°26'00" W	2	179	0.046%	86	37.96306	-122.43333
Castro Point Area	SFB-CC-11	429-060	37°56'08" N	122°24'55" W	1	8	0.002%	87	37.93556	-122.41528
Richmond-San Rafael Bridge	SFB-CC-12	429-061	37°56'01" N	122°25'26" W	2	1,282	0.330%	88	37.93361	-122.42389
Castro Rocks	SFB-CC-13	429-062	37°55'57" N	122°24'57" W	0	0	0.000%	89	37.93250	-122.41583
Red Rock	SFB-CC-14	429-039	37°55'45" N	122°25'50" W	1	384	0.099%	90	37.92917	-122.43056
Standard Oil Long Wharf	SFB-CC-15	429-063	37°55'31" N	122°24'14" W	1	6	0.002%	91	37.92528	-122.40389
Richmond Harbor Entrance Channel	SFB-CC-16	429-064	37°54'18" N	122°22'38" W	1	12	0.003%	92	37.90500	-122.37722
Brooks Island Area	SFB-CC-17	429-065	37°53'47" N	122°21'16" W	3	220	0.057%	93	37.89639	-122.35444
Richmond Inner Harbor	SFB-CC-18	429-066	37°54'36" N	122°21'42" W	1	12	0.003%	94	37.91000	-122.36167
Albany Hill Cove	SFB-AL-01	429-067	37°53'33" N	122°18'49" W	1	2	0.001%	95	37.89250	-122.31361
Berkeley Yacht Harbor Breakwaters	SFB-AL-02	429-068	37°51'59" N	122°19'05" W	1	38	0.010%	96	37.86639	-122.31806
Berkeley Pier	SFB-AL-03	429-069	37°51'15" N	122°20'29" W	1	40	0.010%	97	37.85417	-122.34139
Bay Bridge "Toll Plaza Point"	SFB-AL-04	429-070	37°49'52" N	122°18'47" W	1	2	0.001%	98	37.83111	-122.31306
San Fran-Oakland Bay Bridge E.	SFB-AL-05	429-071	37°49'10" N	122°20'31" W	2	1,530	0.394%	99	37.81944	-122.34194
Oakland Outer Harbor	SFB-AL-06	429-072	37°48'59" N	122°19'25" W	1	8	0.002%	100	37.81639	-122.32361
Oakland Middle Harbor	SFB-AL-07	429-073	37°48'01" N	122°21'50" W	1	10	0.003%	101	37.80028	-122.36389

Appendix 1B cont. Available marine bird colony data along coast of north/central California: related colony information.

Colony Name	California Colony Code	USFWS Colony Number	Latitude	Longitude	No. of Breeding Species	Colony Size (No. of Breeding Birds)	Percent Total	Downcoast Order (North to South)	Decimal Latitude	Decimal Longitude
Oakland Inner Harbor	SFB-AL-08	429-074	37°47'27" N	122°18'07" W	1	6	0.002%	102	37.79083	-122.30194
Government Island Area	SFB-AL-09	429-075	37°47'05" N	122°15'18" W	1	2	0.001%	103	37.78472	-122.25500
Alameda Naval Air Station	SFB-AL-10	429-010	37°47'12" N	122°19'49" W	3	1,840	0.474%	104	37.78667	-122.33028
Ballena Bay	SFB-AL-11	429-076	37°46'00" N	122°17'13" W	0	0	0.000%	105	37.76667	-122.28694
Bay Farm Island	SFB-AL-12	429-077	37°44'36" N	122°15'00" W	0	0	0.000%	106	37.74333	-122.25000
Oakland International Airport	SFB-AL-13	429-011	37°43'22" N	122°14'42" W	1	18	0.005%	107	37.72278	-122.24500
Mulford Landing Channel	SFB-AL-14	429-078	37°41'26" N	122°11'51" W	1	2	0.001%	108	37.69056	-122.19750
Hayward Marsh, Basin 3A	SFB-AL-15	429-079	37°37'47" N	122°08'44" W	1	2	0.001%	109	37.62972	-122.14556
Baumberg Plant #1, Pond 10	SFB-AL-16	429-015	37°36'41" N	122°08'41" W	1	814	0.210%	110	37.61139	-122.14472
Baumberg Plant #1, Ponds 10 &11	SFB-AL-17	429-080	37°36'42" N	122°08'17" W	0	0	0.000%	111	37.61167	-122.13806
Baumberg Plant #1, Pond 8A	SFB-AL-18	429-081	37°35'49" N	122°07'52" W	1	313	0.081%	112	37.59694	-122.13111
Baumberg Plant #1, Pond 6B	SFB-AL-19	429-082	37°35'53" N	122°06'39" W	1	85	0.022%	113	37.59806	-122.11083
Baumberg Plant #1, Ponds 1, 2, 7	SFB-AL-20	429-017	37°35'08" N	122°07'30" W	0	0	0.000%	114	37.58556	-122.12500
Baumberg Plant #2, Ponds 2, 4, 7	SFB-AL-21	429-017	37°34'49" N	122°07'06" W	0	0	0.000%	115	37.58028	-122.11833
Baumberg Plant #1, Ponds 4, 5, 7	SFB-AL-22	429-085	37°34'51" N	122°06'33" W	1	94	0.024%	116	37.58083	-122.10917
Plant #1, Pond 1A-NW	SFB-AL-23	429-017	37°34'07" N	122°07'27" W	0	0	0.000%	117	37.56861	-122.12417
Plant #1, Pond 1A	SFB-AL-24	429-087	37°34'02" N	122°07'07" W	0	0	0.000%	118	37.56722	-122.11861
Plant #1, Pond 2A	SFB-AL-25	429-088	37°33'36" N	122°07'24" W	1	125	0.032%	119	37.56000	-122.12333
Plant #1, Pond 3A	SFB-AL-26	429-089	37°33'14" N	122°06'40" W	0	0	0.000%	120	37.55389	-122.11111
Plant #1, Ponds 4, 5, 6, 7	SFB-AL-27	429-090	37°32'03" N	122°06'10" W	0	0	0.000%	121	37.53417	-122.10278
KGO Radio Towers	SFB-AL-28	429-091	37°31'31" N	122°06'00" W	0	0	0.000%	122	37.52528	-122.10000
Plant #1, Pond 3	SFB-AL-29	429-092	37°30'45" N	122°06'02" W	1	99	0.026%	123	37.51250	-122.10056
Plant #1, Pond 1	SFB-AL-30	429-093	37°31'32" N	122°04'37" W	1	204	0.053%	124	37.52556	-122.07694
Plant #2, Ponds 11, 26	SFB-AL-31	429-094	37°29'50" N	122°02'42" W	0	0	0.000%	125	37.49722	-122.04500
Plant #2, Ponds 4, 5	SFB-AL-32	429-019	37°28'27" N	121°59'17" W	1	634	0.163%	126	37.47417	-121.98806
Alviso Plant, Pond A17	SFB-SR-01	430-002	37°27'33" N	121°58'03" W	1	25	0.006%	127	37.45917	-121.96750
Alviso Plant, Pond A18	SFB-SR-02	430-003	37°26'49" N	121°56'33" W	0	0	0.000%	128	37.44694	-121.94250
Alviso Plant, Pond A16	SFB-SR-03	430-004	37°26'31" N	121°57'43" W	1	43	0.011%	129	37.44194	-121.96194
Alviso Plant, Ponds A9, A10	SFB-SR-04	430-005	37°26'57" N	121°59'34" W	2	512	0.132%	130	37.44917	-121.99278
Alviso Plant, Pond A8	SFB-SR-05	429-020	37°25'43" N	121°59'42" W	1	158	0.041%	131	37.42861	-121.99500
Alviso Plant, Pond A7	SFB-SR-06	429-020	37°26'29" N	122°00'27" W	1	95	0.024%	132	37.44139	-122.00750
Alviso Plant, Pond A6	SFB-SR-07	429-020	37°27'24" N	122°01'26" W	3	4,526	1.166%	133	37.45667	-122.02389
Alviso Plant, Pond A5	SFB-SR-08	429-020	37°26'37" N	122°01'23" W	0	0	0.000%	134	37.44361	-122.02306
Alviso Plant, Pond B2	SFB-SR-09	429-020	37°26'22" N	122°02'52" W	1	480	0.124%	135	37.43944	-122.04778
Alviso Plant, Pond A1	SFB-SR-10	429-099	37°26'11" N	122°05'07" W	2	40	0.010%	136	37.43639	-122.08528
Charleston Slough	SFB-SR-11	429-100	37°26'33" N	122°05'22" W	1	250	0.064%	137	37.44250	-122.08944
Redwood City Plant, Pond 1	SFB-SM-01	429-101	37°29'51" N	122°08'59" W	1	100	0.026%	138	37.49750	-122.14972
Redwood City Plant, Pond 3	SFB-SM-02	429-102	37°29'15" N	122°08'48" W	0	0	0.000%	139	37.48750	-122.14667
Bair Island, Pond A10	SFB-SM-03	429-103	37°31'01" N	122°13'52" W	0	0	0.000%	140	37.51694	-122.23111
Bair Island, Pond A9	SFB-SM-04	429-016	37°30'58" N	122°14'17" W	0	0	0.000%	141	37.51611	-122.23806
Bair Island, Pond B3	SFB-SM-05	429-016	37°31'42" N	122°14'03" W	0	0	0.000%	142	37.52833	-122.23417
Bair Island, Pond B1	SFB-SM-06	429-016	37°32'12" N	122°12'25" W	2	863	0.222%	143	37.53667	-122.20694
San Mateo Bridge and PG&E Towers	SFB-SM-07	429-107	37°35'24" N	122°14'40" W	2	216	0.056%	144	37.59000	-122.24444
San Francisco Ship Channel	SFB-SM-08	429-108	37°40'05" N	122°21'31" W	1	8	0.002%	145	37.66806	-122.35861
Oyster Point Area	SFB-SM-09	429-109	37°39'01" N	122°22'49" W	2	12	0.003%	146	37.65028	-122.38028
Double Rock	SFB-SF-01	429-110	37°43'14" N	122°22'52" W	1	2	0.001%	147	37.72056	-122.38111
Hunter's Point	SFB-SF-02	429-111	37°43'42" N	122°21'22" W	1	50	0.013%	148	37.72833	-122.35611
Lash Lighter Basin	SFB-SF-03	429-112	37°44'24" N	122°22'05" W	1	40	0.010%	149	37.74000	-122.36806
Potrero Point	SFB-SF-04	429-113	37°45'19" N	122°22'47" W	1	6	0.002%	150	37.75528	-122.37972
San Francisco Piers South	SFB-SF-05	429-114	37°46'51" N	122°22'59" W	1	232	0.060%	151	37.78083	-122.38306
San Fran.-Oakland Bay Bridge West	SFB-SF-06	429-115	37°48'03" N	122°22'26" W	1	48	0.012%	152	37.80083	-122.37389

Appendix 1B cont. Available marine bird colony data along coast of north/central California: related colony information.

Colony Name	California Colony Code	USFWS Colony Number	Latitude	Longitude	No. of Breeding Species	Colony Size (No. of Breeding Birds)	Percent Total	Downcoast Order (North to South)	Decimal Latitude	Decimal Longitude
Yerba Buena Island	SFB-SF-07	429-038	37°48'34" N	122°22'15" W	3	67	0.017%	153	37.80944	-122.37083
Treasure Island	SFB-SF-08	429-116	37°49'48" N	122°21'53" W	1	96	0.025%	154	37.83000	-122.36472
San Francisco Piers North	SFB-SF-09	429-117	37°48'27" N	122°24'00" W	1	62	0.016%	155	37.80750	-122.40000
Pier 45	SFB-SF-10	429-037	37°48'34" N	122°25'00" W	1	66	0.017%	156	37.80944	-122.41667
Alcatraz Island	SFB-SF-11	429-036	37°49'34" N	122°25'20" W	3	2,483	0.640%	157	37.82611	-122.42222
Fort Point Rock to Helmut Rock	SF-374-01	429-044	37°48'15" N	122°28'38" W	1	6	0.002%	158	37.80417	-122.47722
Lobos Rock and Land's End	SF-374-02	429-029	37°47'15" N	122°30'20" W	3	270	0.070%	159	37.78750	-122.50556
Seal Rocks	SF-374-03	429-009	37°46'42" N	122°30'53" W	3	233	0.060%	160	37.77833	-122.51472
Eel Rock Cliffs	SF-372-05	429-031	37°24'15" N	122°25'30" W	1	9	0.002%	161	37.40417	-122.42500
North Farallon Islands	SF-FAI-01	429-051	37°46'04" N	123°05'56" W	6	72,203	18.606%	162	37.76778	-123.09889
South Farallon Islands	SF-FAI-02	429-052	37°42'00" N	123°00'00" W	12	184,442	47.528%	163	37.70000	-123.00000
Mussel Rock Area	SM-374-01	429-045	37°40'00" N	122°29'47" W	2	11	0.003%	164	37.66667	-122.49639
Mori Point	SM-372-01	429-046	37°37'05" N	122°29'47" W	2	49	0.013%	165	37.61806	-122.49639
San Pedro Rock	SM-372-02	429-013	37°35'43" N	122°31'20" W	3	142	0.037%	166	37.59528	-122.52222
Devil's Slide Rock and Mainland	SM-372-03	429-014	37°34'39" N	122°31'14" W	5	1,354	0.349%	167	37.57750	-122.52056
Pillar Point	SM-372-04	429-030	37°29'30" N	122°29'55" W	2	7	0.002%	168	37.49167	-122.49861
Seal Rock Cliffs	SM-372-06	429-032	37°23'00" N	122°25'00" W	4	174	0.045%	169	37.38333	-122.41667
Martin's Beach	SM-372-07	429-033	37°22'00" N	122°24'30" W	3	129	0.033%	170	37.36667	-122.40833
Pomponio Beach to Pescadero Beach	SM-370-01	429-047	37°16'42" N	122°24'30" W	2	22	0.006%	171	37.27833	-122.40833
Pigeon Point	SM-370-02	429-034	37°10'55" N	122°23'20" W	2	10	0.003%	172	37.18194	-122.38889
Gazos Creek North	SM-370-03	429-048	37°10'23" N	122°20'00" W	2	12	0.003%	173	37.17306	-122.33333
Año Nuevo Island	SM-370-04	429-023	37°06'30" N	122°20'09" W	7	5,065	1.305%	174	37.10833	-122.33583
Punta del Año Nuevo	SM-370-05	429-022	37°07'07" N	122°20'09" W	2	216	0.056%	175	37.11861	-122.33583
Greyhound Rock to El Jarro Point	SC-370-01	429-049	37°03'31" N	122°15'00" W	4	398	0.103%	176	37.05861	-122.25000
El Jarro Point to Davenport	SC-370-02	429-050	37°01'05" N	122°12'23" W	4	408	0.105%	177	37.01806	-122.20639
Davenport to Sand Hill Bluff	SC-364-01	454-038	36°59'45" N	122°10'33" W	3	509	0.131%	178	36.99583	-122.17583
Sand Hill Bluff to Needle Rock Point	SC-364-02	454-039	36°58'01" N	122°07'46" W	3	250	0.064%	179	36.96694	-122.12944
Needle Rock Point to Terrace Point	SC-364-03	454-040	36°57'09" N	122°05'06" W	4	275	0.071%	180	36.95250	-122.08500
Terrace Point to Point Santa Cruz	SC-364-04	454-041	36°57'09" N	122°02'30" W	4	316	0.081%	181	36.95250	-122.04167
Palm Beach	SC-364-05	454-056	36°52'00" N	121°49'05" W	0	0	0.000%	182	36.86667	-121.81806
Salinas River Old Mouth	MO-364-01	454-057	36°49'12" N	121°47'34" W	0	0	0.000%	183	36.82000	-121.79278
Elkhorn Slough Salt Ponds	MO-364-02	454-003	36°49'04" N	121°46'30" W	1	10	0.003%	184	36.81778	-121.77500
Elkhorn Slough Estuarine Reserve	MO-364-03	454-058	36°49'03" N	121°44'25" W	2	36	0.009%	185	36.81750	-121.74028
Moss Landing Harbor	MO-364-04	454-042	36°48'28" N	121°47'06" W	1	16	0.004%	186	36.80778	-121.78500
Moro Cojo Slough	MO-364-05	454-059	36°47'49" N	121°46'40" W	0	0	0.000%	187	36.79694	-121.77778
Salinas River New Mouth	MO-364-06	454-060	36°44'25" N	121°47'58" W	2	568	0.146%	188	36.74028	-121.79944
Monterey Harbor	MO-362-01	454-043	36°36'22" N	121°53'26" W	3	553	0.143%	189	36.60611	-121.89056
Cannery Row	MO-362-02	454-044	36°36'47" N	121°53'48" W	4	682	0.176%	190	36.61306	-121.89667
Bird Rock (Monterey Co.)	MO-362-03	454-006	36°35'31" N	121°57'59" W	3	1,676	0.432%	191	36.59194	-121.96639
North Carmel Bay	MO-362-04	454-045	36°33'56" N	121°56'37" W	2	15	0.004%	192	36.56556	-121.94361
Pescadero Rocks	MO-362-05	454-022	36°33'43" N	121°56'33" W	3	44	0.011%	193	36.56194	-121.94250
Guillemot Island Area	MO-362-06	454-023	36°31'45" N	121°56'47" W	5	632	0.163%	194	36.52917	-121.94639
Pinnacle Point Area	MO-362-07	454-007	36°31'35" N	121°57'14" W	4	46	0.012%	195	36.52639	-121.95389
Sand Hill Cove	MO-362-08	454-008	36°31'01" N	121°57'01" W	3	23	0.006%	196	36.51694	-121.95028
Bird Island (Monterey Co.)	MO-362-09	454-009	36°30'25" N	121°56'33" W	5	2,791	0.719%	197	36.50694	-121.94250
Carmel Highlands	MO-362-10	454-046	36°30'00" N	121°56'23" W	2	3	0.001%	198	36.50000	-121.93972
Yankee Point	MO-362-11	454-024	36°29'29" N	121°56'41" W	1	1,744	0.449%	199	36.49139	-121.94472
Yankee Point South	MO-362-12	454-047	36°28'47" N	121°56'18" W	4	32	0.008%	200	36.47972	-121.93833
Soberanes Creek Rocks	MO-362-13	454-026	36°27'18" N	121°55'35" W	5	68	0.018%	201	36.45500	-121.92639
Lobos Rocks	MO-362-14	454-025	36°27'18" N	121°56'10" W	3	16	0.004%	202	36.45500	-121.93611
Soberanes Point South	MO-362-15	454-027	36°26'47" N	121°55'35" W	4	81	0.021%	203	36.44639	-121.92639

Appendix 1B cont. Available marine bird colony data along coast of north/central California: related colony information.

Colony Name	California Colony Code	USFWS Colony Number	Latitude	Longitude	No. of Breeding Species	Colony Size (No. of Breeding Birds)	Percent Total	Downcoast Order (North to South)	Decimal Latitude	Decimal Longitude
Kasler Point North	MO-362-16	454-048	36°24'47" N	121°54'52" W	3	6	0.002%	204	36.41306	-121.91444
Rocky Point	MO-362-17	454-028	36°24'06" N	121°54'40" W	3	77	0.020%	205	36.40167	-121.91111
Bench Mark-227x	MO-362-18	454-029	36°23'21" N	121°54'13" W	5	1,092	0.281%	206	36.38917	-121.90361
Castle Rocks and Mainland	MO-362-19	454-010	36°22'35" N	121°54'25" W	7	3,322	0.856%	207	36.37639	-121.90694
Hurricane Point Rocks	MO-362-20	454-011	36°21'40" N	121°54'25" W	5	1,445	0.372%	208	36.36111	-121.90694
Point Sur	MO-360-01	454-012	36°18'22" N	121°53'39" W	3	36	0.009%	209	36.30611	-121.89417
Molera Rock	MO-360-02	454-030	36°16'45" N	121°51'30" W	2	13	0.003%	210	36.27917	-121.85833
Cooper Point and Islands	MO-360-03	454-031	36°14'55" N	121°50'10" W	4	37	0.010%	211	36.24861	-121.83611
Pfeiffer Point	MO-360-04	454-032	36°13'59" N	121°48'33" W	3	52	0.013%	212	36.23306	-121.80917
Wreck Beach South	MO-360-05	454-049	36°13'56" N	121°47'30" W	3	21	0.005%	213	36.23222	-121.79167
Grimes Point	MO-360-06	454-033	36°12'20" N	121°44'15" W	2	34	0.009%	214	36.20556	-121.73750
Lafler Rock and Mainland	MO-360-07	454-034	36°12'00" N	121°43'36" W	2	52	0.013%	215	36.20000	-121.72667
Torre Canyon Rocks	MO-360-08	454-013	36°11'25" N	121°42'46" W	2	16	0.004%	216	36.19028	-121.71278
Partington Point	MO-360-09	454-050	36°10'43" N	121°42'01" W	2	19	0.005%	217	36.17861	-121.70028
Partington Ridge North	MO-360-10	454-014	36°10'06" N	121°41'14" W	6	309	0.080%	218	36.16833	-121.68722
McWay Rocks	MO-360-11	454-015	36°09'46" N	121°40'44" W	3	29	0.007%	219	36.16278	-121.67889
Partington Ridge South	MO-360-12	454-035	36°09'36" N	121°40'25" W	3	173	0.045%	220	36.16000	-121.67361
Anderson Canyon Rocks	MO-360-13	454-016	36°09'07" N	121°39'53" W	5	65	0.017%	221	36.15194	-121.66472
Burns Creek Rocks	MO-360-14	454-017	36°08'29" N	121°39'28" W	4	15	0.004%	222	36.14139	-121.65778
Buck Creek	MO-360-15	454-051	36°08'06" N	121°38'53" W	1	2	0.001%	223	36.13500	-121.64806
Dolan Rock	MO-360-16	454-018	36°05'06" N	121°37'02" W	0	0	0.000%	224	36.08500	-121.61722
Bench Mark 223	MO-360-17	454-052	36°04'55" N	121°36'53" W	1	11	0.003%	225	36.08194	-121.61472
Square Black Rock	MO-360-18	454-019	36°04'21" N	121°36'35" W	0	0	0.000%	226	36.07250	-121.60972
Gamboa Point	MO-360-19	454-053	36°02'51" N	121°35'14" W	3	61	0.016%	227	36.04750	-121.58722
Bench Mark 247	MO-360-20	454-036	36°02'11" N	121°34'45" W	0	0	0.000%	228	36.03639	-121.57917
Lopez Rock	MO-360-21	454-020	36°01'34" N	121°34'46" W	1	0	0.000%	229	36.02611	-121.57944
Lopez Point South	MO-360-22	454-054	36°01'13" N	121°33'34" W	1	2	0.001%	230	36.02028	-121.55944
Rockland Landing North	MO-360-23	454-037	36°00'57" N	121°32'30" W	4	172	0.044%	231	36.01583	-121.54167
Rockland Landing	MO-360-24	454-055	36°00'26" N	121°31'06" W	3	25	0.006%	232	36.00722	-121.51833
Kirk Creek to Mill Creek	MO-354-01	477-039	35°59'51" N	121°29'33" W	1	2	0.001%	233	35.99750	-121.49250
36 North	MO-354-02	477-013	35°58'36" N	121°29'15" W	0	0	0.000%	234	35.97667	-121.48750
Larus Rock	MO-354-03	477-014	35°57'44" N	121°29'01" W	2	4	0.001%	235	35.96222	-121.48361
Unnamed Point	MO-354-04	477-015	35°57'00" N	121°28'51" W	1	8	0.002%	236	35.95000	-121.48083
Gorda Area	MO-354-05	477-040	35°55'55" N	121°28'59" W	3	14	0.004%	237	35.93194	-121.48306
Small Rocks & Mainland N.E. of Plaskett Rk.	MO-354-06	477-001	35°55'16" N	121°28'22" W	4	74	0.019%	238	35.92111	-121.47278
Plaskett Rock	MO-354-07	477-002	35°55'14" N	121°28'41" W	3	32	0.008%	239	35.92056	-121.47806
Cape San Martin	MO-354-08	477-003	35°53'17" N	121°27'55" W	3	663	0.171%	240	35.88806	-121.46528
Unnamed Rock	MO-354-09	477-004	35°53'05" N	121°27'46" W	1	4	0.001%	241	35.88472	-121.46278
Mainland Point across from Bird Rock	MO-354-10	477-016	35°52'37" N	121°26'59" W	2	31	0.008%	242	35.87694	-121.44972
Point North of Redwood Gulch	MO-354-11	477-017	35°50'20" N	121°24'04" W	2	4	0.001%	243	35.83889	-121.40111
Redwood Gulch Rock	MO-354-12	477-005	35°49'32" N	121°23'29" W	2	2	0.001%	244	35.82556	-121.39139
Seastack South of Redwood Gulch	MO-354-13	477-018	35°49'30" N	121°23'22" W	3	149	0.038%	245	35.82500	-121.38944
Unmapped Island	MO-354-14	477-019	35°48'20" N	121°22'26" W	3	30	0.008%	246	35.80556	-121.37389
Salmon Creek	MO-354-15	477-020	35°48'31" N	121°21'47" W	0	0	0.000%	247	35.80861	-121.36306
Arched Peninsula South of Salmon Creek	MO-354-16	477-021	35°48'05" N	121°21'14" W	2	52	0.013%	248	35.80139	-121.35389
Ragged Point Lodge Colony	SL-354-01	477-022	35°46'53" N	121°19'56" W	2	144	0.037%	249	35.78139	-121.33222
Ragged Point South	SL-354-02	477-041	35°45'24" N	121°19'28" W	1	2	0.001%	250	35.75667	-121.32444
3 Rocks	SL-354-03	477-023	35°45'06" N	121°19'07" W	4	192	0.049%	251	35.75167	-121.31861
La Cruz Rock	SL-354-04	477-006	35°42'23" N	121°18'45" W	2	18	0.005%	252	35.70639	-121.31250
Piedras Blancas Island	SL-352-01	477-007	35°39'52" N	121°17'18" W	5	1,291	0.333%	253	35.66444	-121.28833
Point Piedras Blancas	SL-352-02	477-042	35°39'45" N	121°16'53" W	2	4	0.001%	254	35.66250	-121.28139

Appendix 1B cont. Available marine bird colony data along coast of north/central California: related colony information.

Colony Name	California Colony Code	USFWS Colony Number	Latitude	Longitude	No. of Breeding Species	Colony Size (No. of Breeding Birds)	Percent Total	Downcoast Order (North to South)	Decimal Latitude	Decimal Longitude
Two Rocks South of Point Piedras Blancas	SL-352-03	477-024	35°39'30" N	121°16'02" W	4	27	0.007%	255	35.65833	-121.26722
Point San Simeon	SL-352-04	477-038	35°38'00" N	121°12'00" W	3	53	0.014%	256	35.63333	-121.20000
South San Simeon	SL-352-05	477-043	35°37'05" N	121°09'11" W	1	22	0.006%	257	35.61806	-121.15306
Island South of Cayucos Point	SL-352-06	477-025	35°26'45" N	120°55'51" W	1	6	0.002%	258	35.44583	-120.93083
Morro Rock and Pillar Rock	SL-352-07	477-026	35°22'13" N	120°52'08" W	5	1,149	0.296%	259	35.37028	-120.86889
Fairbank Point	SL-352-08	477-044	35°21'05" N	120°50'38" W	1	812	0.209%	260	35.35139	-120.84389
Morro Bay Spit	SL-252-09	477-046	35°21'33" N	120°51'24" W	0	0	0.000%	261	35.35917	-120.85667
Spooner's Cove	SL-350-01	477-027	35°16'21" N	120°53'57" W	1	56	0.014%	262	35.27250	-120.89917
Point Buchon	SL-350-02	477-009	35°15'20" N	120°53'58" W	5	368	0.095%	263	35.25556	-120.89944
Unnamed Rocks	SL-350-03	477-010	35°14'40" N	120°53'39" W	5	757	0.195%	264	35.24444	-120.89417
Pup Rock and Adjacent Mainland	SL-350-04	477-028	35°13'18" N	120°52'13" W	3	820	0.211%	265	35.22167	-120.87028
Lion Rock	SL-350-05	477-011	35°13'03" N	120°52'17" W	4	467	0.120%	266	35.21750	-120.87139
Diablo Rock & Adjacent Mainland	SL-350-06	477-029	35°12'36" N	120°51'38" W	3	415	0.107%	267	35.21000	-120.86056
Diablo Canyon Nuclear Power Plant South	SL-350-07	477-030	35°12'07" N	120°50'39" W	5	191	0.049%	268	35.20194	-120.84417
Double Rock Region	SL-350-08	477-031	35°11'39" N	120°50'29" W	4	32	0.008%	269	35.19417	-120.84139
Pecho Rock	SL-350-09	477-032	35°10'45" N	120°48'59" W	2	204	0.053%	270	35.17917	-120.81639
Smith and Whaler Islands	SL-350-10	477-033	35°09'00" N	120°45'15" W	2	19	0.005%	271	35.15000	-120.75417
Port San Luis	SL-350-11	477-045	35°10'42" N	120°44'44" W	2	20	0.005%	272	35.17833	-120.74556
Fossil Point	SL-350-12	477-034	35°10'26" N	120°43'26" W	4	205	0.053%	273	35.17389	-120.72389
Shell Beach Rocks	SL-350-13	477-035	35°09'06" N	120°40'11" W	6	447	0.115%	274	35.15167	-120.66972
North Pismo Beach Rocks	SL-350-14	477-036	35°08'57" N	120°39'23" W	5	133	0.034%	275	35.14917	-120.65639
Oso Flako Lake North	SL-350-15	477-047	35°02'57" N	120°37'16" W	1	6	0.002%	276	35.04917	-120.62111
Oso Flako Lake South	SL-350-16	477-037	35°01'14" N	120°37'26" W	0	0	0.000%	277	35.02056	-120.62389
Guadalupe Dunes North	SL-344-01	501-023	34°59'08" N	120°38'19" W	0	0	0.000%	278	34.98556	-120.63861
Guadalupe Dunes South	SB-344-01	501-001	34°57'12" N	120°38'44" W	1	40	0.010%	279	34.95333	-120.64556
Mussel Point	SB-344-02	501-017	34°55'48" N	120°39'46" W	3	21	0.005%	280	34.93000	-120.66278
Point Sal	SB-344-03	501-018	34°54'12" N	120°40'12" W	3	52	0.013%	281	34.90333	-120.67000

Notes

1. This table is a continuation of Appendix 1A and contains additional information for the colonies of breeding marine birds. It contains information on colonies in the study area, from Pt. Arena to Pt. Sal, and also in San Francisco Bay. Colonies are listed north to south. See Appendix 1A for colony information by species. Additional data to the north and south are available from the U.S. Fish and Wildlife Service (Gerry McChesney) and NOAA NCCOS (Tracy Gill).
2. Colony size is the total number of breeding birds at a colony. The 281 colonies in this table total 388,070 breeding birds and 12 marine bird species. Maximum colony size=184,442; average size=1,386; median=40.
3. The primary source for the colony data is Carter et al. 1992. Species/colony counts from other sources are in the asociated primary colony table.
4. Although most marine bird species that breed in San Francisco Bay do not signifcantly use the ocean study area, the Bay colonies were included because some Bay breeders do use the coastal ocean, and the data were available.
5. The number of breeding bird species and individuals at a colony can vary significantly from year to year; this table merely reflects a summary of survey snapshots. It was the best available information at the time, and provides an idea of where breeding marine birds occur in, and adjacent to, the study area. Therefore, the numbers for colony totals, number of species, and percent totals are only estimates.
6. The column called Downcast Order shows the north to south order for the colonies, generally based on latitude.
7. This table was compiled by Janet Casey, R.G. Ford and Associates, with help from Tracy Gill (NOAA) and Gerry McChesney (USFWS) on data collection and revisions and Jamie Higgins (NOAA) on revisions.
8. The reference for this table is: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. A Biogeographic Assessment off North/Central California: In Support of the National Marine Sanctuaries of Cordell Bank, Gulf of the Farallones, and Monterey Bay. Prepared by NOAA NCCOS' Biogeography Branch and Partners. Silver Spring, MD. Please contact tracy.gill@noaa.gov if you have questions.

Appendix 2. Body Weights of Selected North American Bird Species

Common Name	Scientific Name	Body Mass (kg)
Common Loon	*Gavia immer*	4.134
Pacific Loon	*Gavia pacifica*	1.659
Red-throated Loon	*Gavia stellata*	1.551
Western Grebe	*Aechmophorus occidentalis*	1.477
Clark's Grebe	*Aechmophorus clarkii*	1.477
Horned Grebe	*Podiceps auritus*	0.453
Red-necked Grebe	*Podiceps grisegena*	1.023
Eared Grebe	*Podiceps nigricollis*	0.297
Black Scoter	*Melanitta nigra*	0.95
Surf Scoter	*Melanitta perspicillata*	0.95
White-winged Scoter	*Melanitta fusca*	1.35
Laysan Albatross	*Phoebastria immutabilis*	3.041
Black-footed Albatross	*Phoebastria nigripes*	3.015
Northern Fulmar	*Fulmarus glacialis*	0.544
Murphy's Petrel	*Pterodroma ultima*	0.428
Cook's Petrel	*Pterodroma cookii*	0.19
Parkinson's Petrel	*Procellaria parkinsoni*	1.062
Pink-footed Shearwater	*Puffinus creatopus*	0.721
Sooty Shearwater	*Puffinus griseus*	0.787
Black-vented Shearwater	*Puffinus opisthomelas*	0.276
Buller's Shearwater	*Puffinus bulleri*	0.38
Flesh-footed Shearwater	*Puffinus carneipes*	1.56
Short-tailed Shearwater	*Puffinus tenuirostris*	0.543
Manx Shearwater	*Puffinus puffinus*	0.453
Townsend's Shearwater	*Puffinus auricularis*	0.276
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	0.055
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	0.04
Ashy Storm-Petrel	*Oceanodroma homochroa*	0.037
Black Storm-Petrel	*Oceanodroma melania*	0.059
Wedge-rumped Storm-Petrel	*Oceanodroma tethys*	0.024
Markham's Storm-Petrel	*Oceanodroma markhami*	0.059
Least Storm-Petrel	*Oceanodroma microsoma*	0.021
Wilson's Storm-Petrel	*Oceanites oceanicus*	0.034
Red-billed Tropicbird	*Phaethon aethereus*	0.75
Brown Booby	*Sula leucogaster*	1.248
Brown Pelican	*Pelecanus occidentalis*	3.392
White Pelican	*Pelecanus erythrorynchos*	7.5
Brandt's Cormorant	*Phalacrocorax penicillatus*	2.113
Double-crested Cormorant	*Phalacrocorax auritus*	1.679

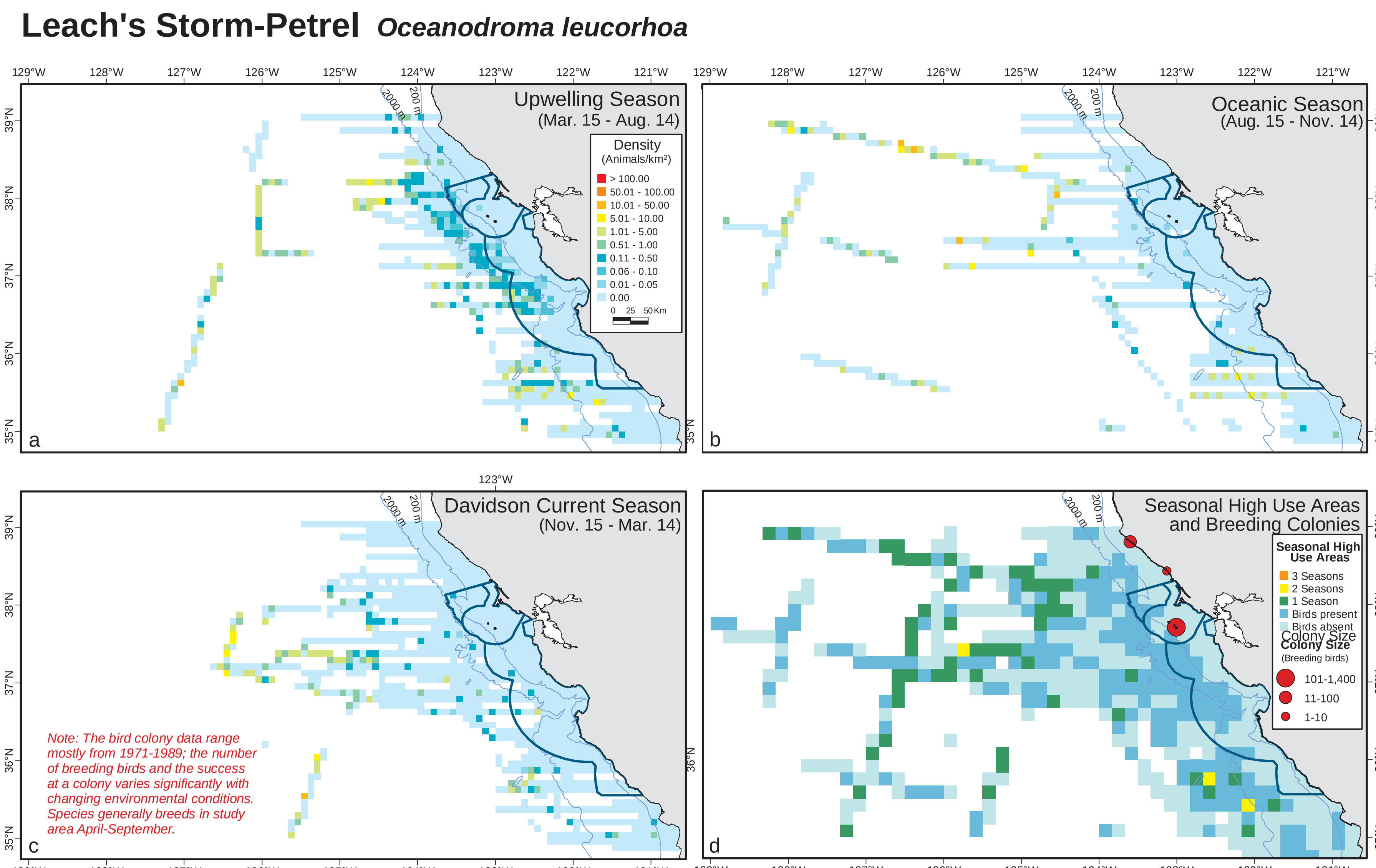
Appendix 2 cont. Body Weights of Selected North American Bird Species

Common Name	Scientific Name	Body Mass (kg)
Pelagic Cormorant	*Phalacrocorax pelagicus*	1.915
Red-necked Phalarope	*Phalaropus lobatus*	0.034
Red Phalarope	*Phalaropus fulicarius*	0.056
South Polar Skua	*Stercorarius maccormicki*	1.156
Pomarine Jaeger	*Stercorarius pomarinus*	0.694
Parasitic Jaeger	*Stercorarius parasiticus*	0.465
Long-tailed Jaeger	*Stercorarius longicaudus*	0.297
Glaucous Gull	*Larus hyperboreus*	1.413
Western Gull	*Larus occidentalis*	1.011
Glaucous-winged Gull	*Larus glaucescens*	1.01
Herring Gull	*Larus argentinus*	1
Thayer's Gull	*Larus thayeri*	0.996
Heermann's Gull	*Larus heermanni*	0.5
Bonaparte's Gull	*Larus philadelphia*	0.212
Mew Gull	*Larus canus*	0.404
Ring-billed Gull	*Larus delawarensis*	0.519
California Gull	*Larus californicus*	0.609
Sabine's Gull	*Xema sabini*	0.191
Black-legged Kittiwake	*Rissa tridactyla*	0.407
Red-legged Kittiwake	*Rissa brevirostris*	0.391
Arctic Tern	*Sterna paradisaea*	0.11
Common Tern	*Sterna hirundo*	0.12
Forster's Tern	*Sterna forsteri*	0.158
Caspian Tern	*Sterna caspia*	0.661
Elegant Tern	*Sterna elegans*	0.257
Royal Tern	*Sterna maxima*	0.47
Common Murre	*Uria aalge*	0.993
Thick-billed Murre	*Uria lomvia*	0.964
Pigeon Guillemot	*Cepphus columba*	0.487
Marbled Murrelet	*Brachyramphus marmoratus*	0.222
Ancient Murrelet	*Synthliboramphus antiquus*	0.206
Xantus's Murrelet	*Synthliboramphus hypoleucus*	0.159
Craveri's Murrelet	*Synthliboramphus craveri*	0.159
Parakeet Auklet	*Aethia psittacula*	0.318
Cassin's Auklet	*Ptychoramphus aleuticus*	0.188
Rhinoceros Auklet	*Cerorhinca monocerata*	0.52
Tufted Puffin	*Fratercula cirrhata*	0.779
Horned Puffin	*Fratercula corniculata*	0.619

From Dunning, J.B. 1993. Body Weights of 686 Species of North American Birds. International Wildlife Rehabilitation Council, University of Georgia, Athens, GA. 59 pp.

Appendix 3A. Leach's Storm-Petrel: pelagic maps of seasonal density, high use areas, and breeding colonies.

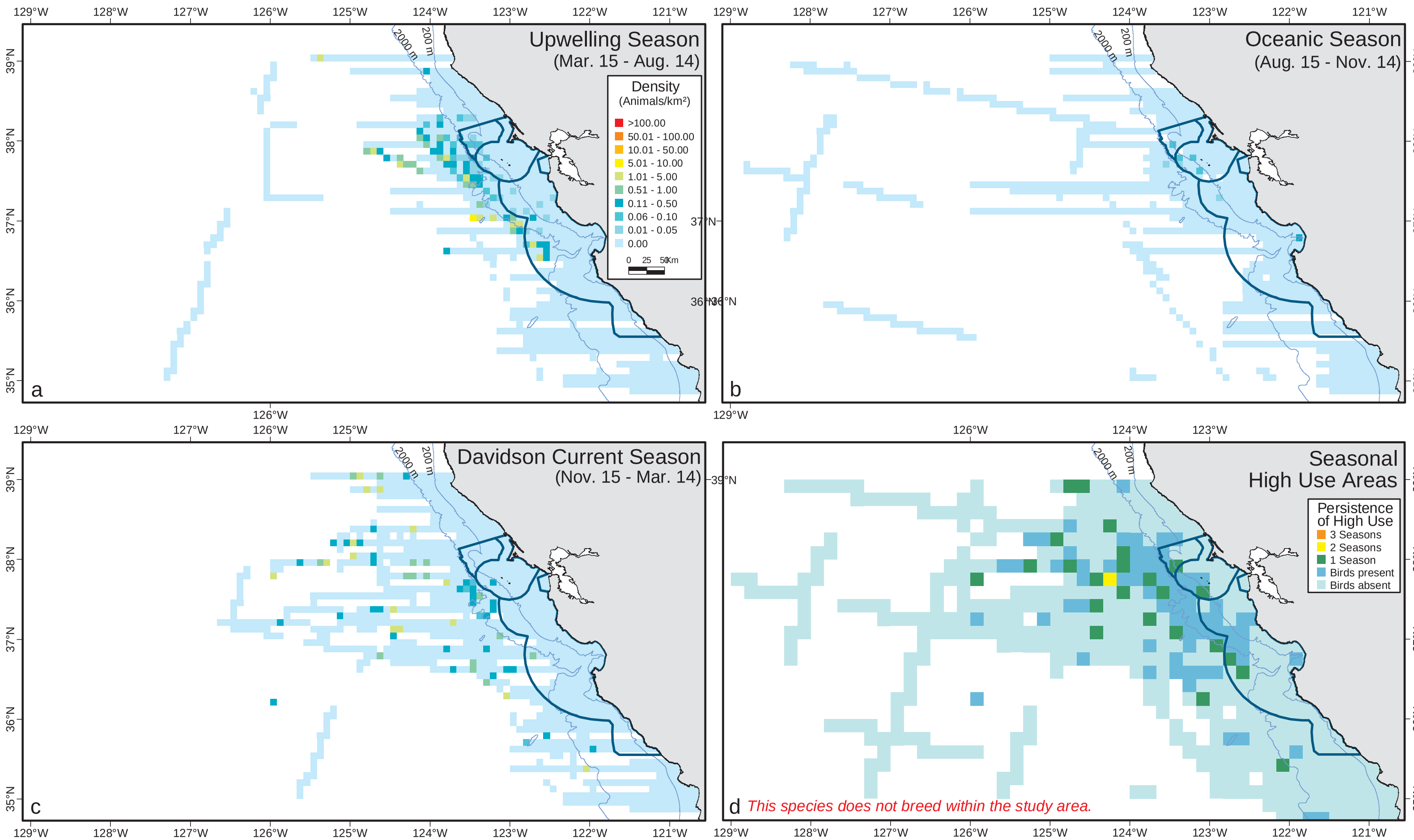
Leach's Storm-Petrel *Oceanodroma leucorhoa*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from Ainley and Lewis, 1974 and Carter et al.,1992.

Appendix 3B. Fork-tailed Storm-Petrel: pelagic maps of seasonal density and high use areas.

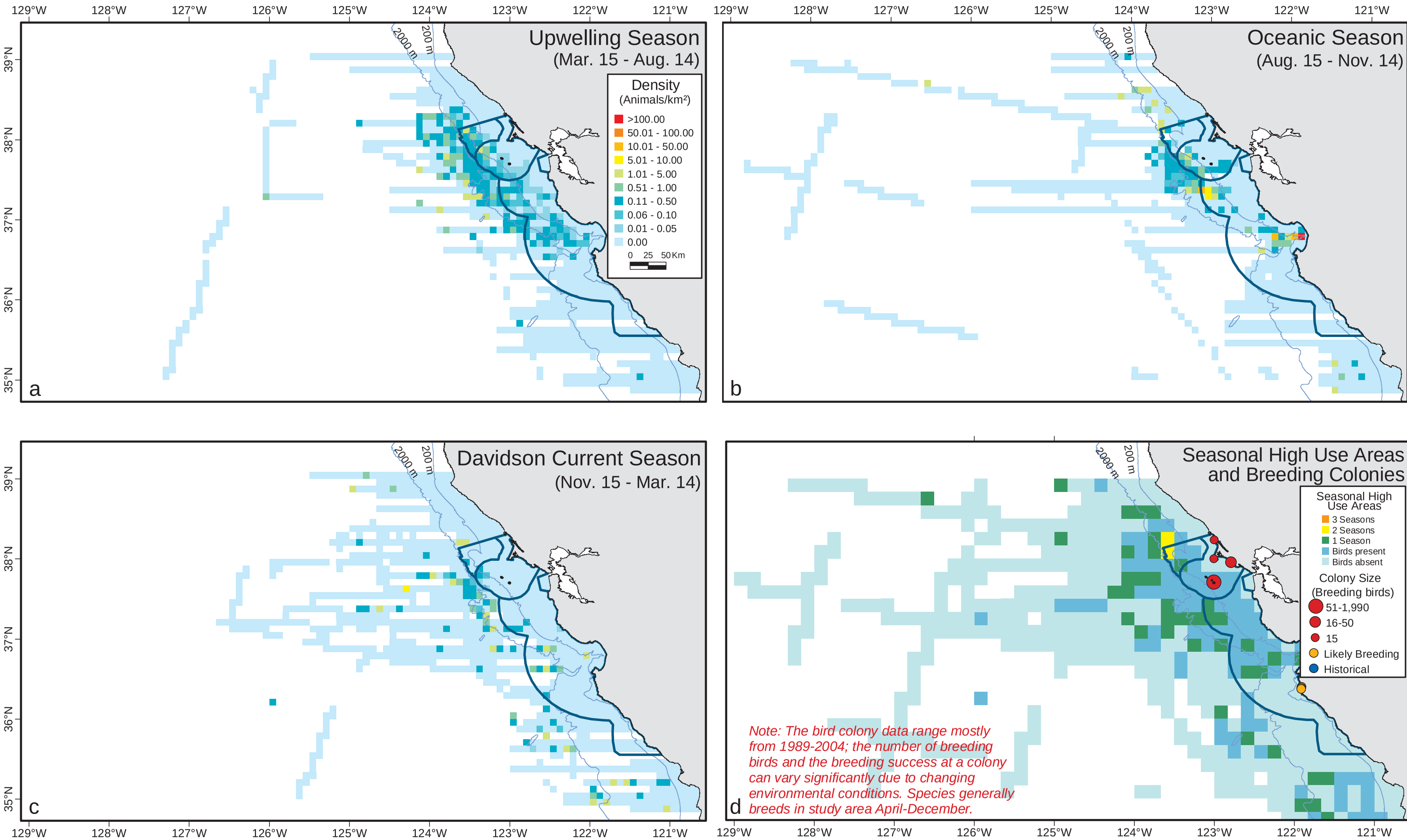
Fork-tailed Storm-Petrel *Oceanodroma furcata*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

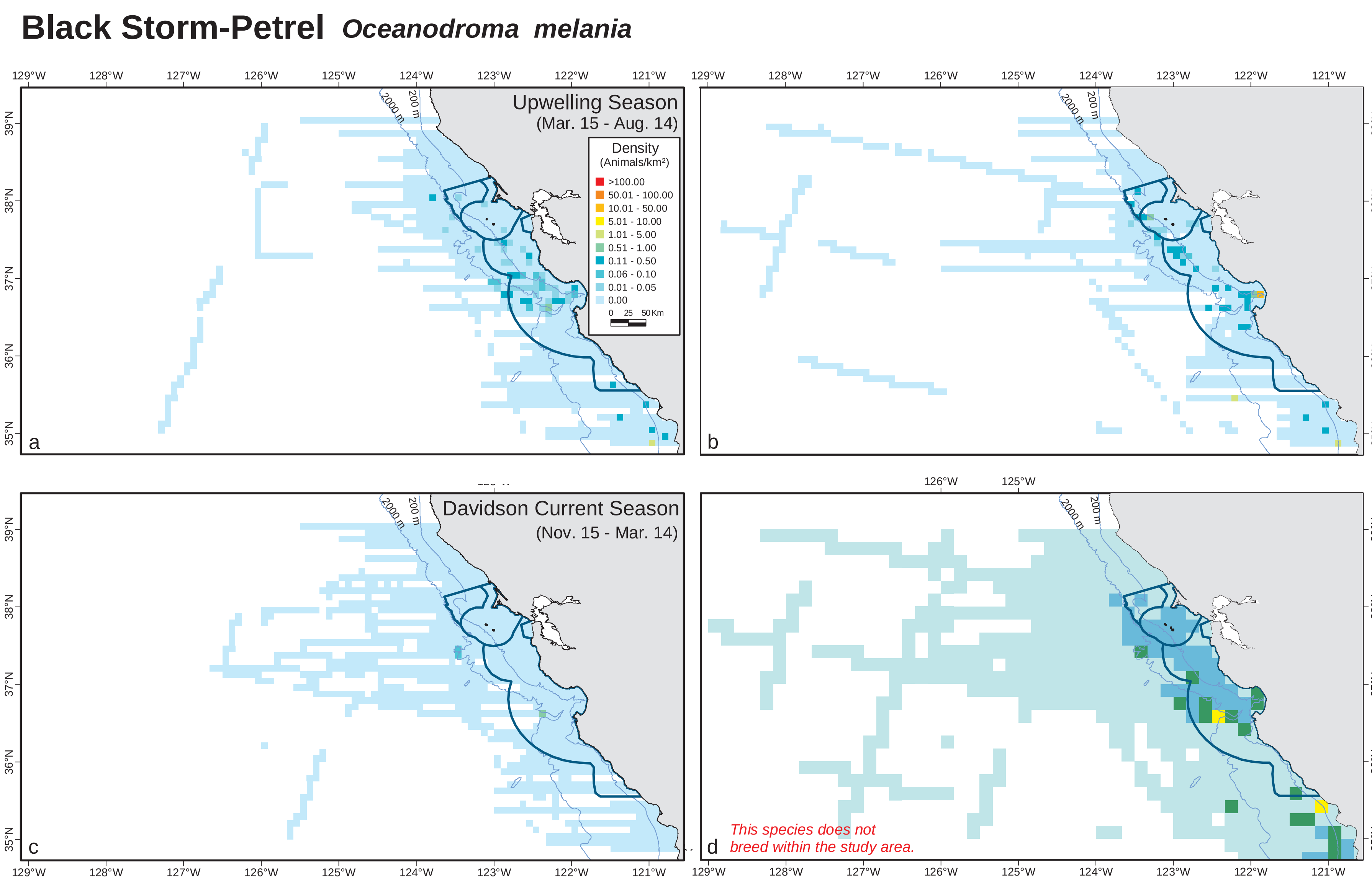
Appendix 3C. Ashy Storm-Petrel: pelagic maps of seasonal density, high use areas, and breeding colonies.

Ashy Storm-Petrel *Oceanodroma homochroa*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003. Colony data from: Whitworth et al. (2002), Sydeman et al. (1998), McChesney et al. (2000), and Carter et al. (1992).

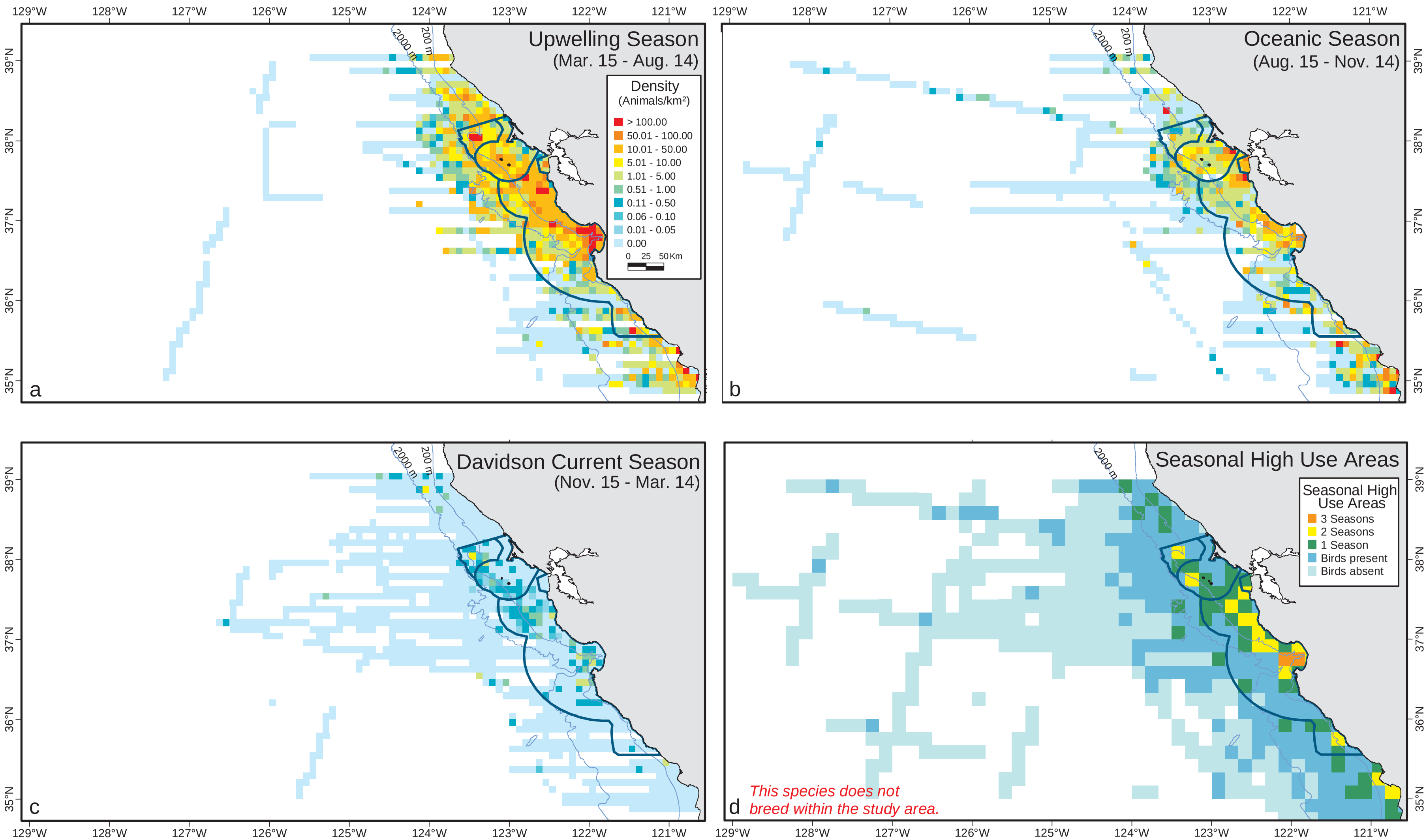
Appendix 3D. Black Storm-Petrel: pelagic maps of seasonal density and high use areas.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

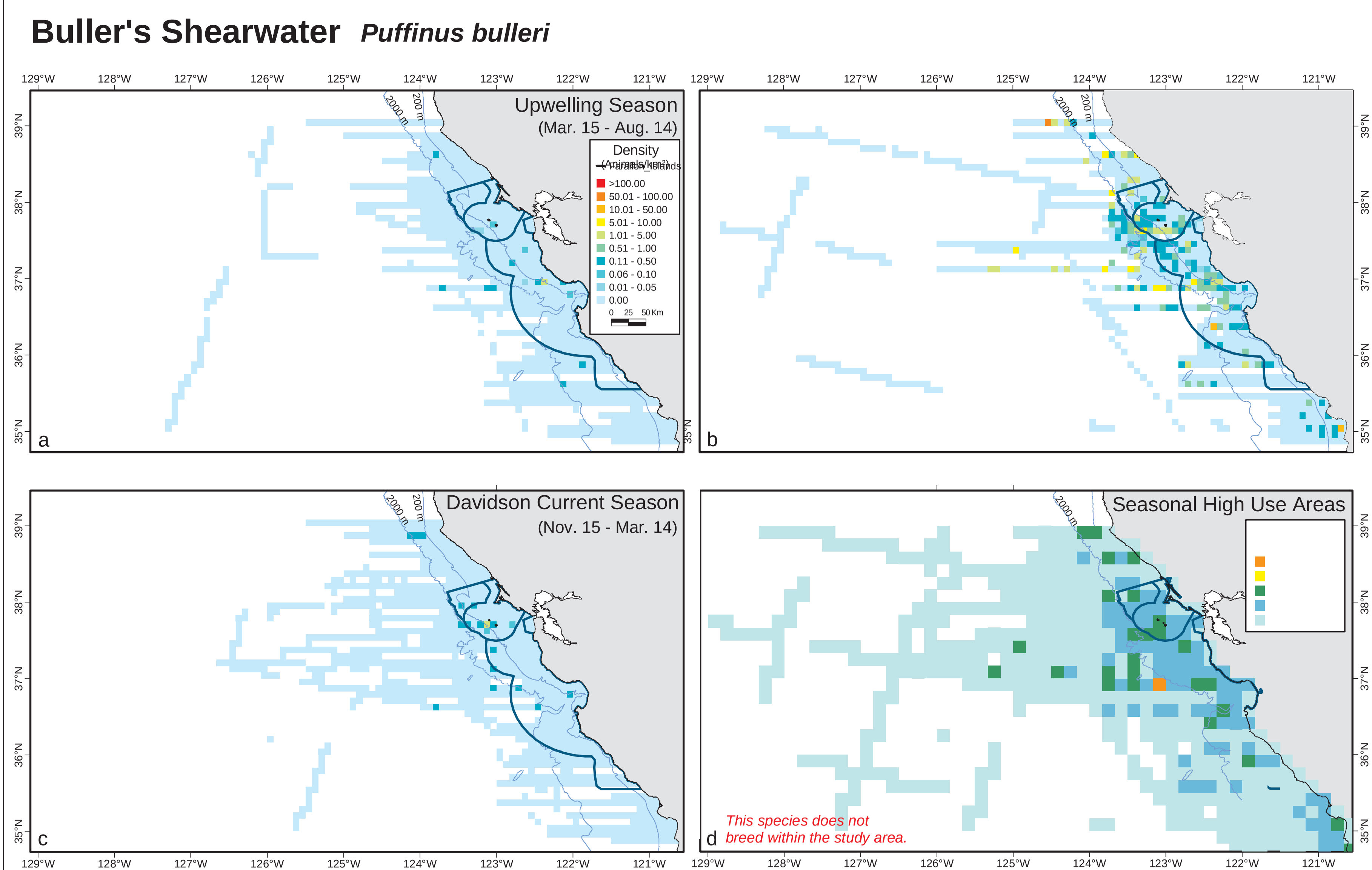
Appendix 3E. Sooty Shearwater: pelagic maps of seasonal density and high use areas.

Sooty Shearwater *Puffinus griseus*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

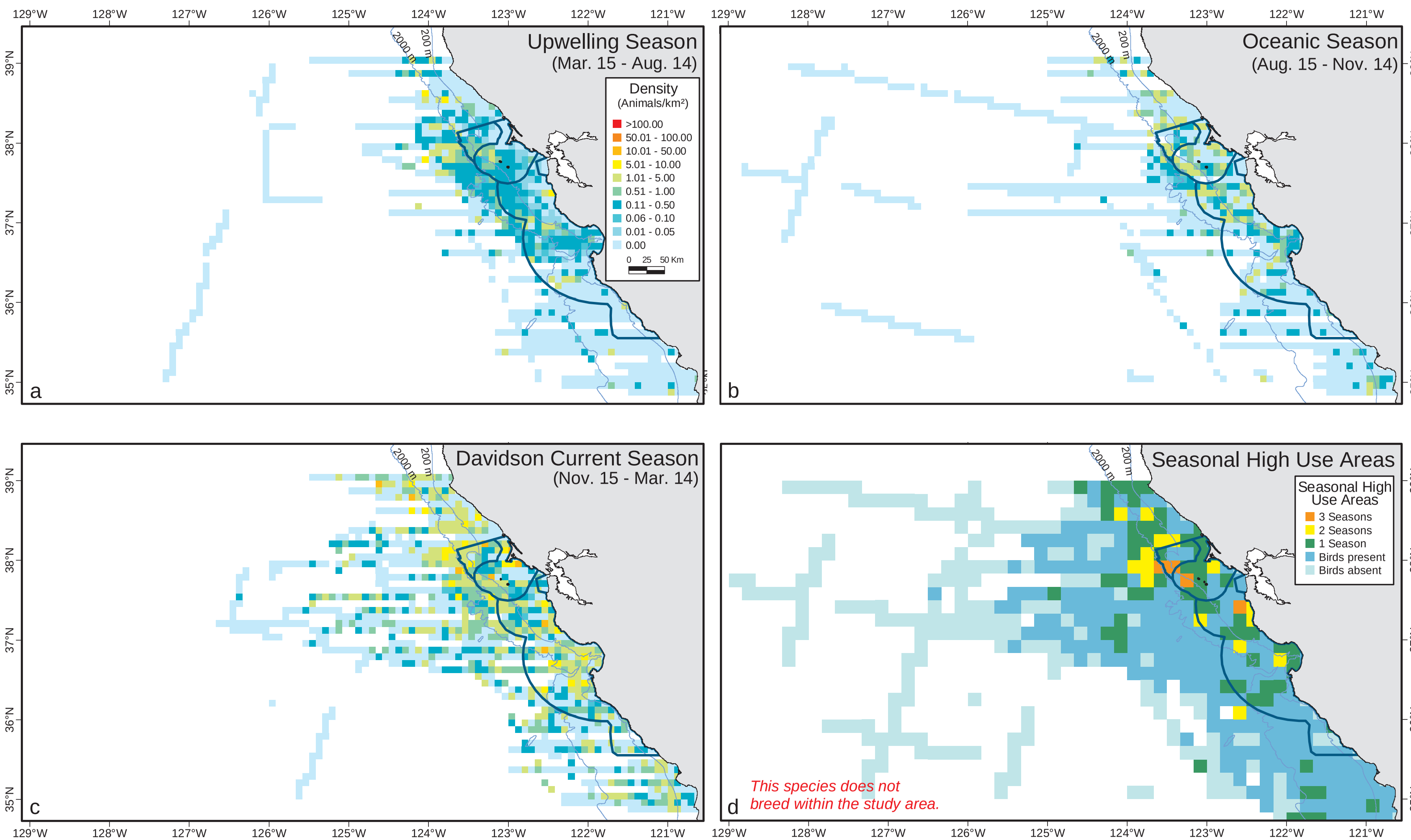
Appendix 3F. Buller's Shearwater: pelagic maps of seasonal density and high use areas.



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Appendix 3G. Northern Fulmar: pelagic maps of seasonal density and high use areas.

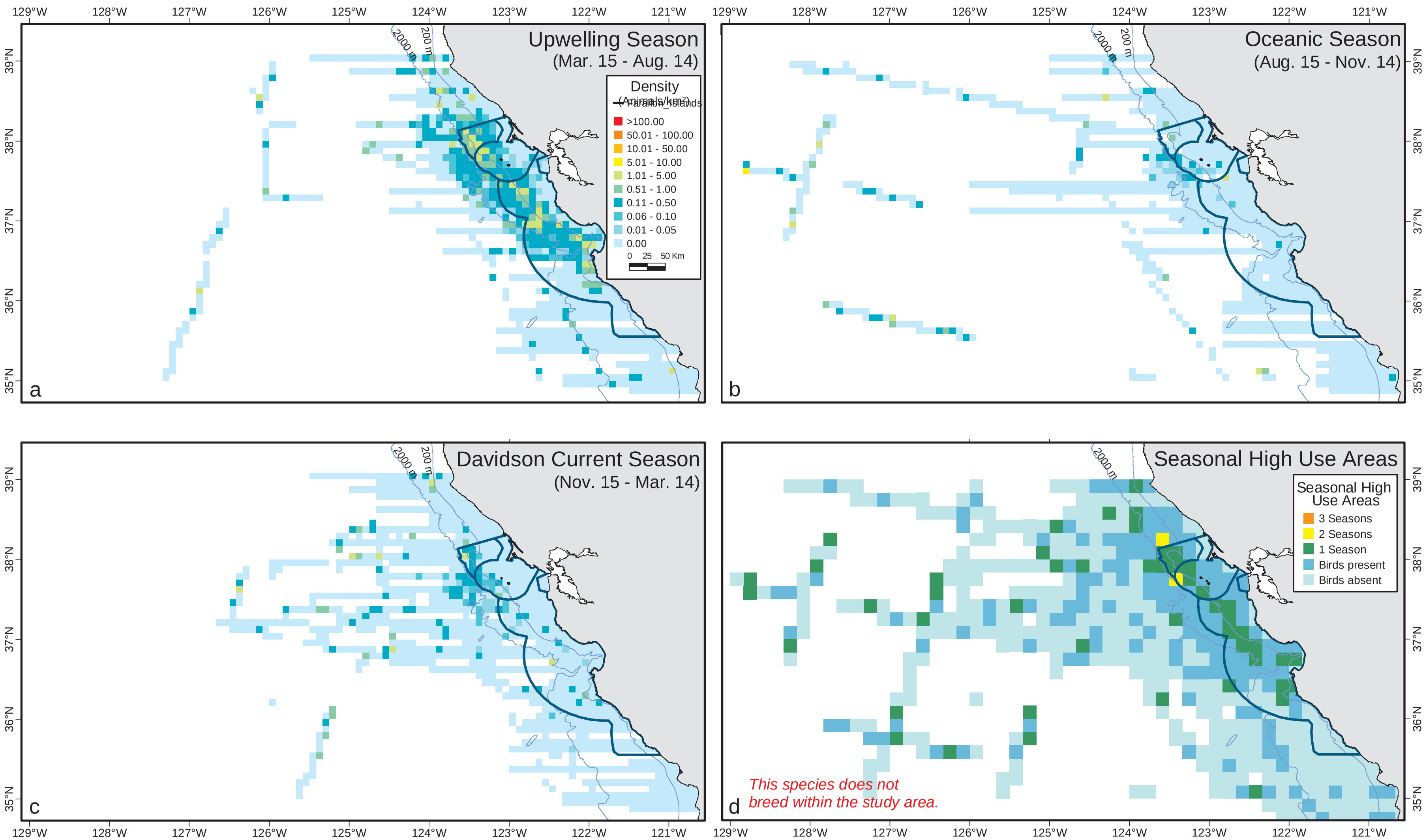
Northern Fulmar *Fulmarus glacialis*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Appendix 3H. Black-footed Albatross: pelagic maps of seasonal density and high use areas.

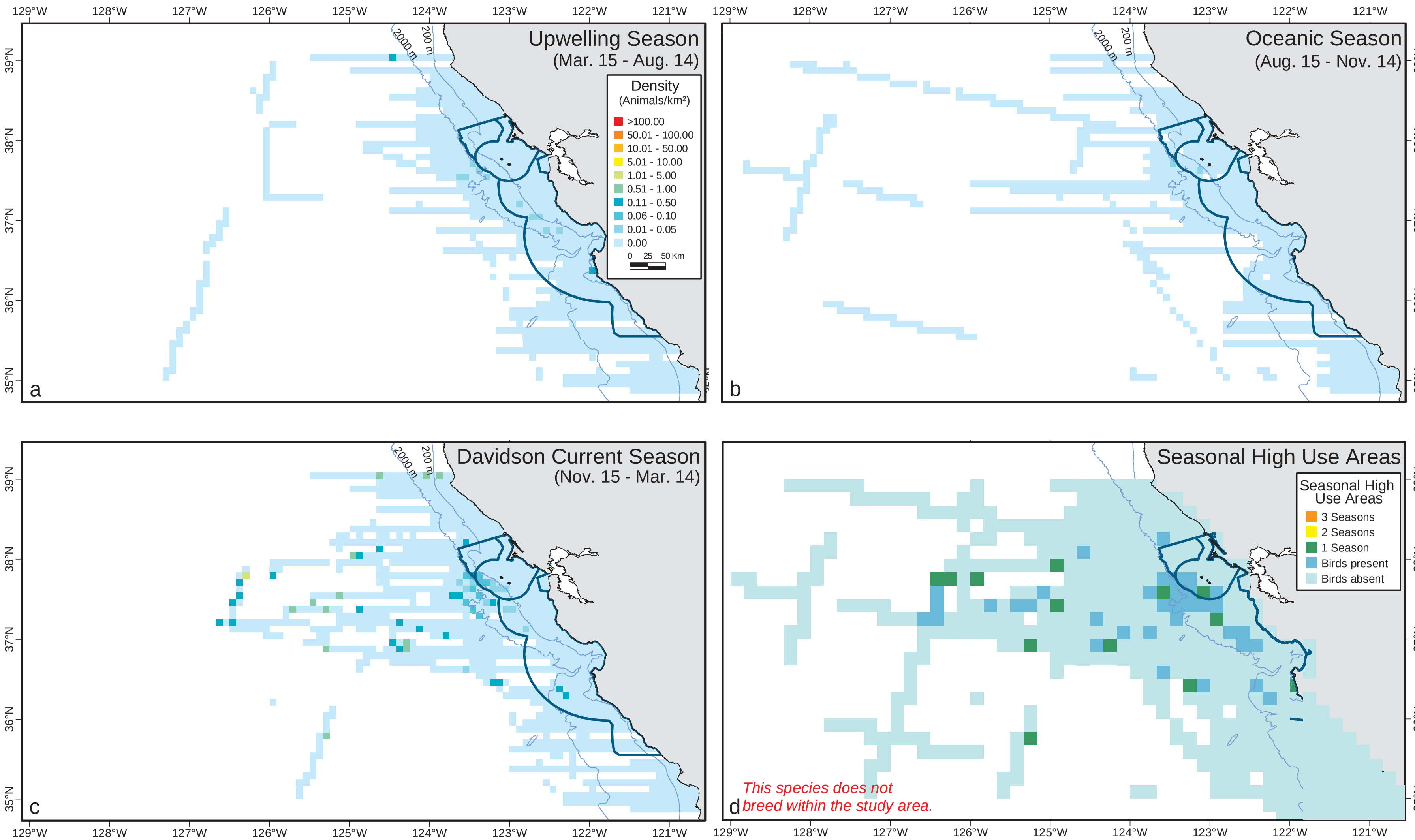
Black-footed Albatross *Phoebastria nigripes*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Appendix 3J. Laysan Albatross: pelagic maps of seasonal density and high use areas.

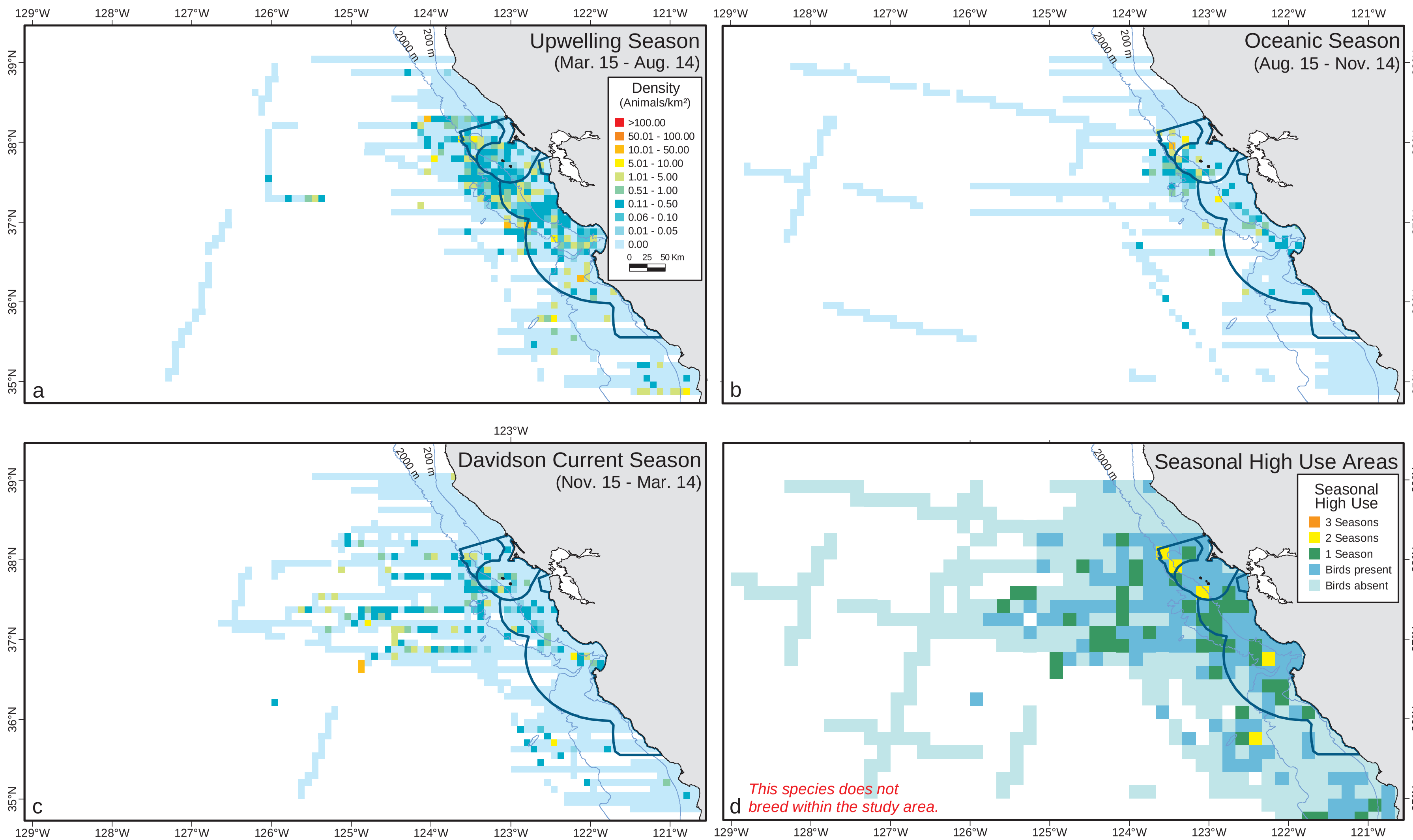
Laysan Albatross *Phoebastria immutabilis*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001),2003.

Appendix 3K. Red Phalarope: pelagic maps of seasonal density and high use areas.

Red Phalarope *Phalaropus fulicarius*



Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.