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.

Chad King

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 Boekelheide, (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.

James F. Parnell

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.

Jeff Poklen

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

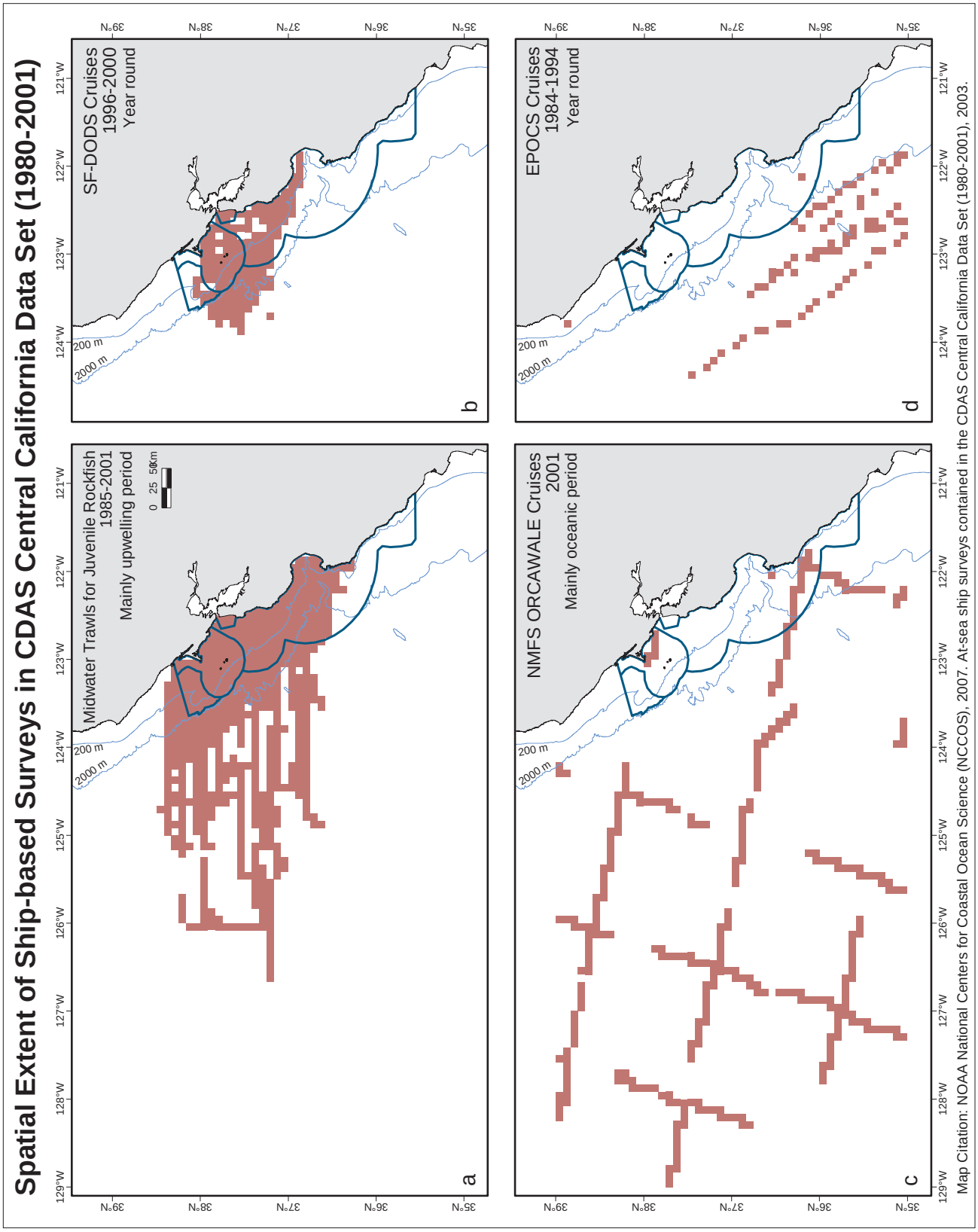

Figure 3.1. Spatial extent of ship-based surveys in the CDAS central California data set (1980-2001) used in the marine bird analysis.

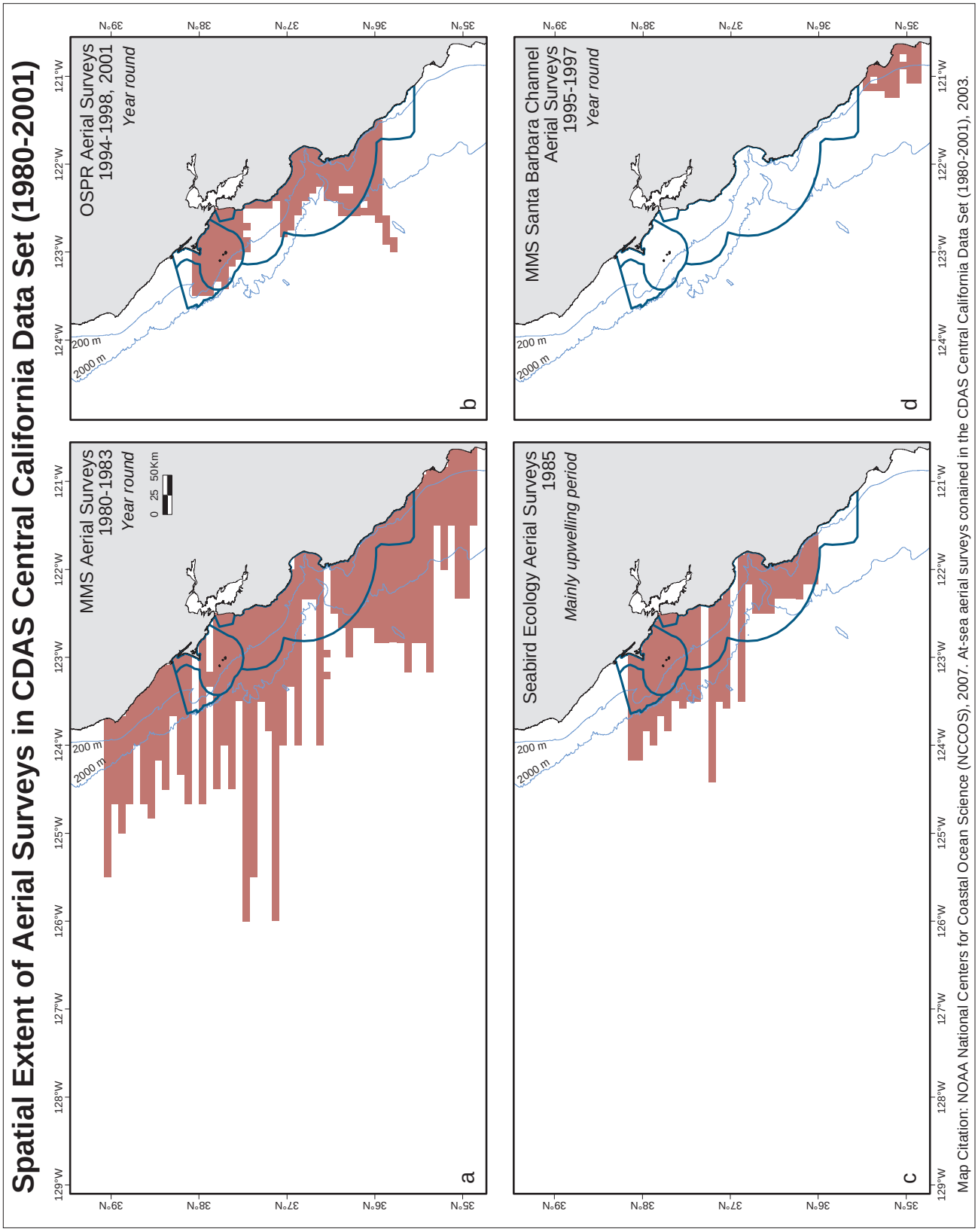

Figure 3.2. Spatial extent of aerial at-sea surveys in in the CDAS central California data set (1980-2001) used in the marine bird analysis.

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

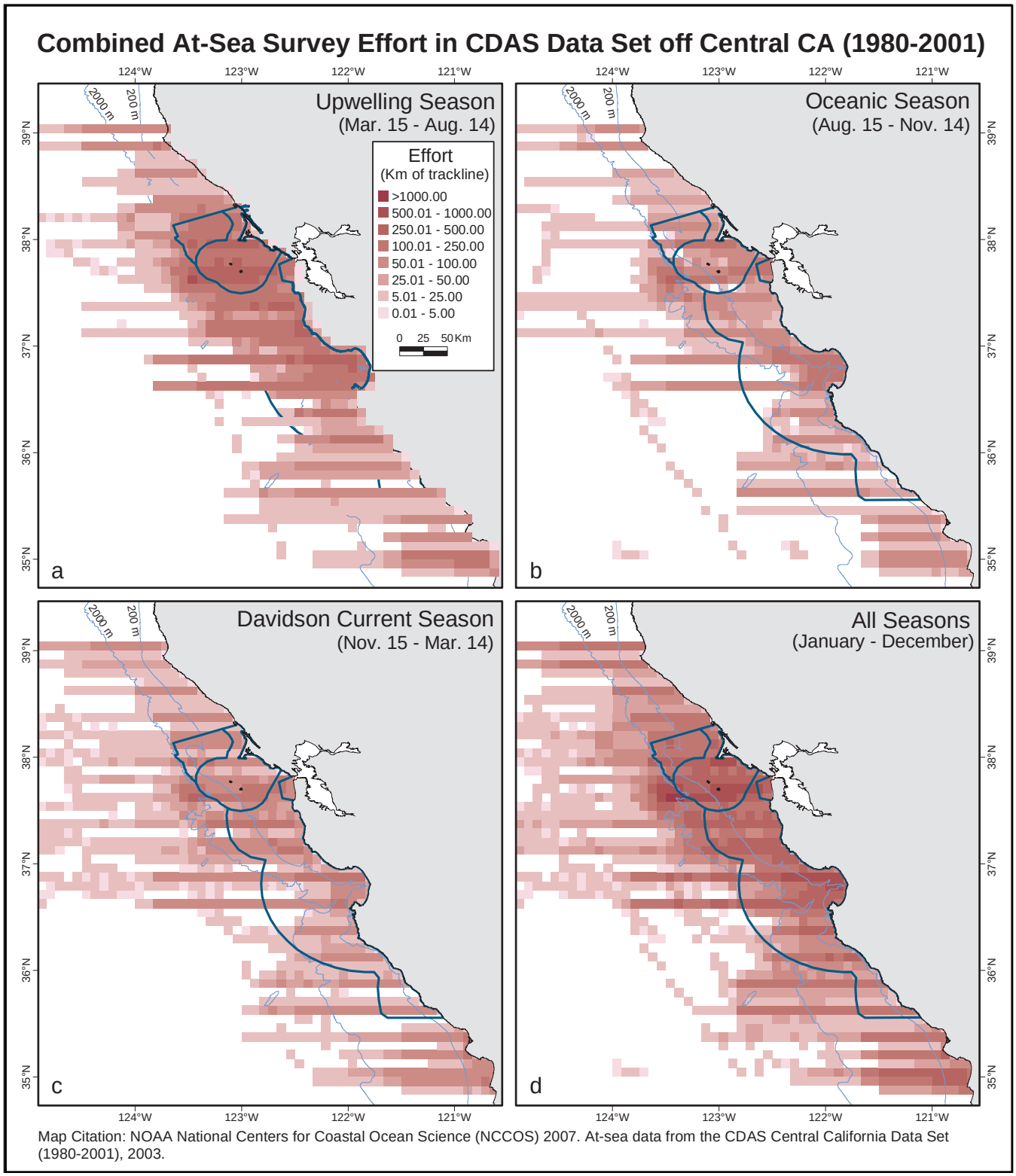

Figure 3.3. Total at-sea survey effort (shipboard and aerial) used for the marine bird analysis, CDAS data (1980-2001), 2003.

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:

$$D = n / (l \times w)$$

Becky Stam-

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).

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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.

Evaluating Variation in Species Abundance at Sea. 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	-

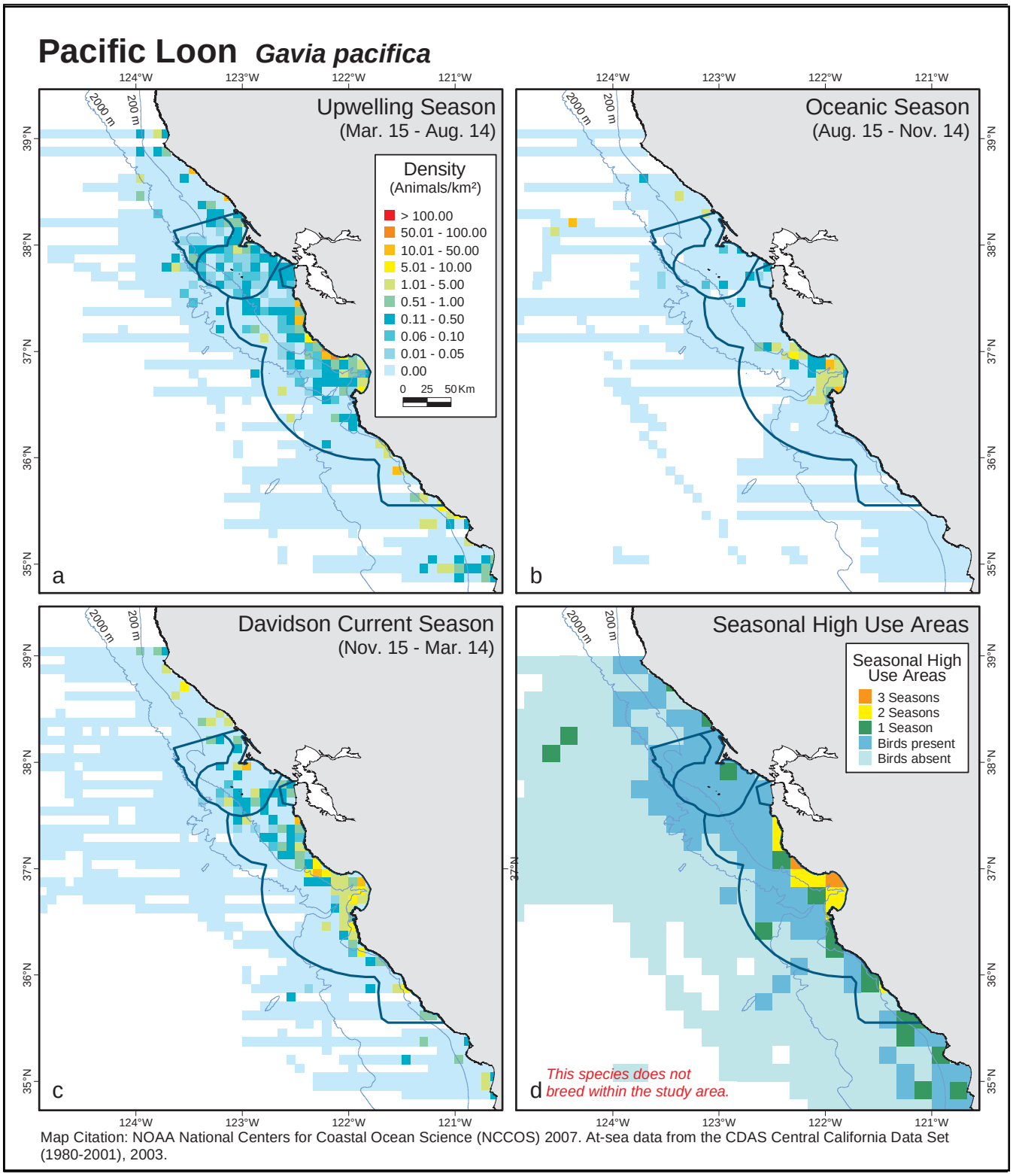
Note: Period of analysis ended in 2001.

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.

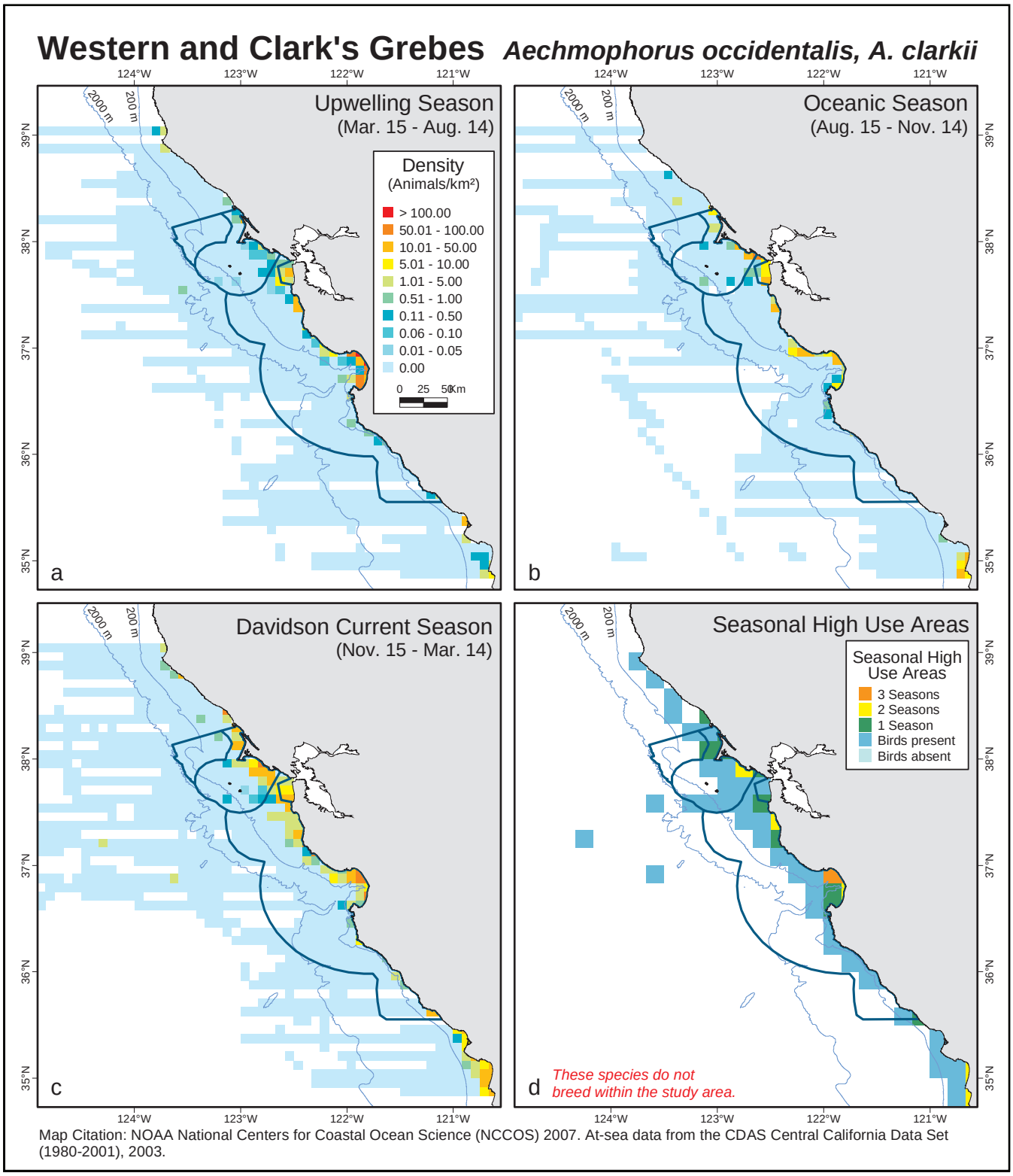


Figure 3.5. Western and Clark's Grebes: maps of seasonal density and high use areas.

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.

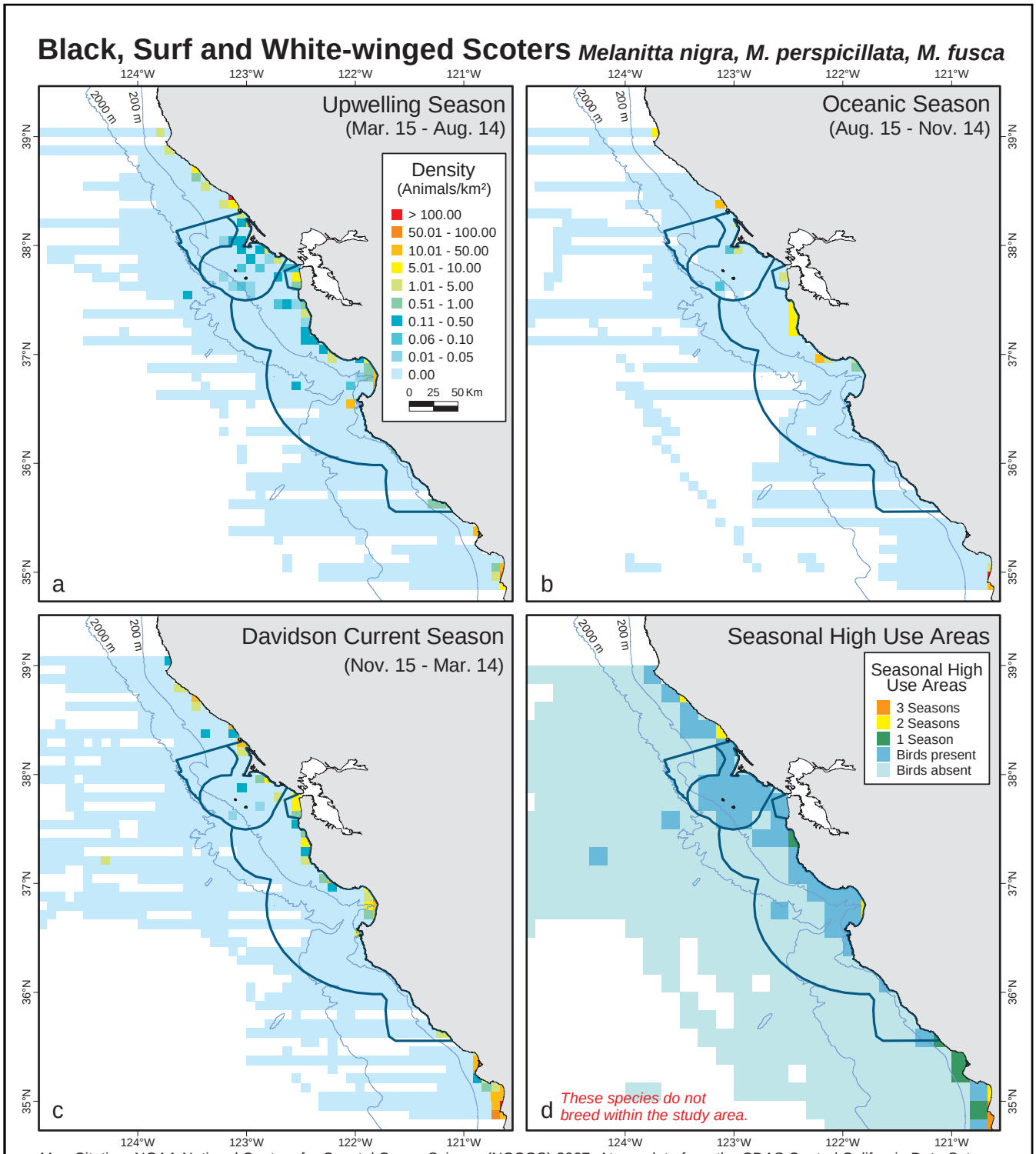
RESULTS AND DISCUSSION

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.



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 3.6. 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.

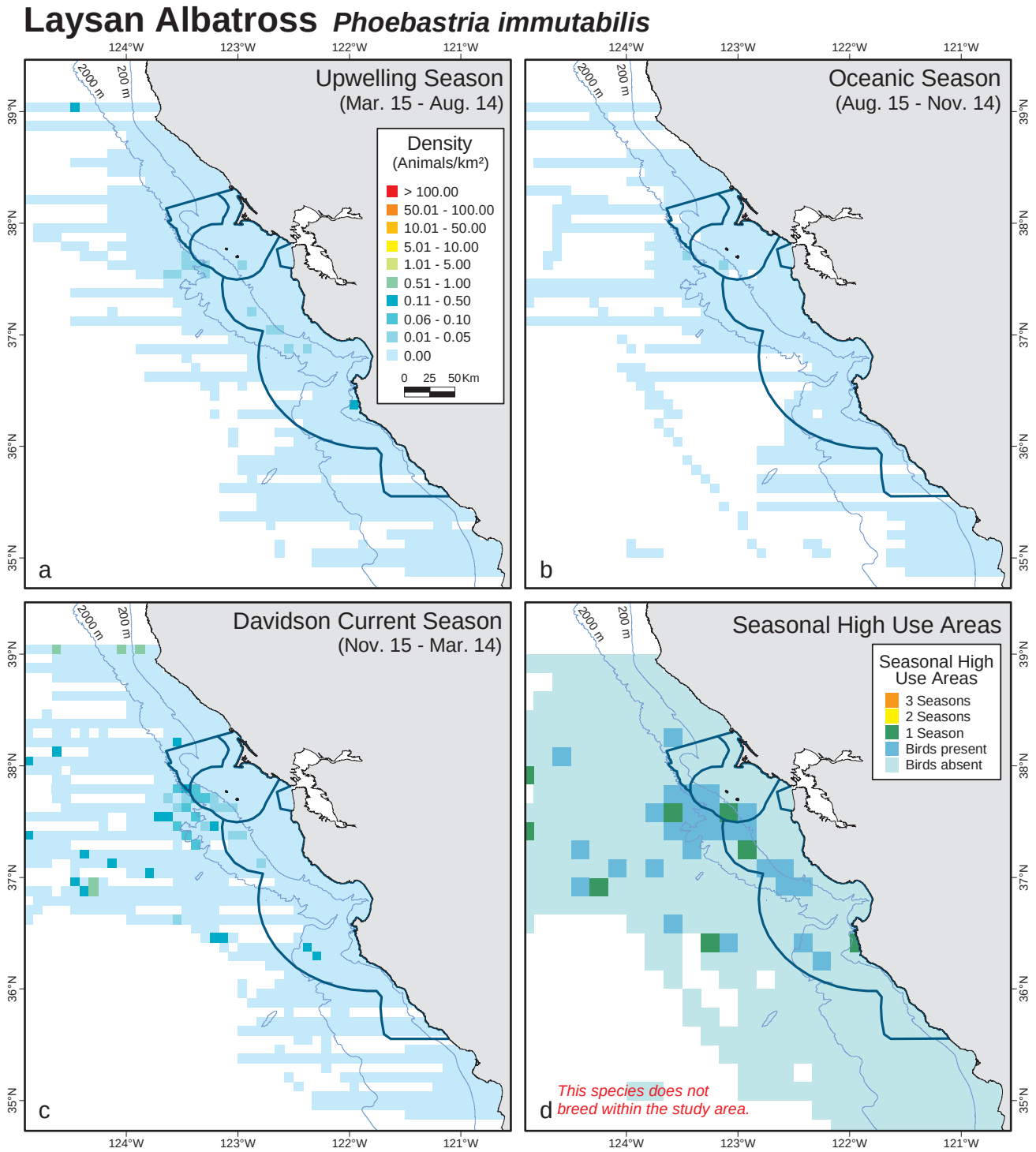
RESULTS AND DISCUSSION

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.



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.

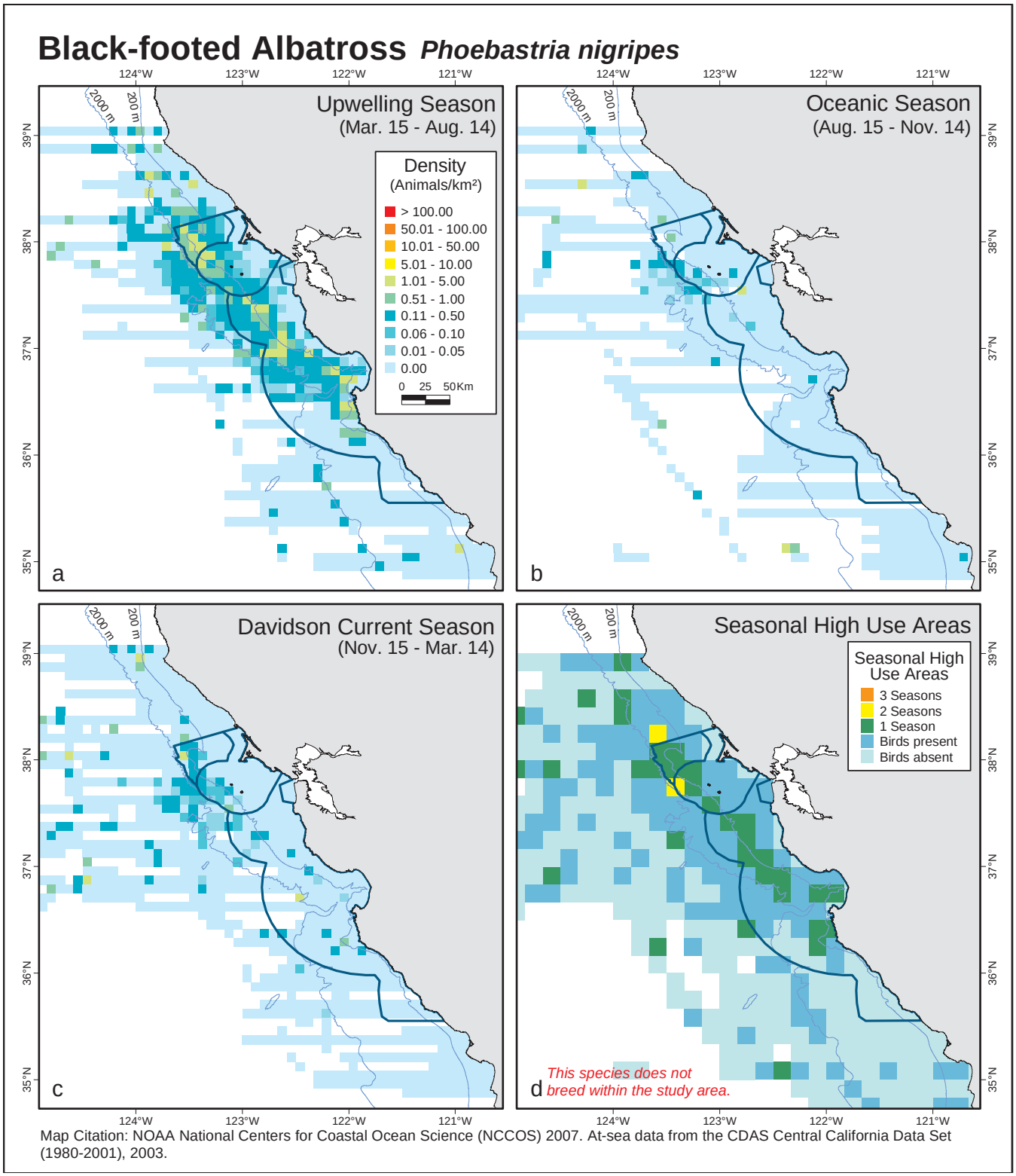


Figure 3.8. Black-footed Albatross: maps of seasonal density and high use areas.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) 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

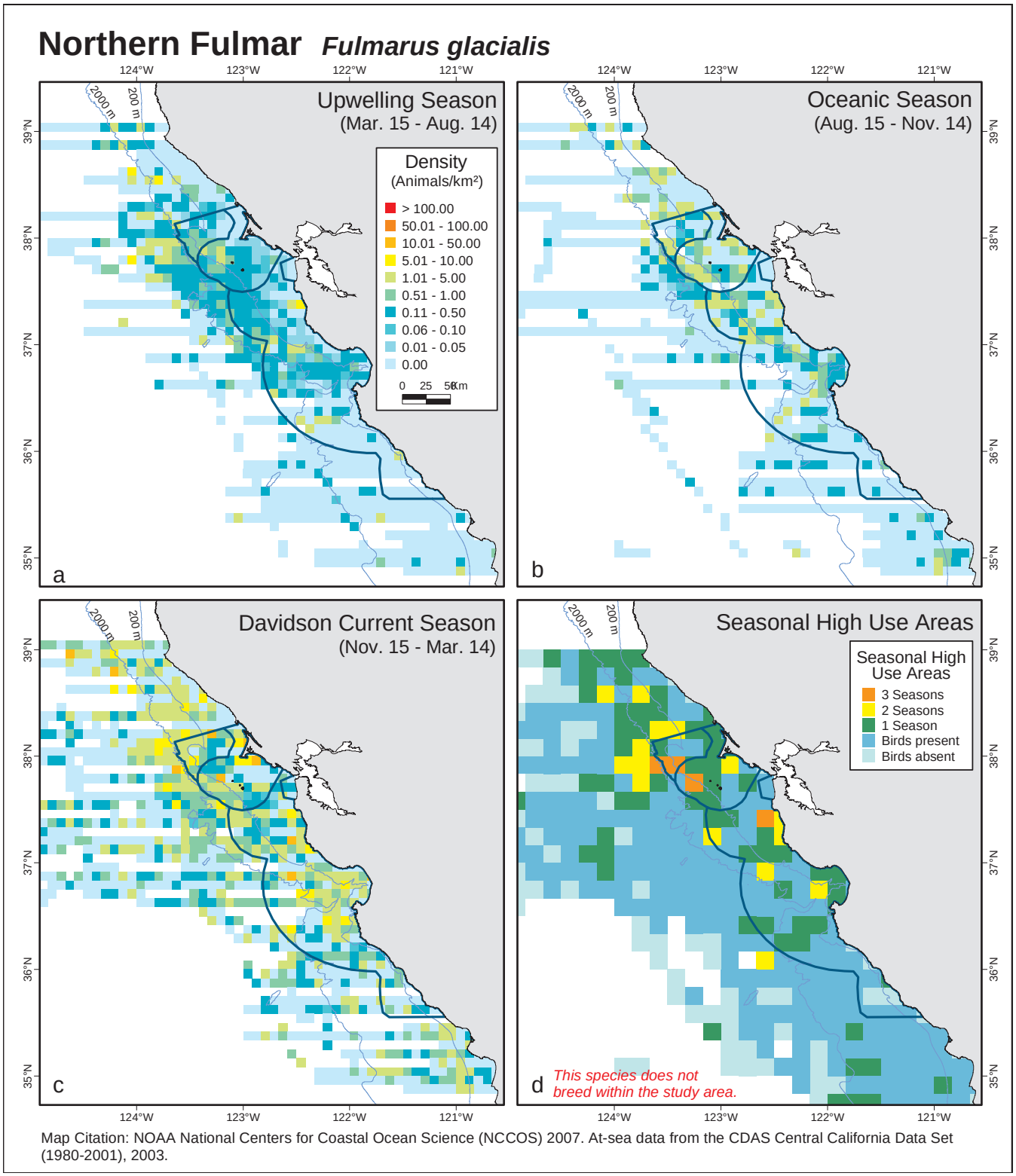


Figure 3.9. Northern Fulmar: maps of seasonal density and high use areas.

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

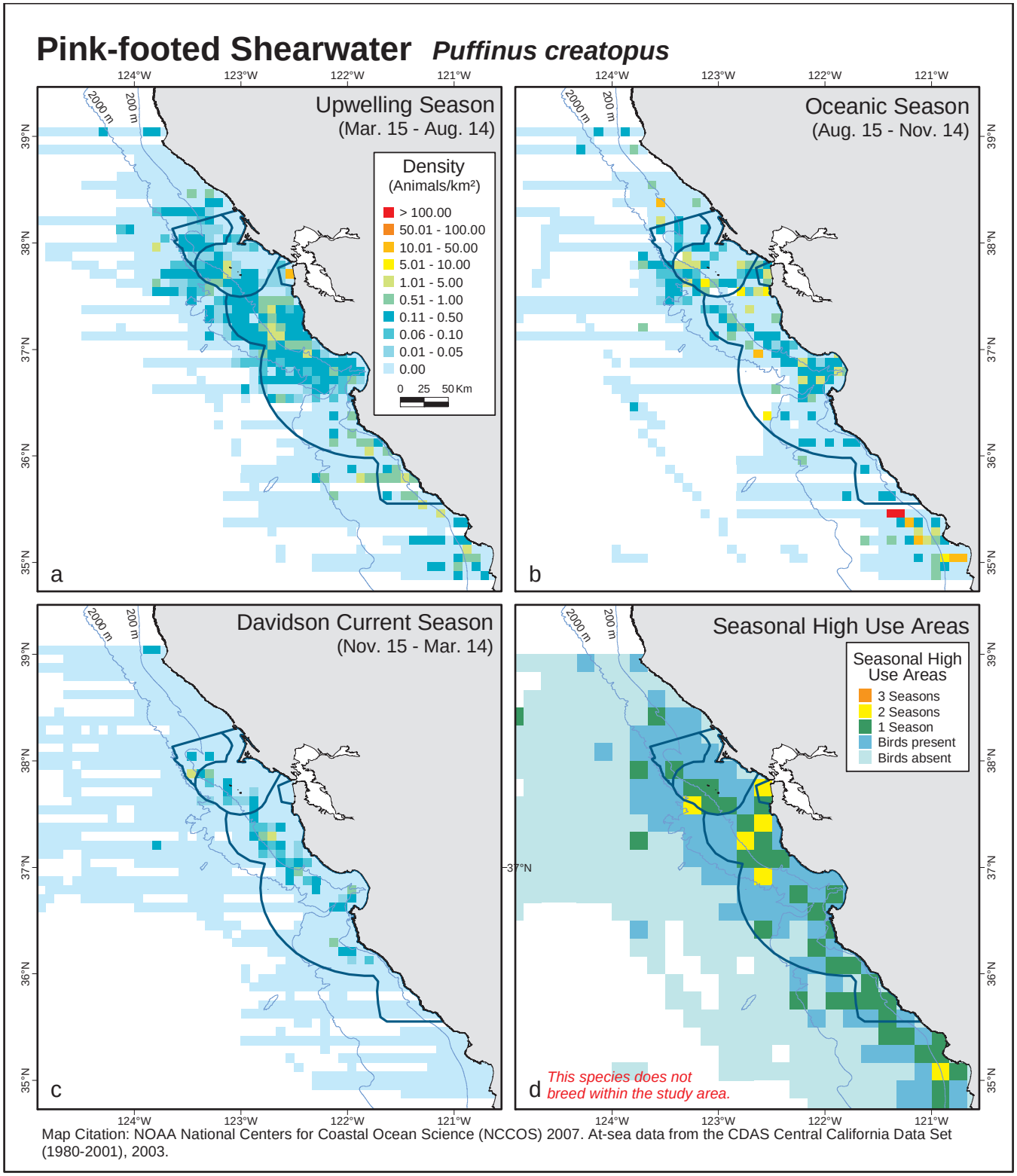


Figure 3.10. Pink-footed Shearwater: maps of seasonal density and high use areas.

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.

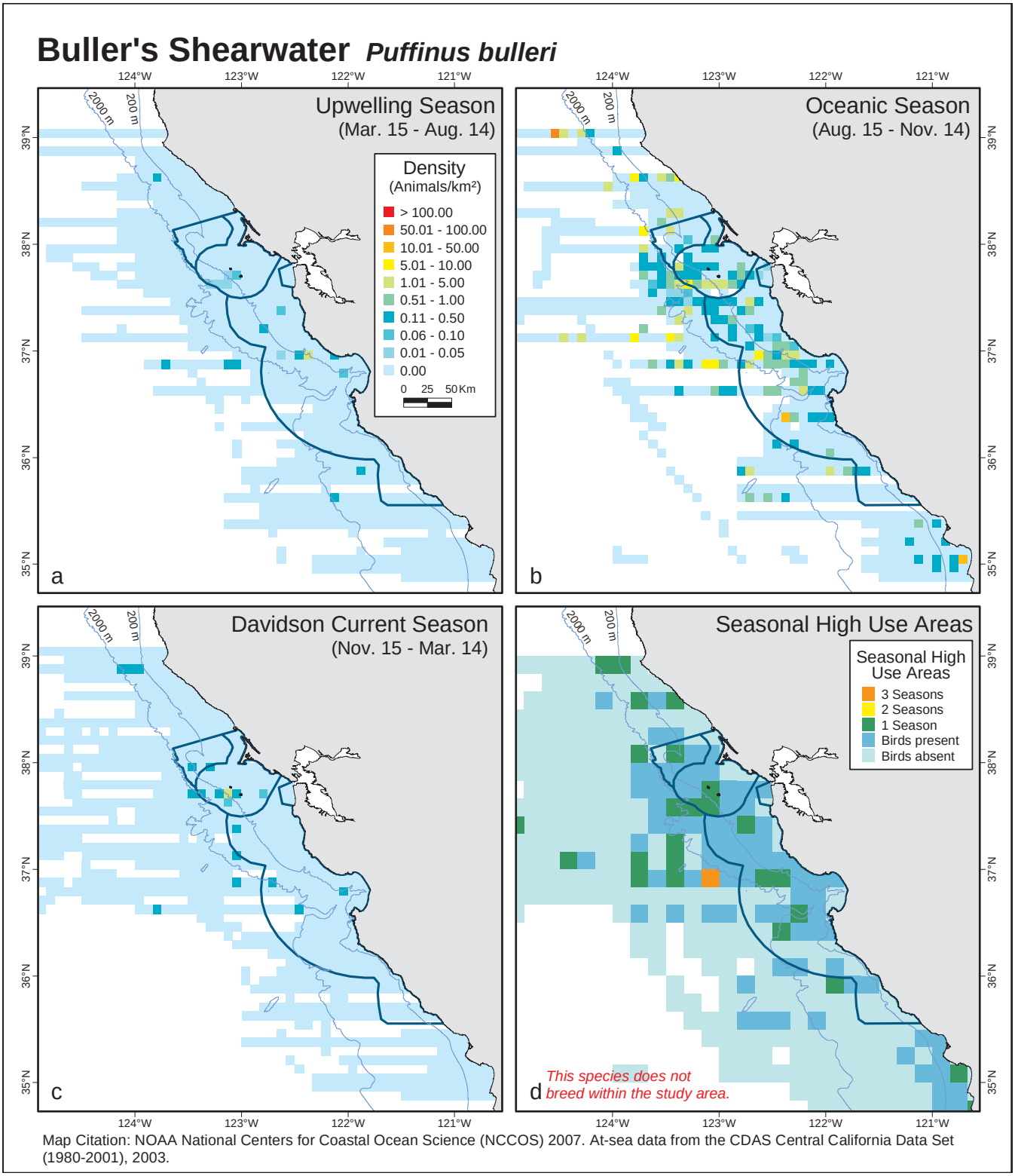


Figure 3.11. Buller's Shearwater: maps of seasonal density and high use areas.

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.

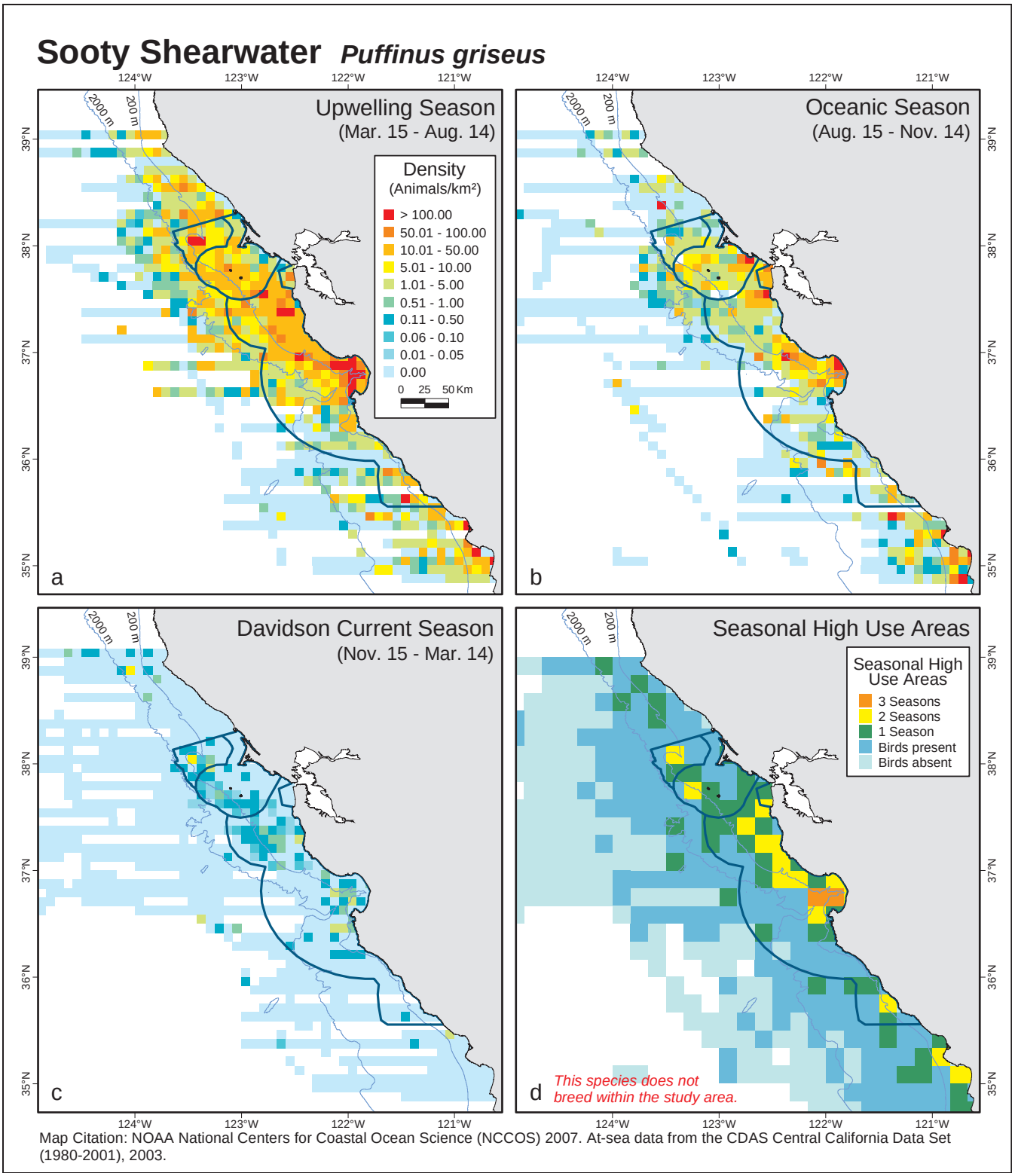


Figure 3.12. Sooty Shearwater: maps of seasonal density and high use areas.

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

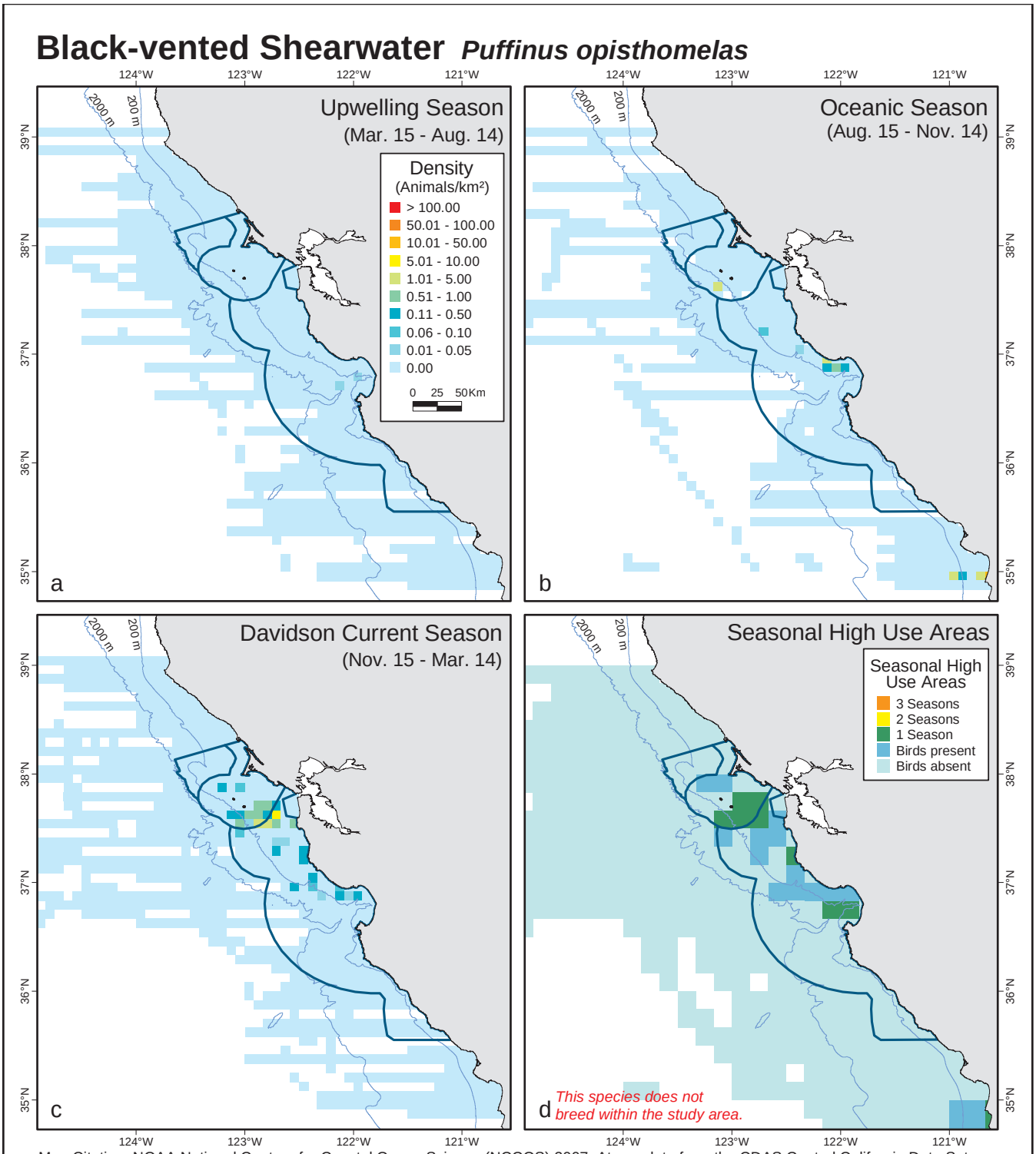


Figure 3.13. Black-vented Shearwater: maps of seasonal density and high use areas.

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.

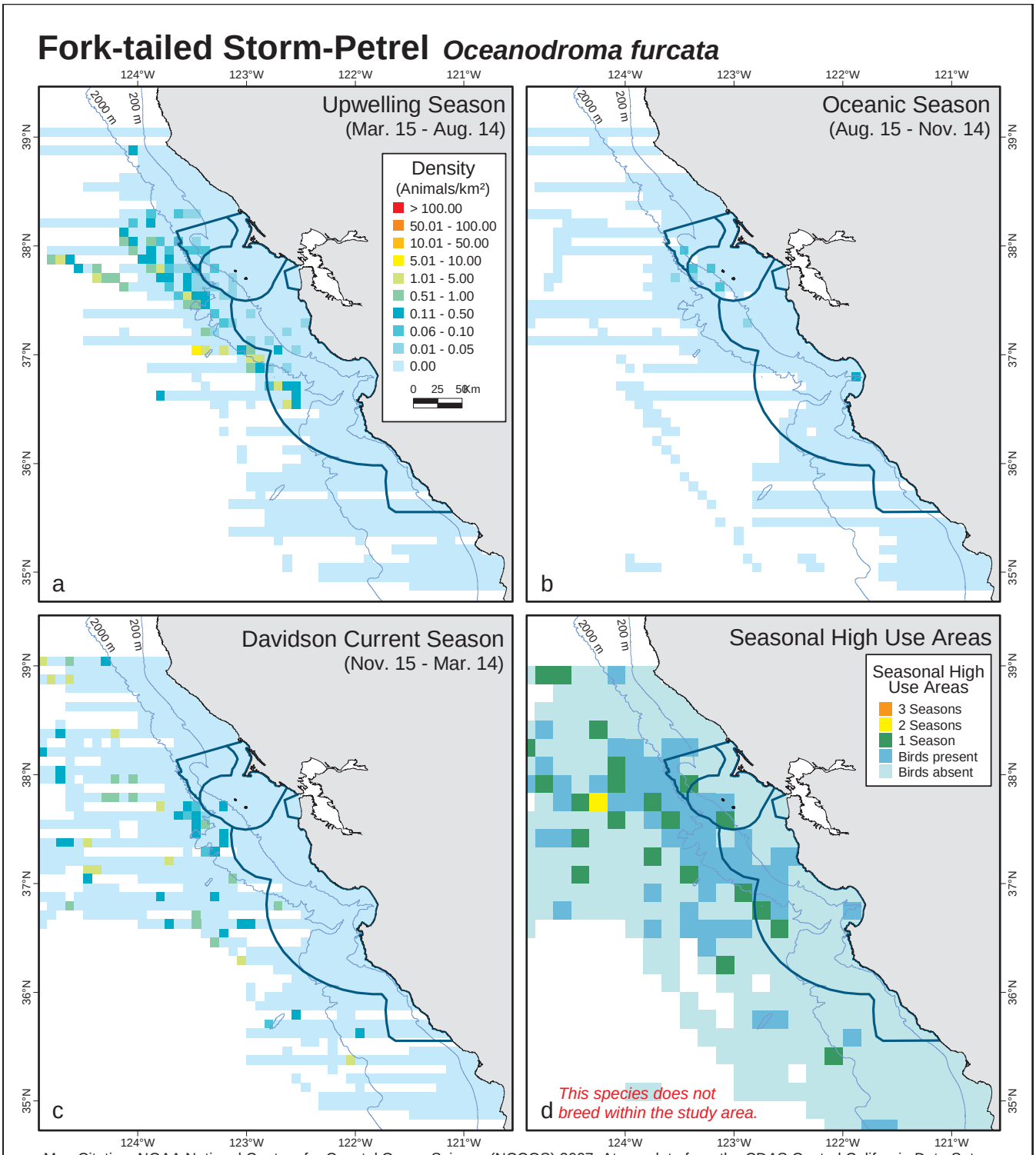
DATA SOURCES AND METHODS

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.

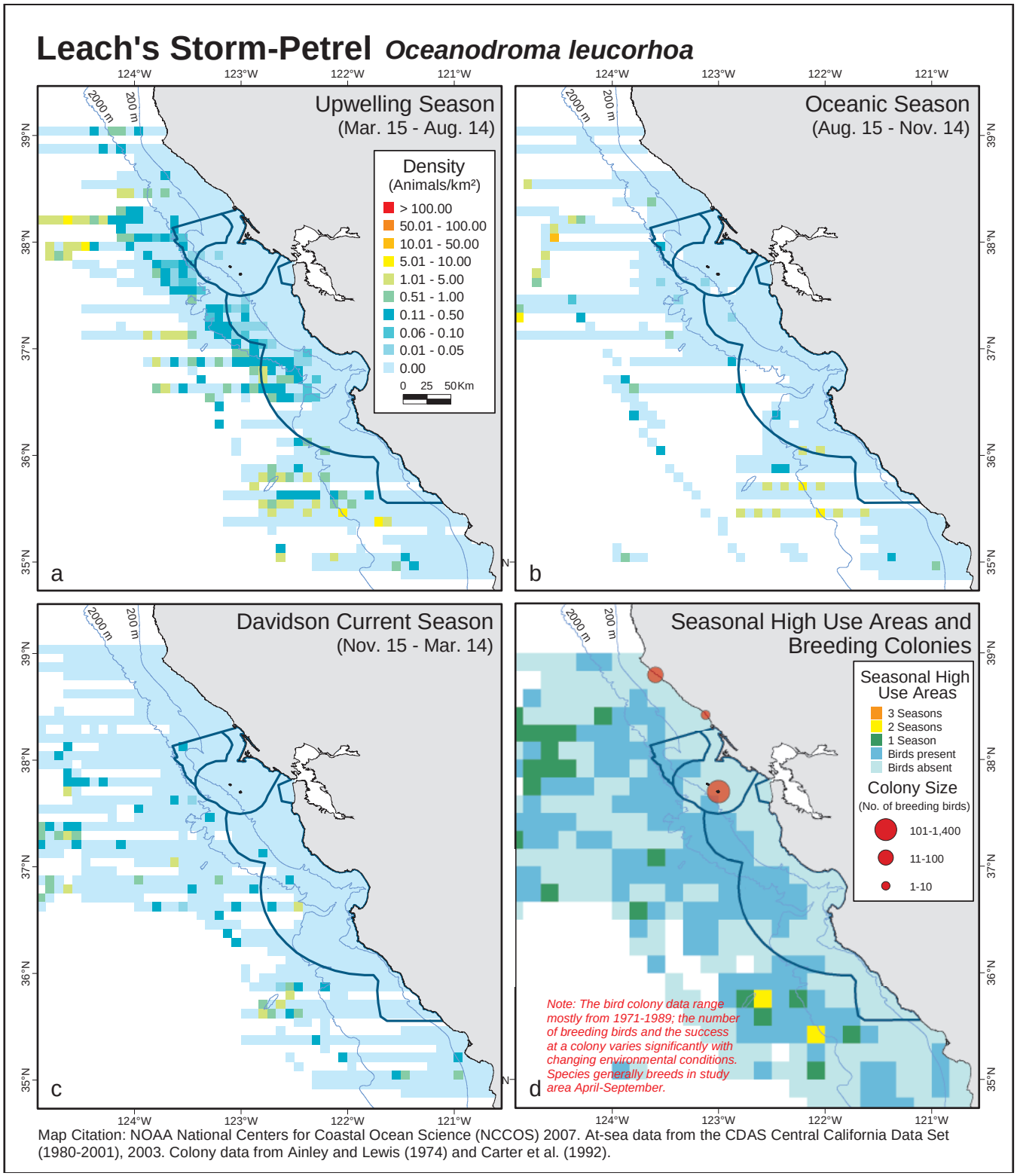


Figure 3.15. Leach's Storm-Petrel: maps of seasonal density, high use areas, and breeding colonies.

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.

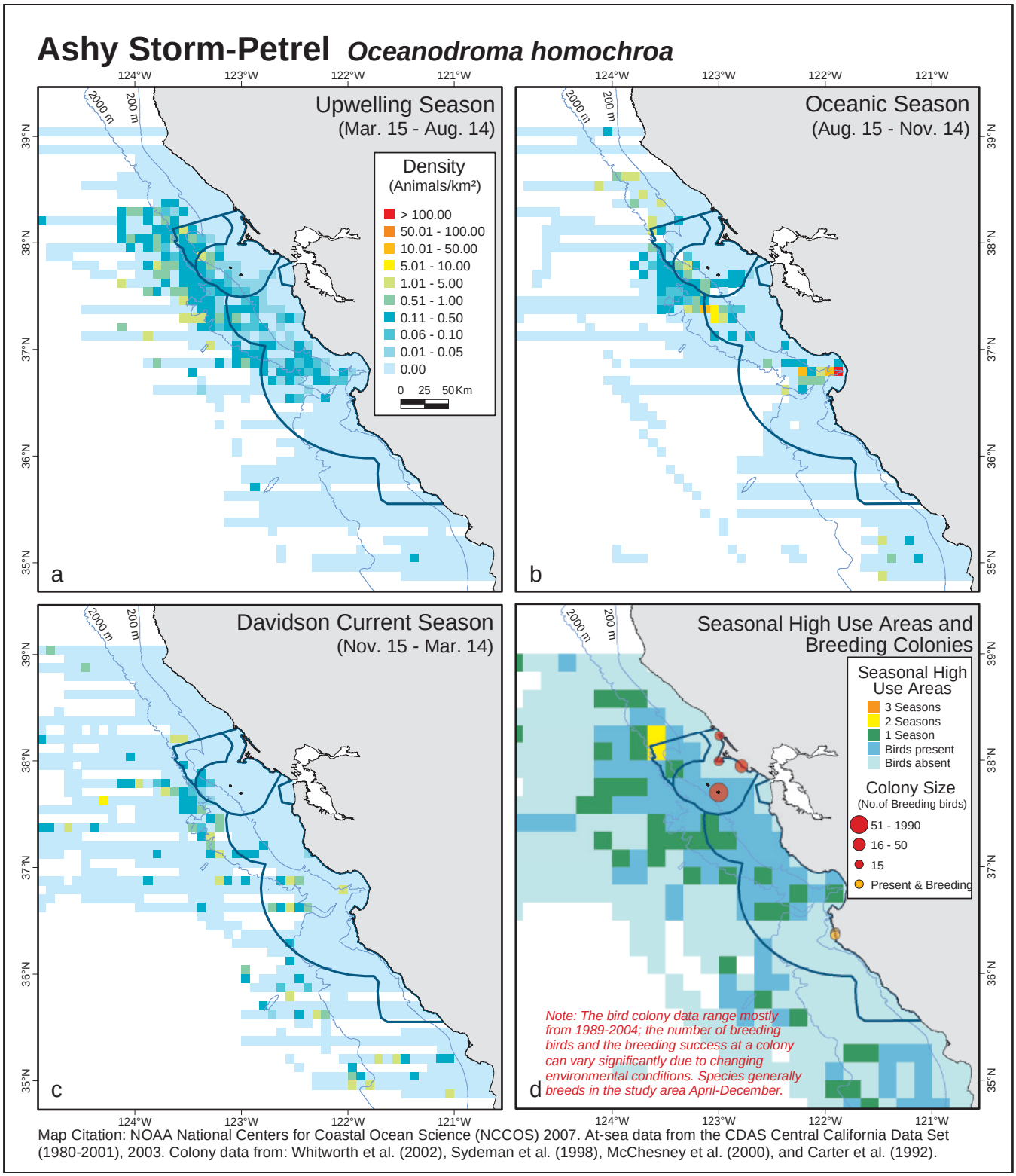


Figure 3.16. Ashy Storm-Petrel: maps of seasonal density, high use areas, and breeding colonies.

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.

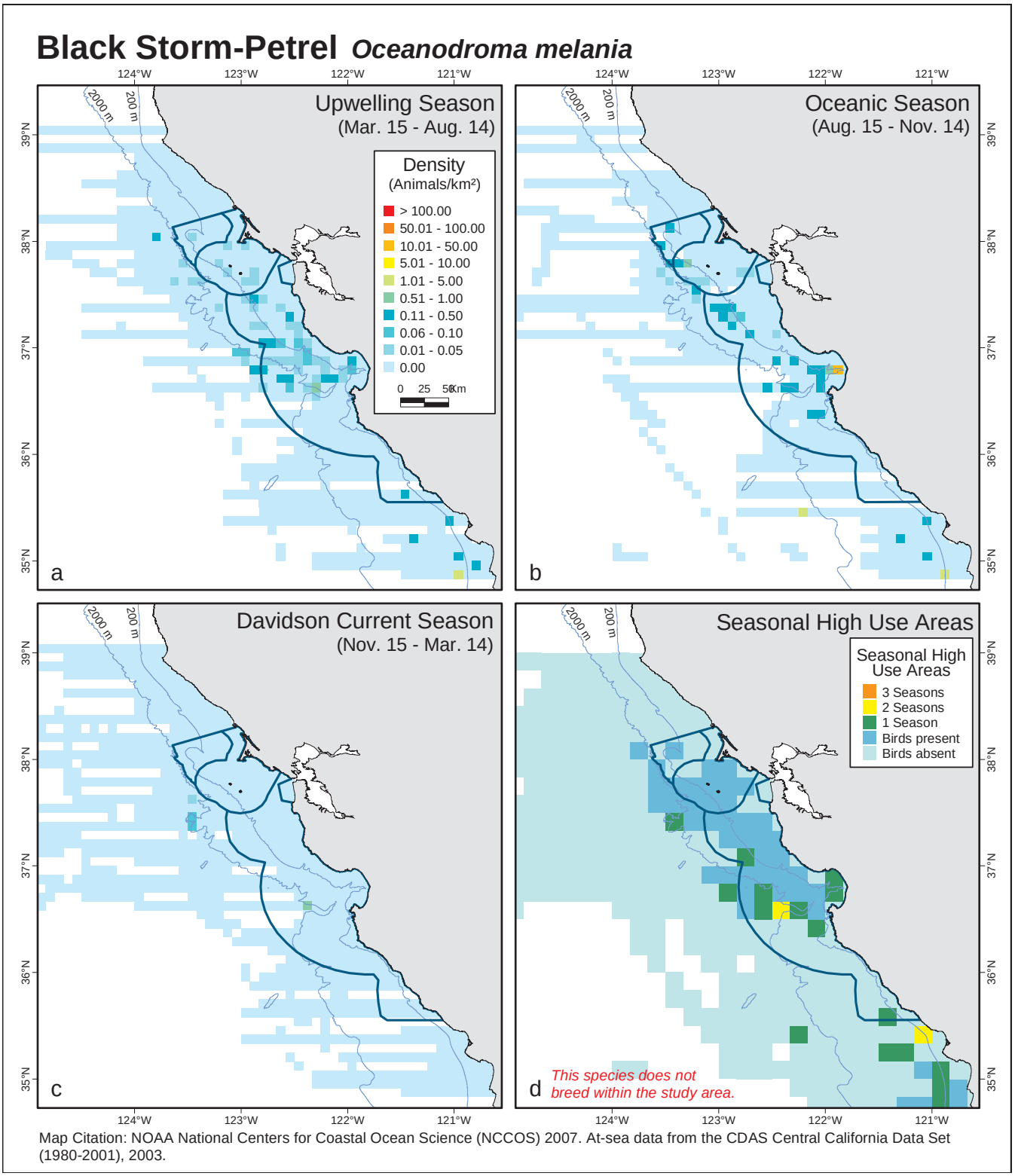


Figure 3.17. Black Storm-Petrel: maps of seasonal density and high use areas.

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

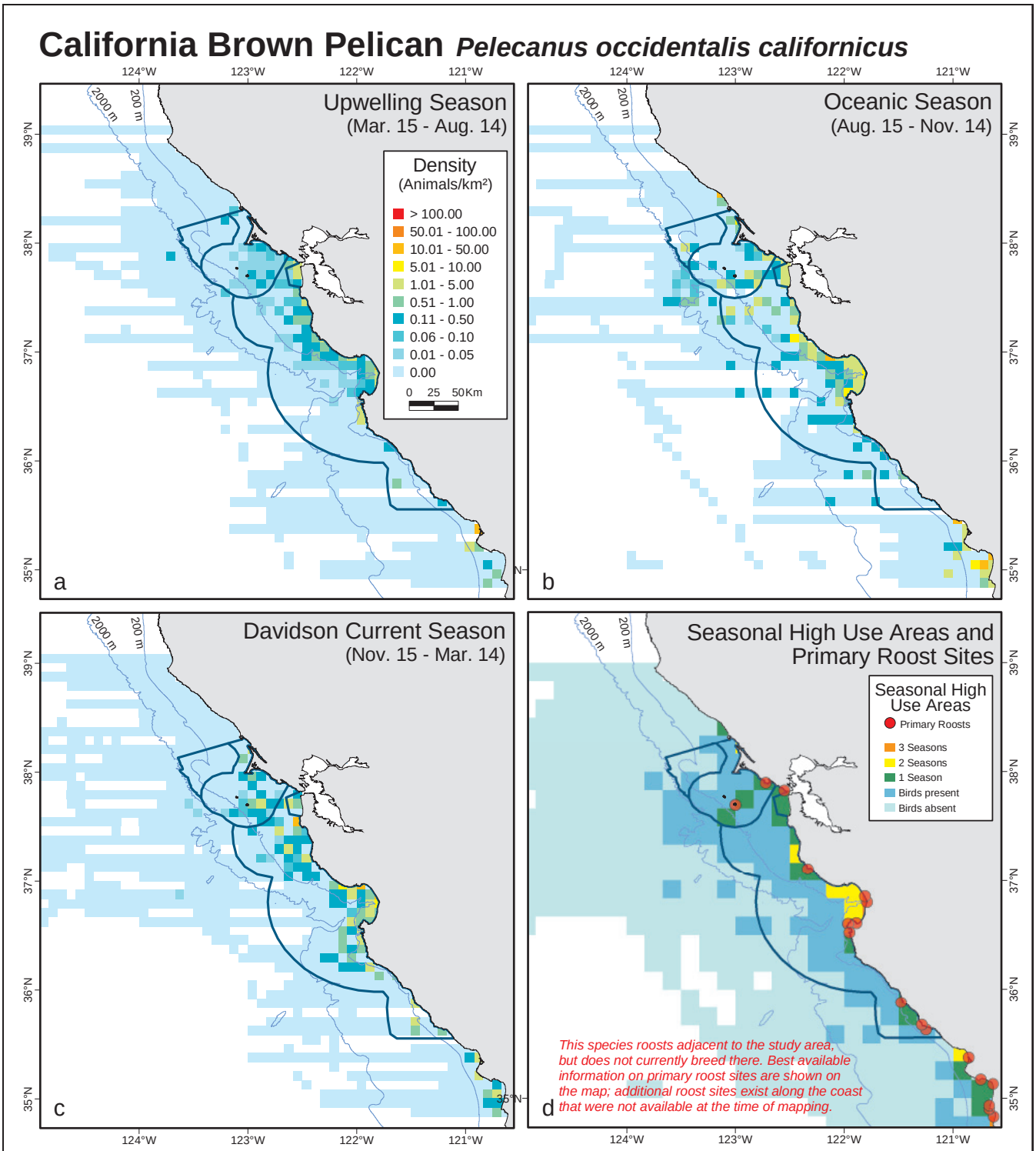
The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys 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

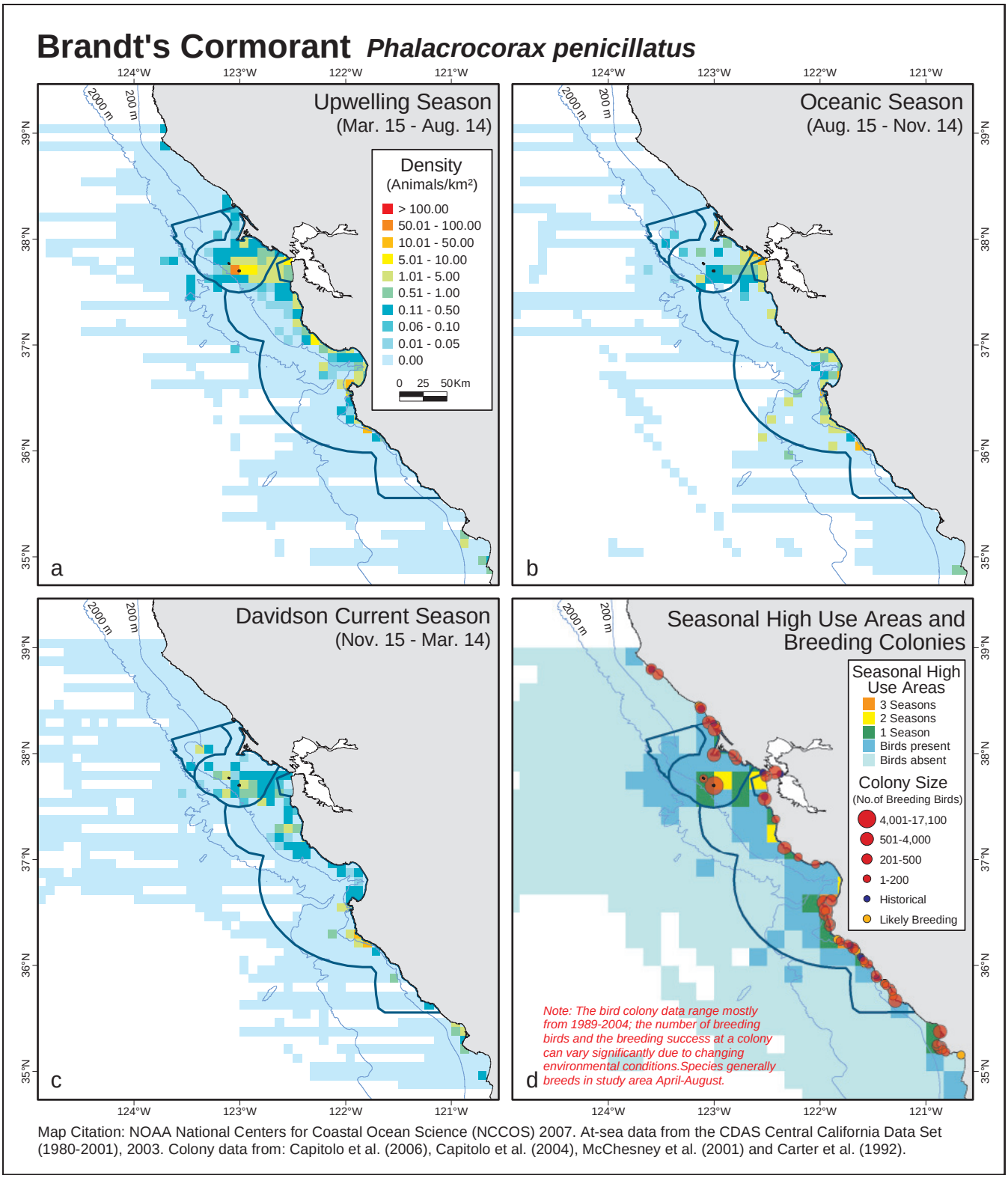


Figure 3.19. Brandt's Cormorant: maps of seasonal density, high use areas, and breeding colonies.

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.

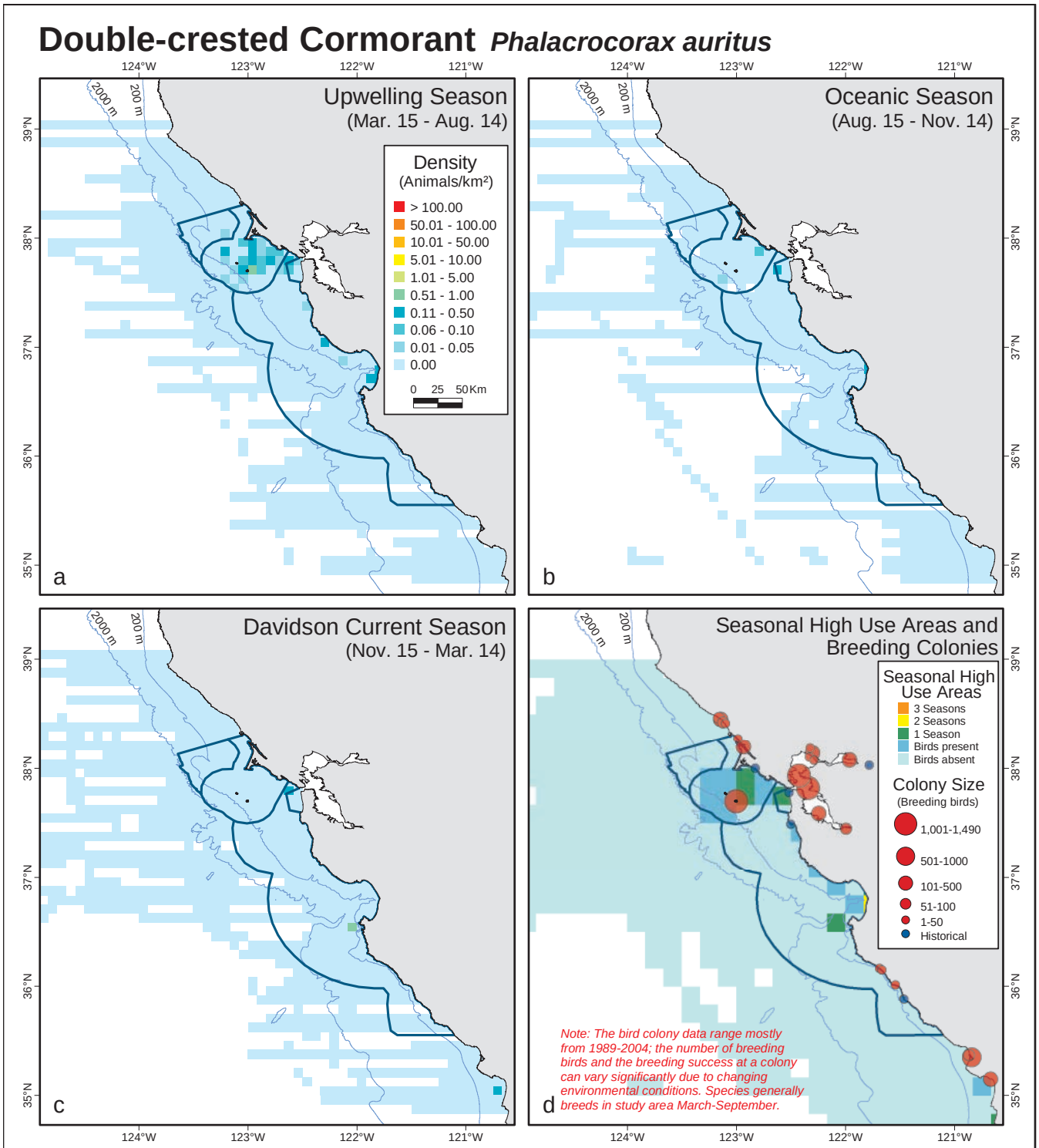
Densities of Brandt's Cormorants at sea were greatest within the boundaries of the National Marine Sanctuaries; to the north and south abundance dropped. A multiple regression model of nine independent variables explained 28.7% of variation in density; important variables were inverse relationships to 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.

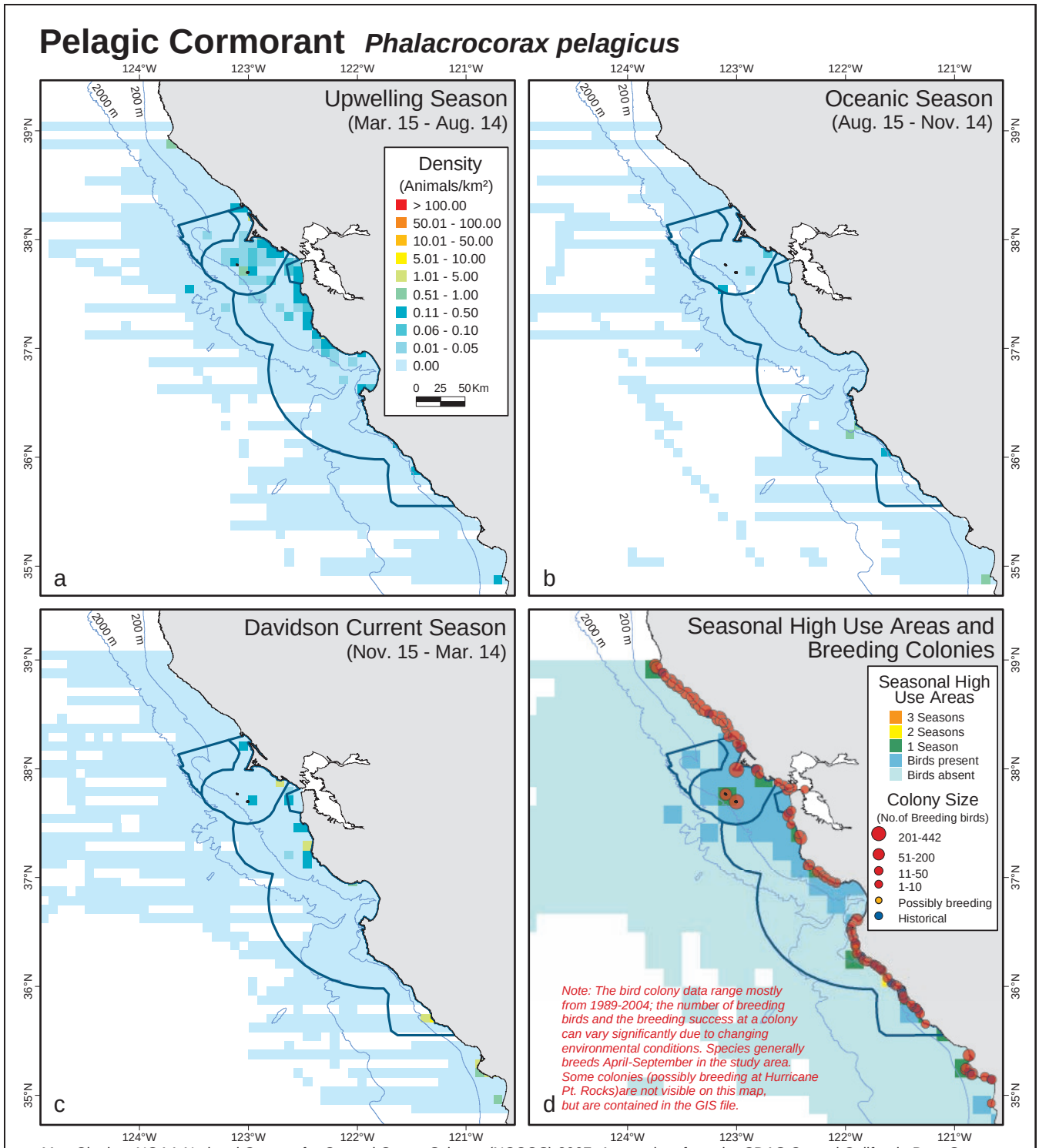


Figure 3.21. Pelagic Cormorant: maps of seasonal density, high use areas, and breeding colonies.

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.

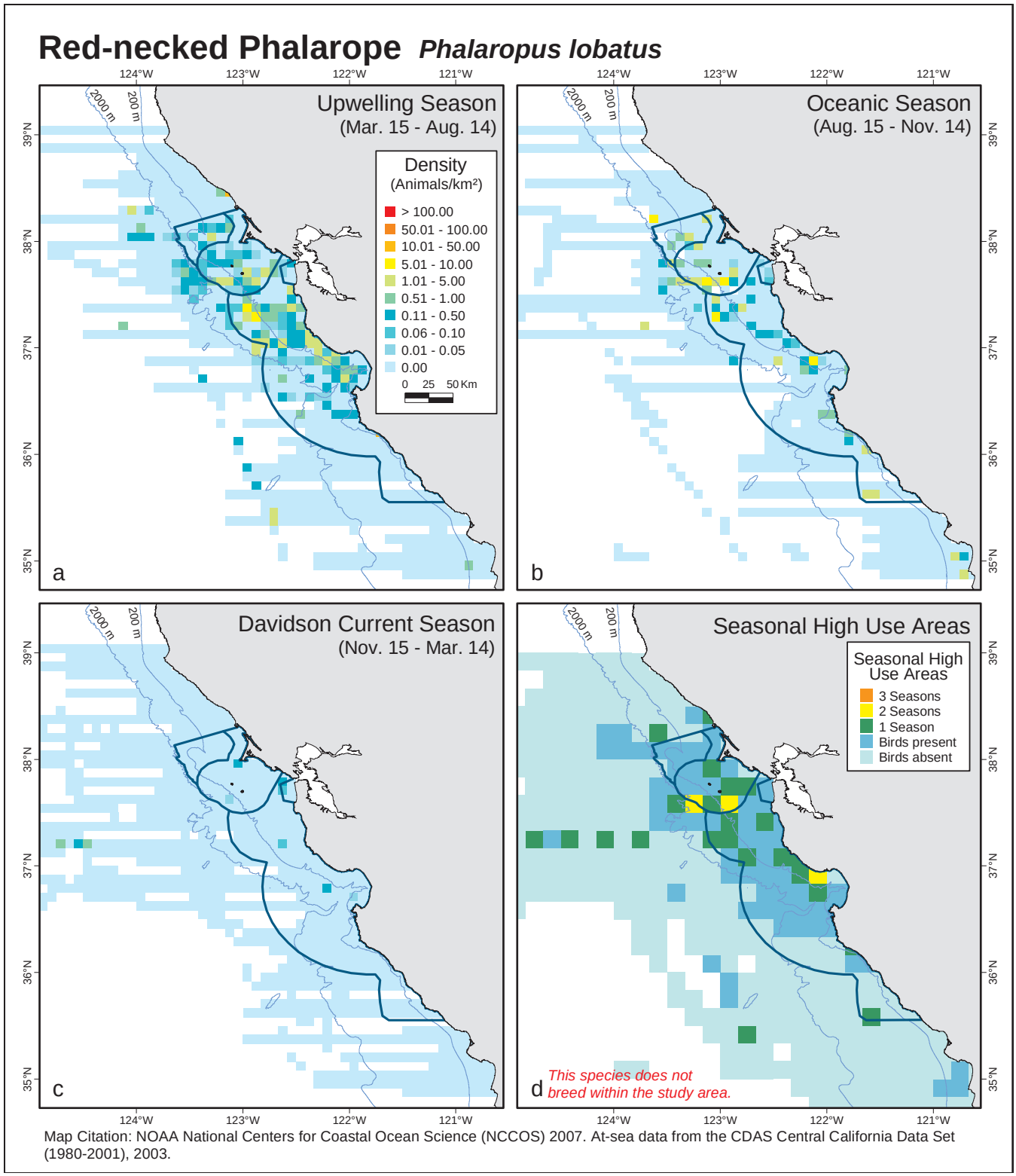


Figure 3.22. Red-necked Phalarope: maps of seasonal density and high use areas.

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.

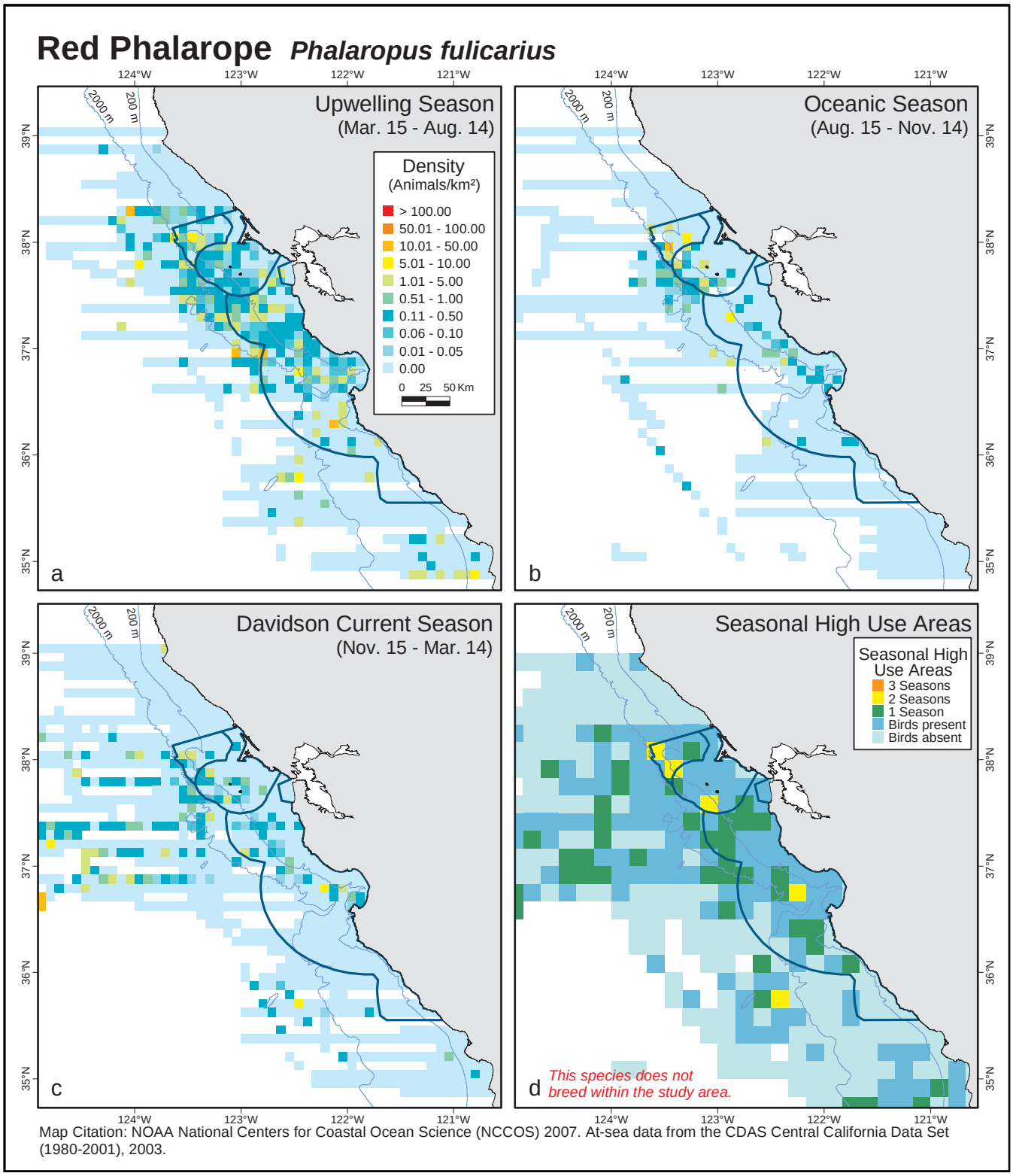


Figure 3.23. Red Phalarope: maps of seasonal density and high use areas.

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.

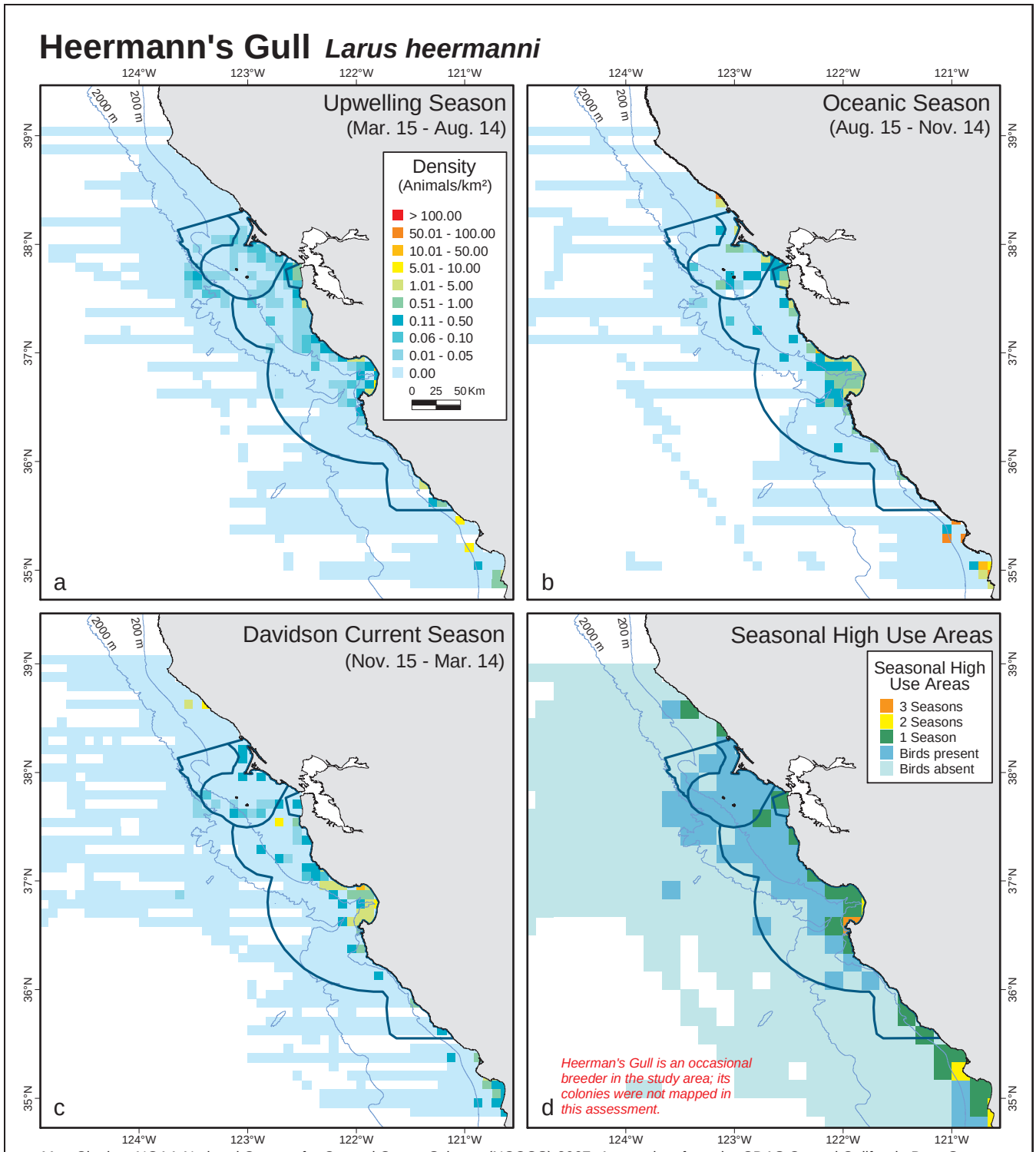
RESULTS AND DISCUSSION

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.

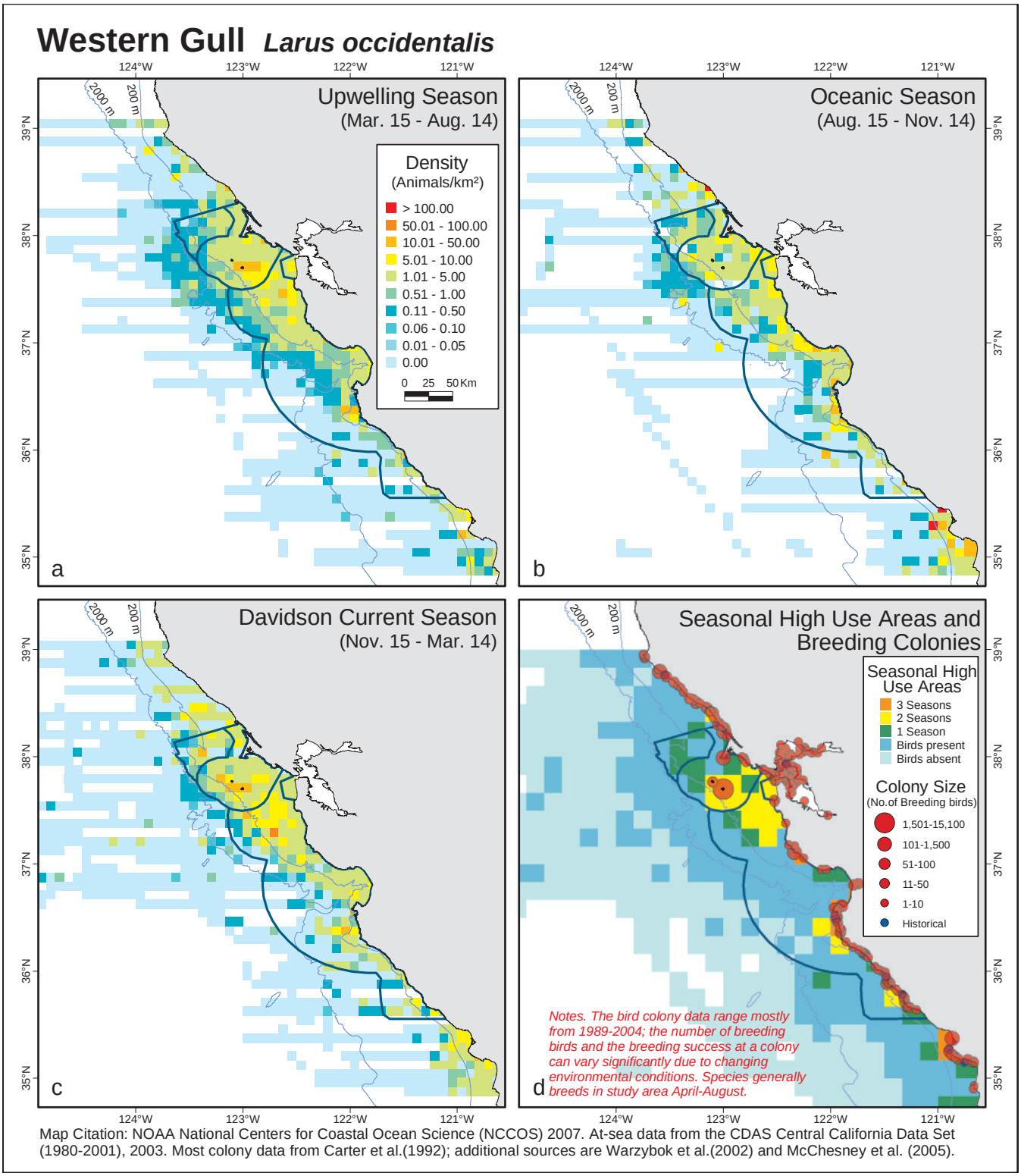


Figure 3.25. Western Gull: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) 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.

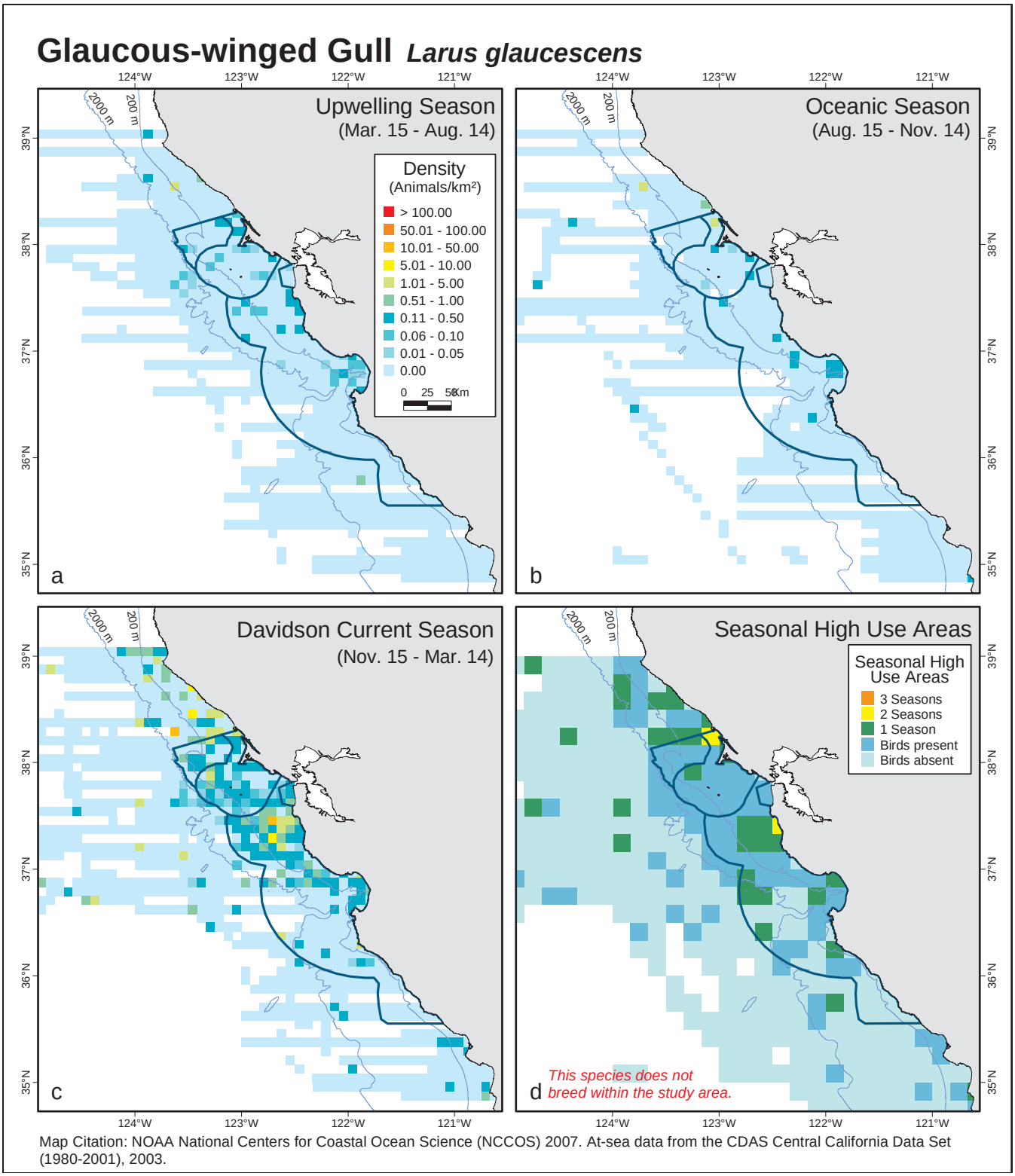


Figure 3.26. Glaucous-winged Gull: maps of seasonal density and high use areas.

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.

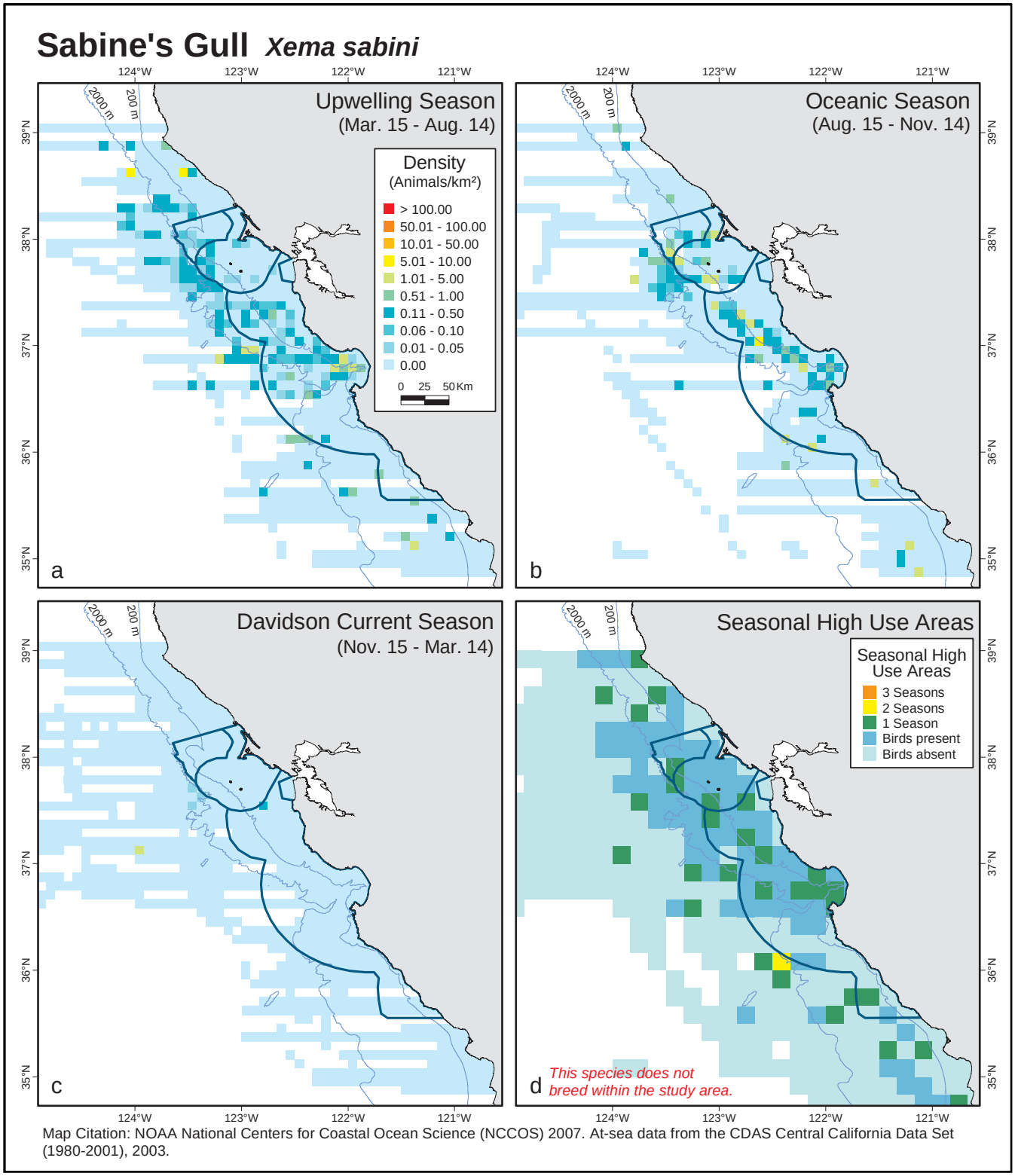


Figure 3.27. Sabine's Gull: maps of seasonal density and high use areas.

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.

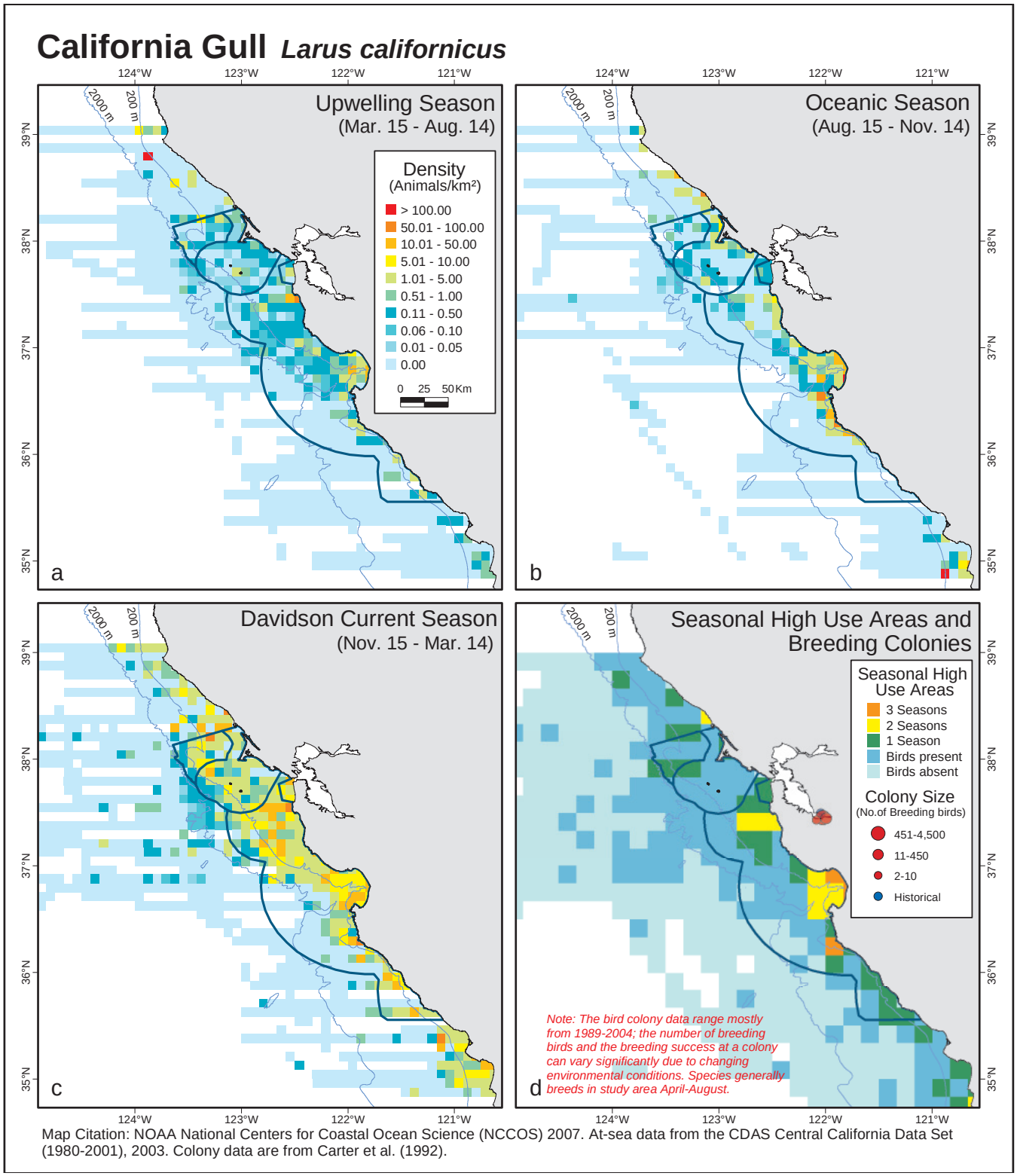


Figure 3.28. California Gull: maps of seasonal density, high use areas, and breeding colonies.

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.

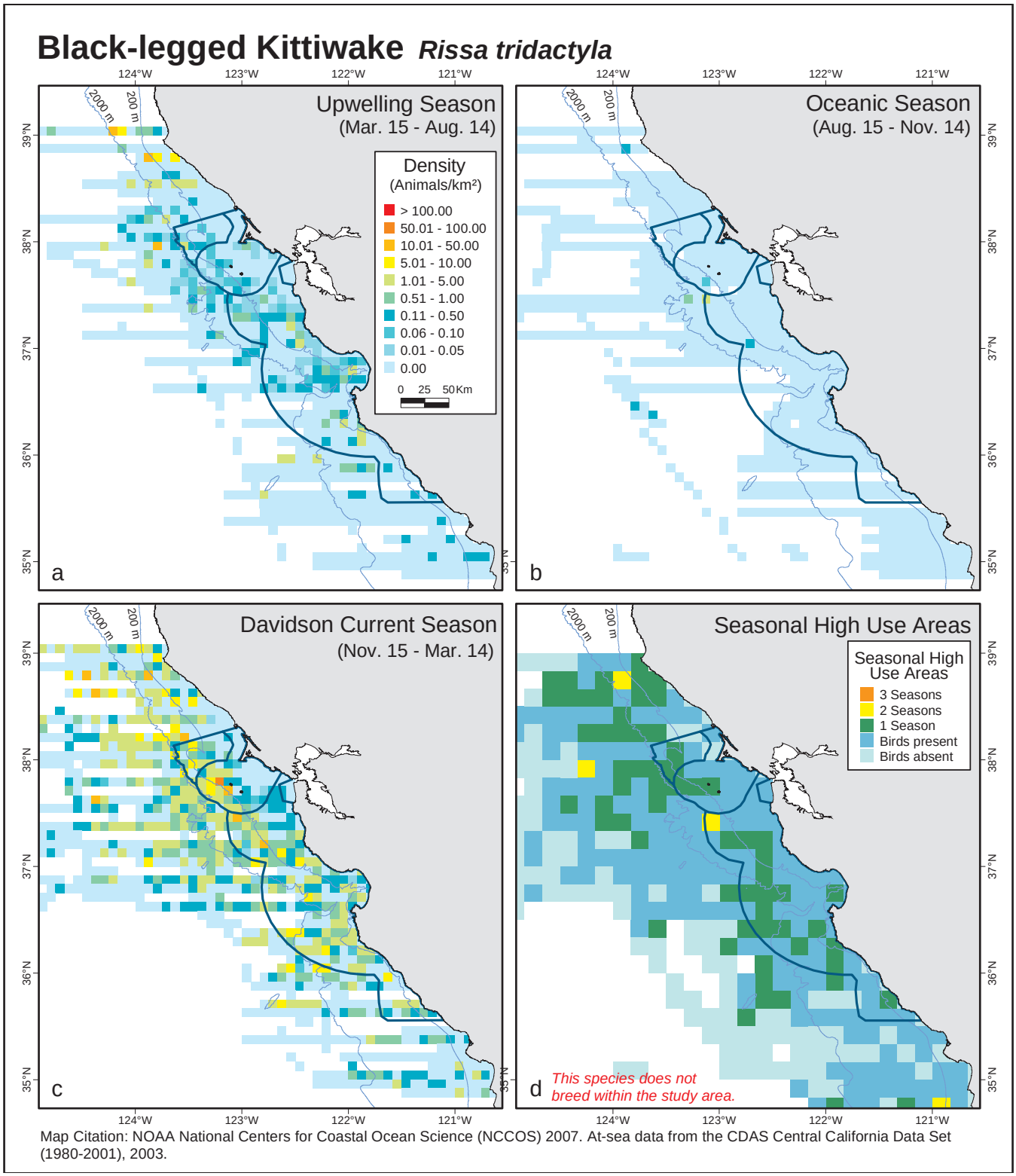


Figure 3.29. Black-legged Kittiwake: maps of seasonal density and high use areas.

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.

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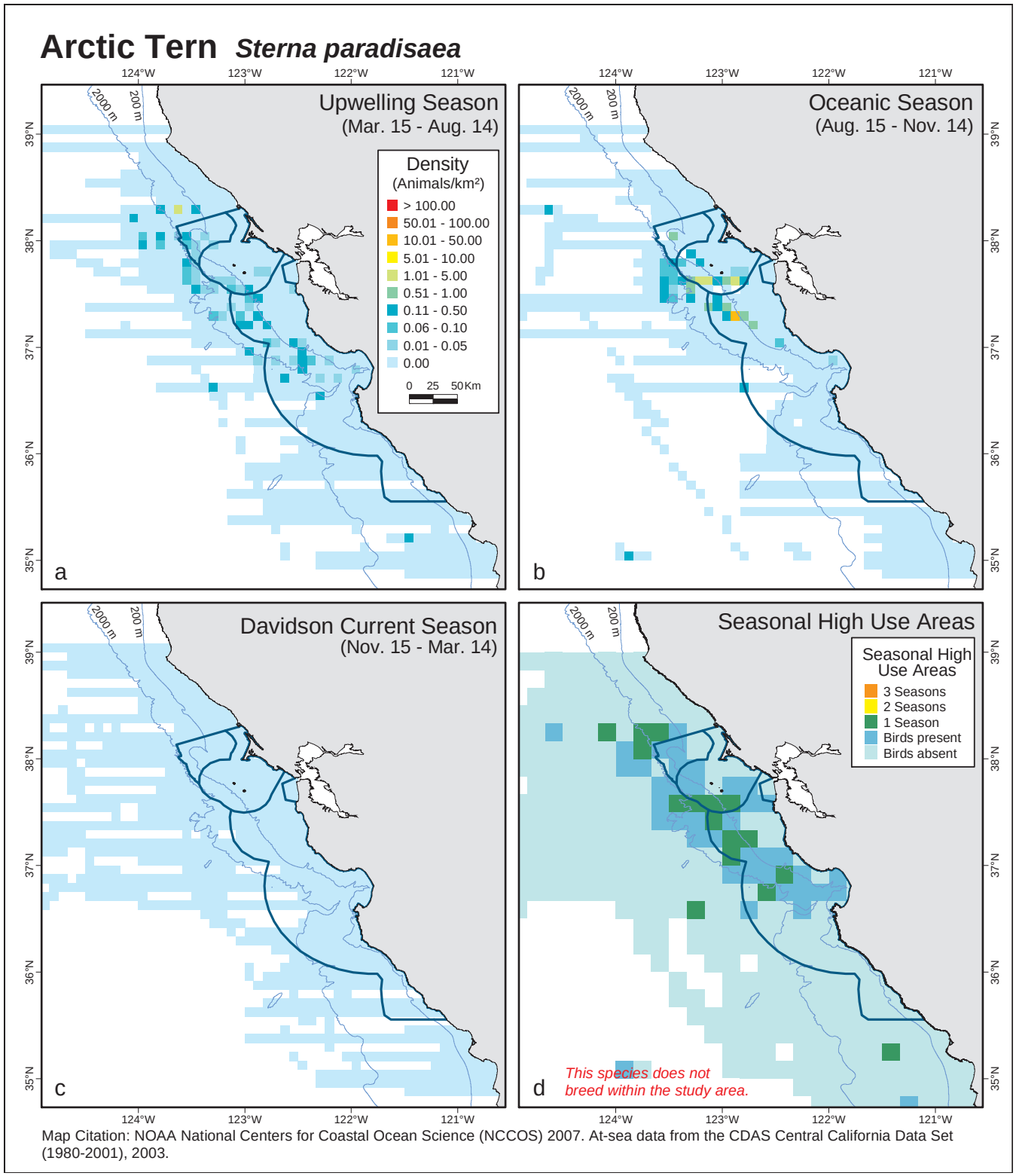


Figure 3.30. Arctic Tern: maps of seasonal density and high use areas.

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.

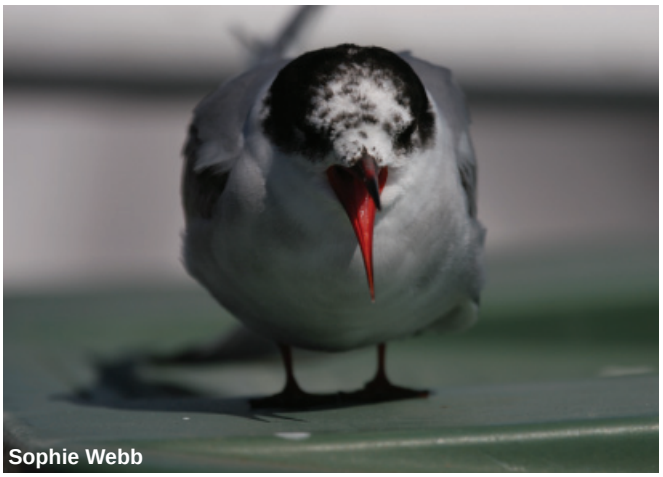
DATA SOURCES AND METHODS

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.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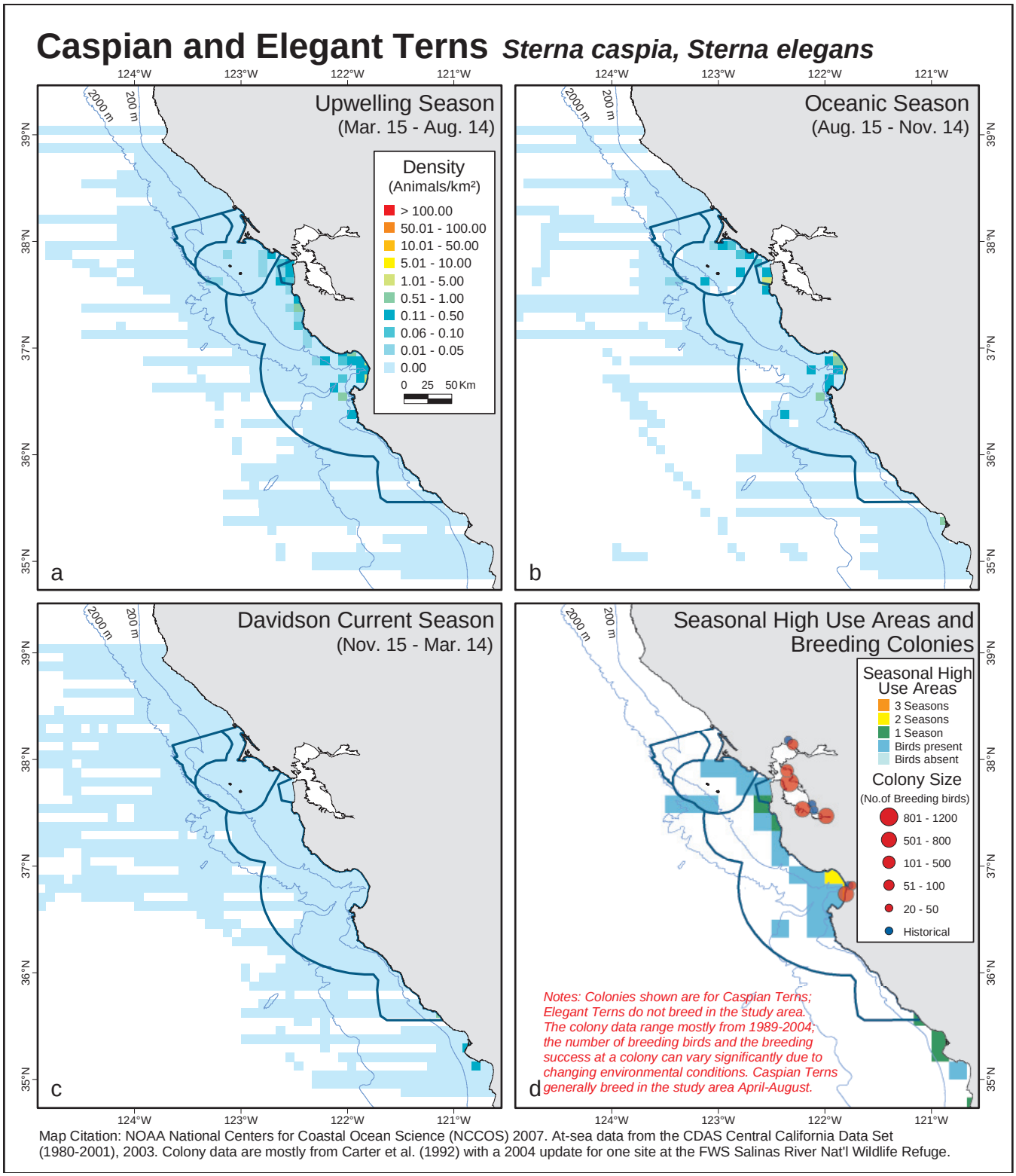

Figure 3.31. Caspian and Elegant Terns: maps of seasonal density, high use areas, and breeding colonies.

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.

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

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.

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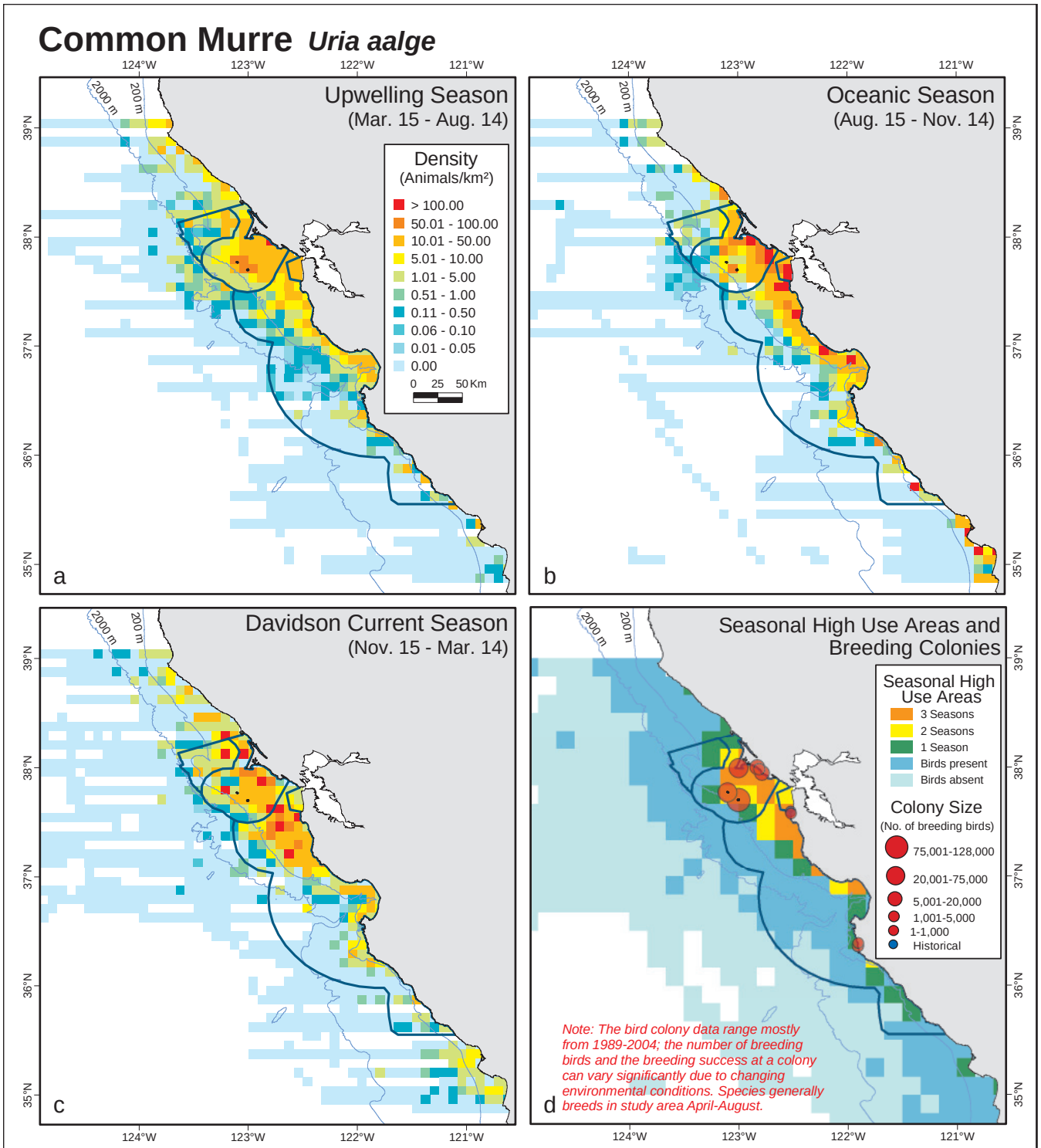

Figure 3.32. Common Murre: maps of seasonal density, high use areas, and breeding colonies.

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.

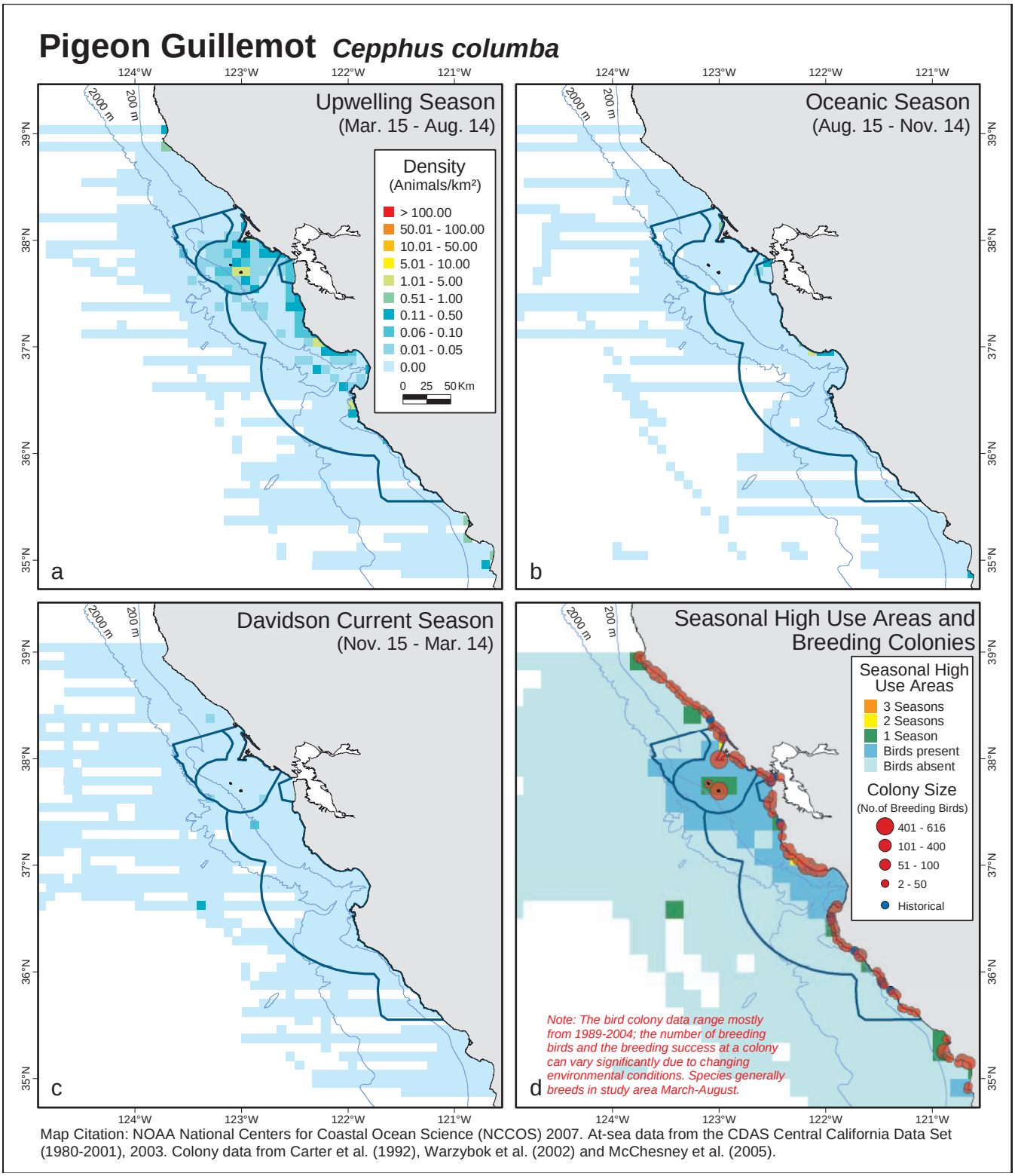

Figure 3.33. Pigeon Guillemot: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) 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.

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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.

Sophie Webb

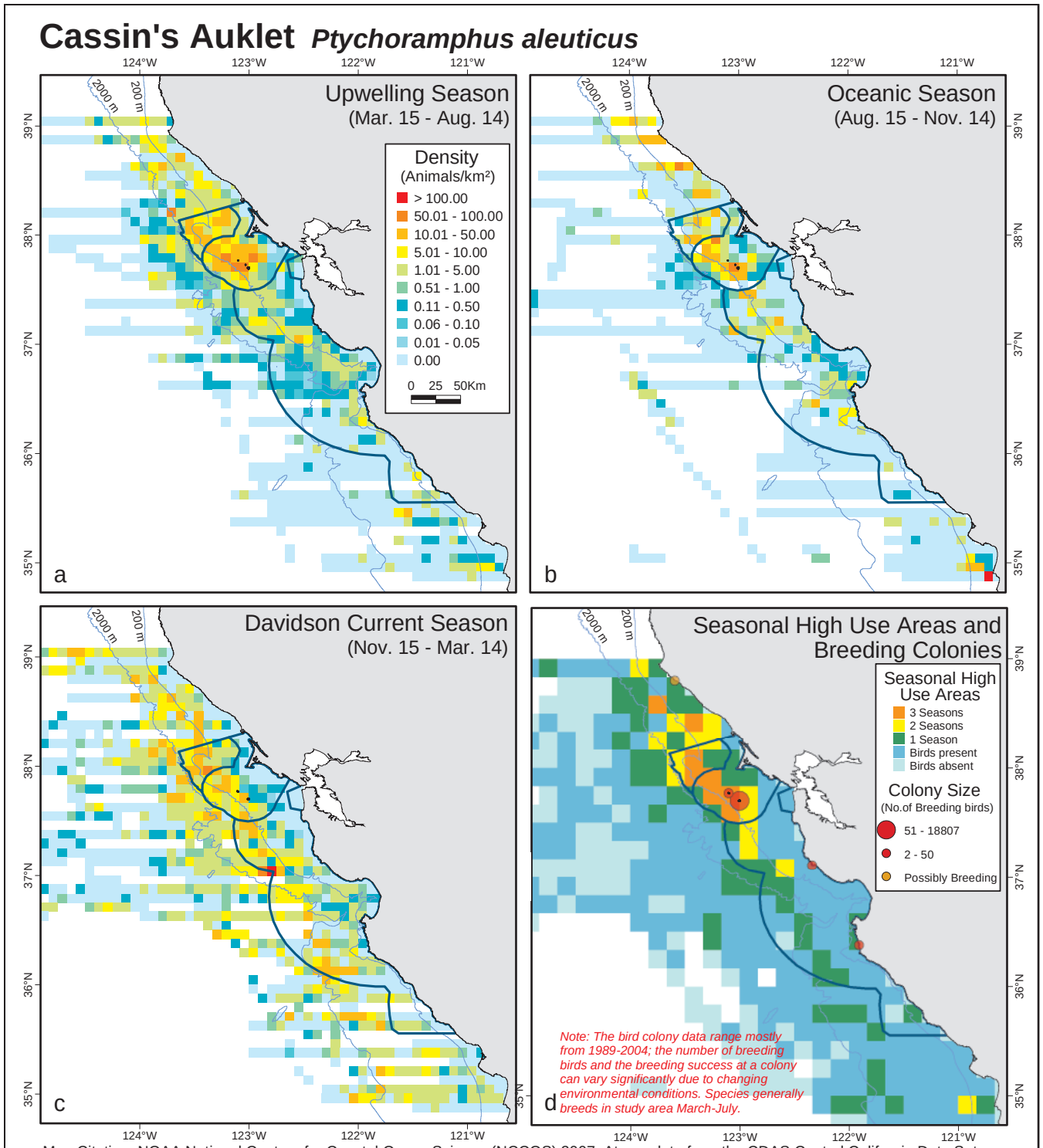

Figure 3.34. Cassin's Auklet: maps of seasonal density, high use areas, and breeding colonies.

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

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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.

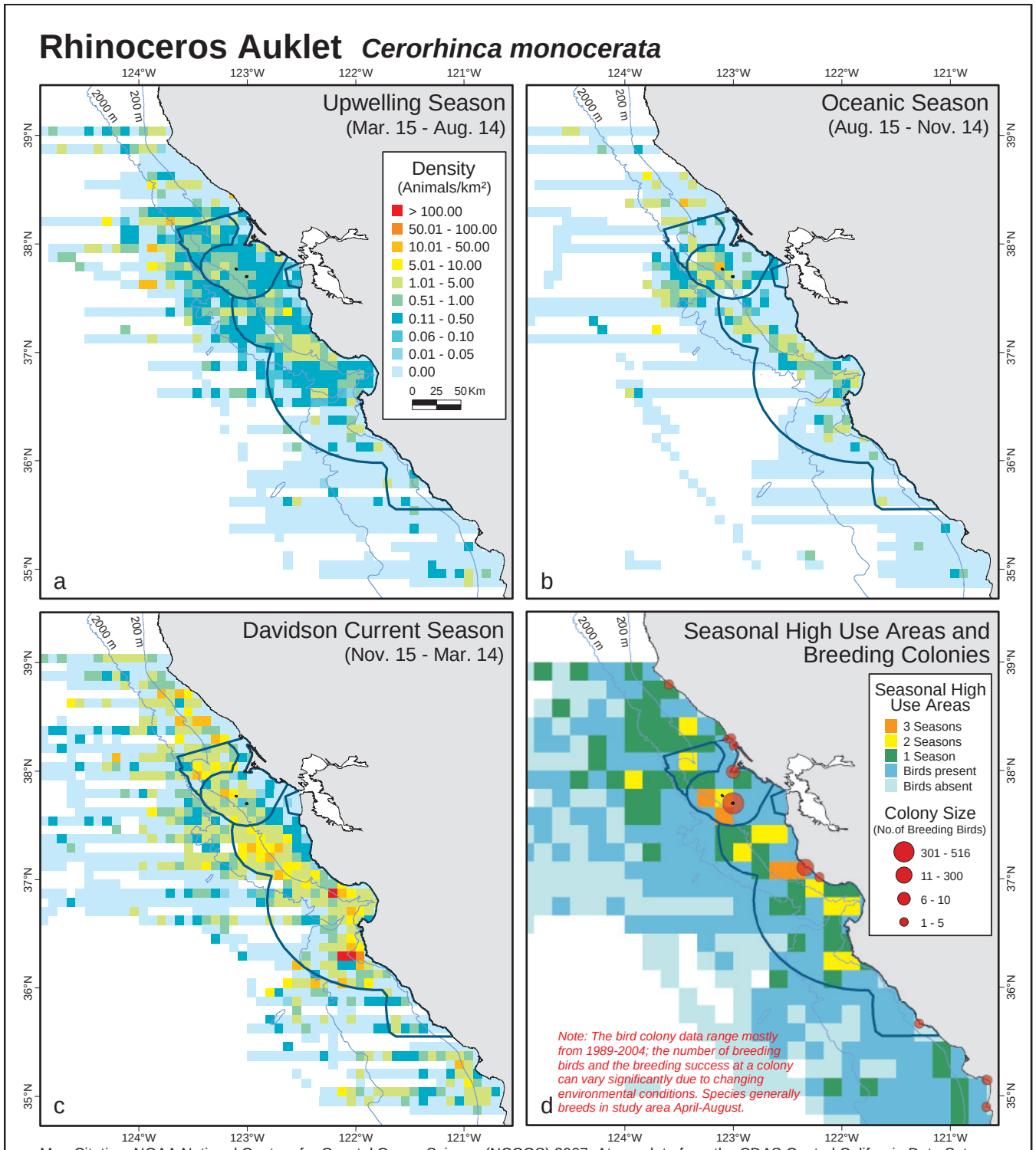


Figure 3.35. Rhinoceros Auklet: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km²) 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.

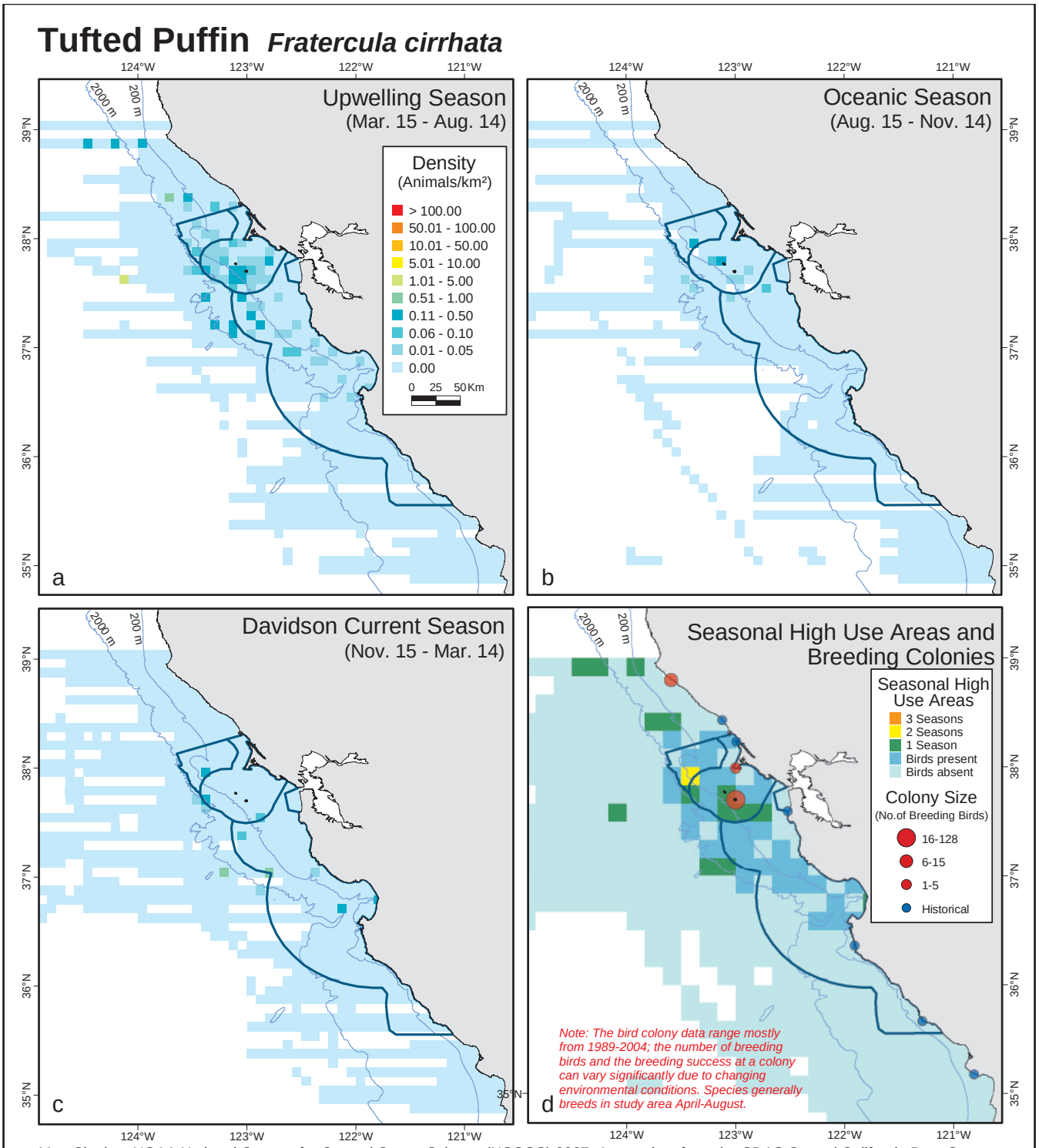


Figure 3.36. Tufted Puffin: maps of seasonal density, high use areas, and breeding colonies.

ABOUT THESE MAPS

Maps a, b and c show the at-sea density (birds/km^2) 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.

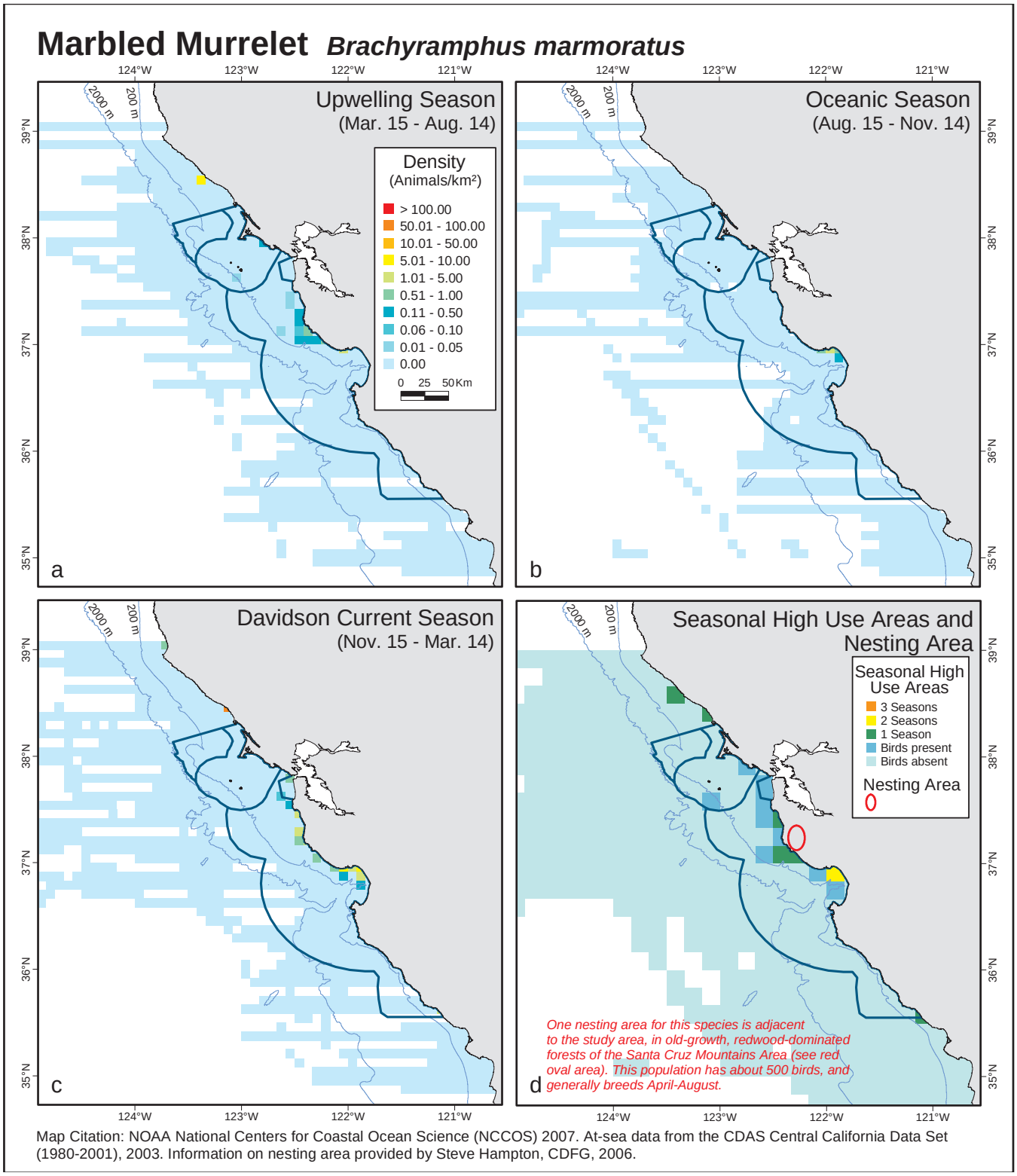


Figure 3.37. Marbled Murrelet: maps of seasonal density, high use areas, and breeding colonies.

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.

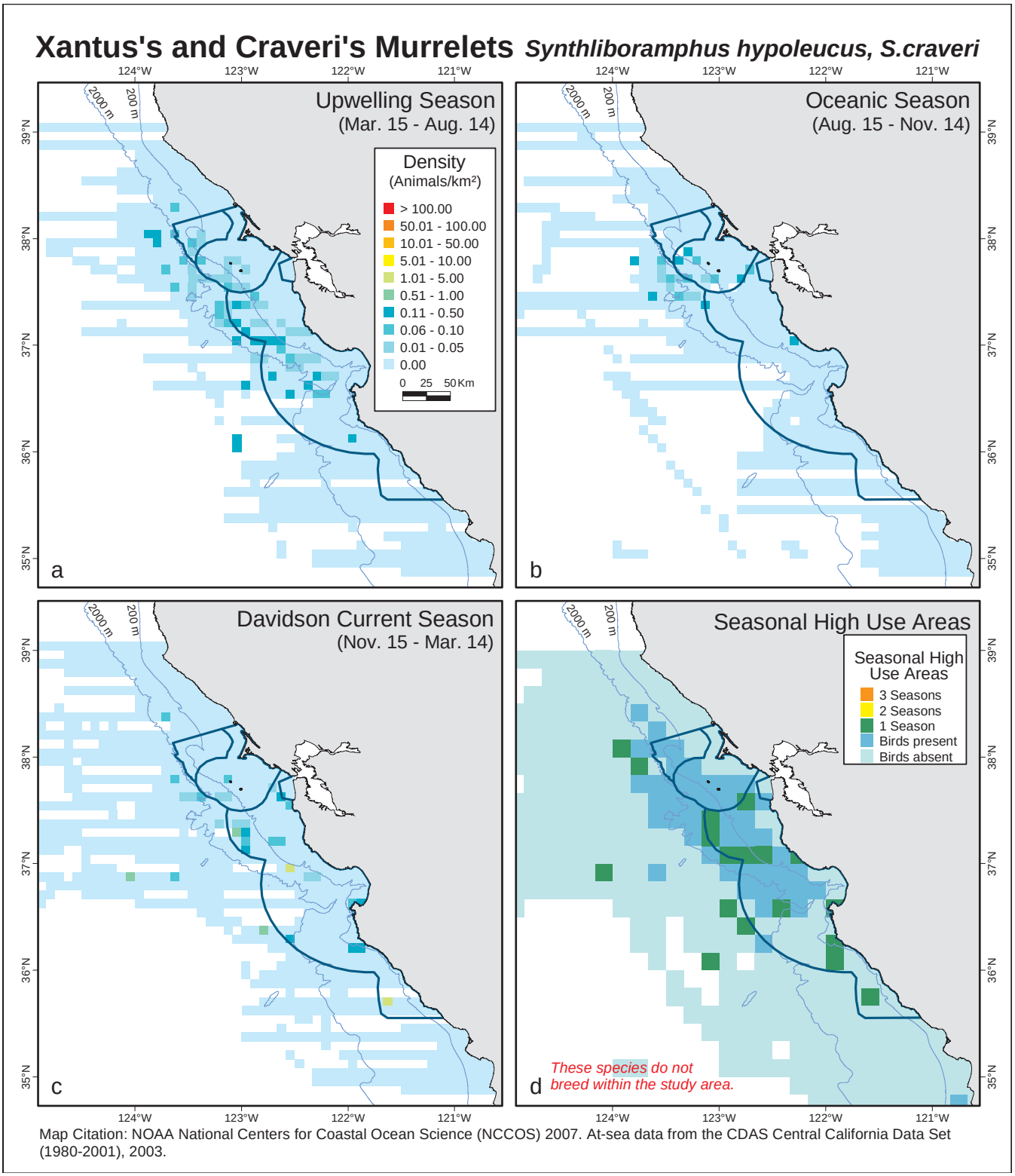


Figure 3.38. Xantus's and Craveri's murrelets: maps of seasonal density and high use areas.

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

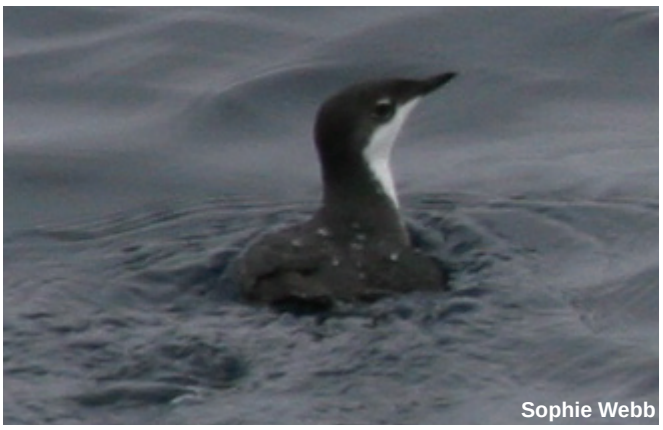
The at-sea data set is referred to as the CDAS central California data set (1980-2001) and was developed using software called Marine Mammal and Seabird Computer Data Analysis System (CDAS), by the R.G. Ford Consulting Co. The data set extends from Pt. Arena to Pt. Sal in the study area, and the surveys 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.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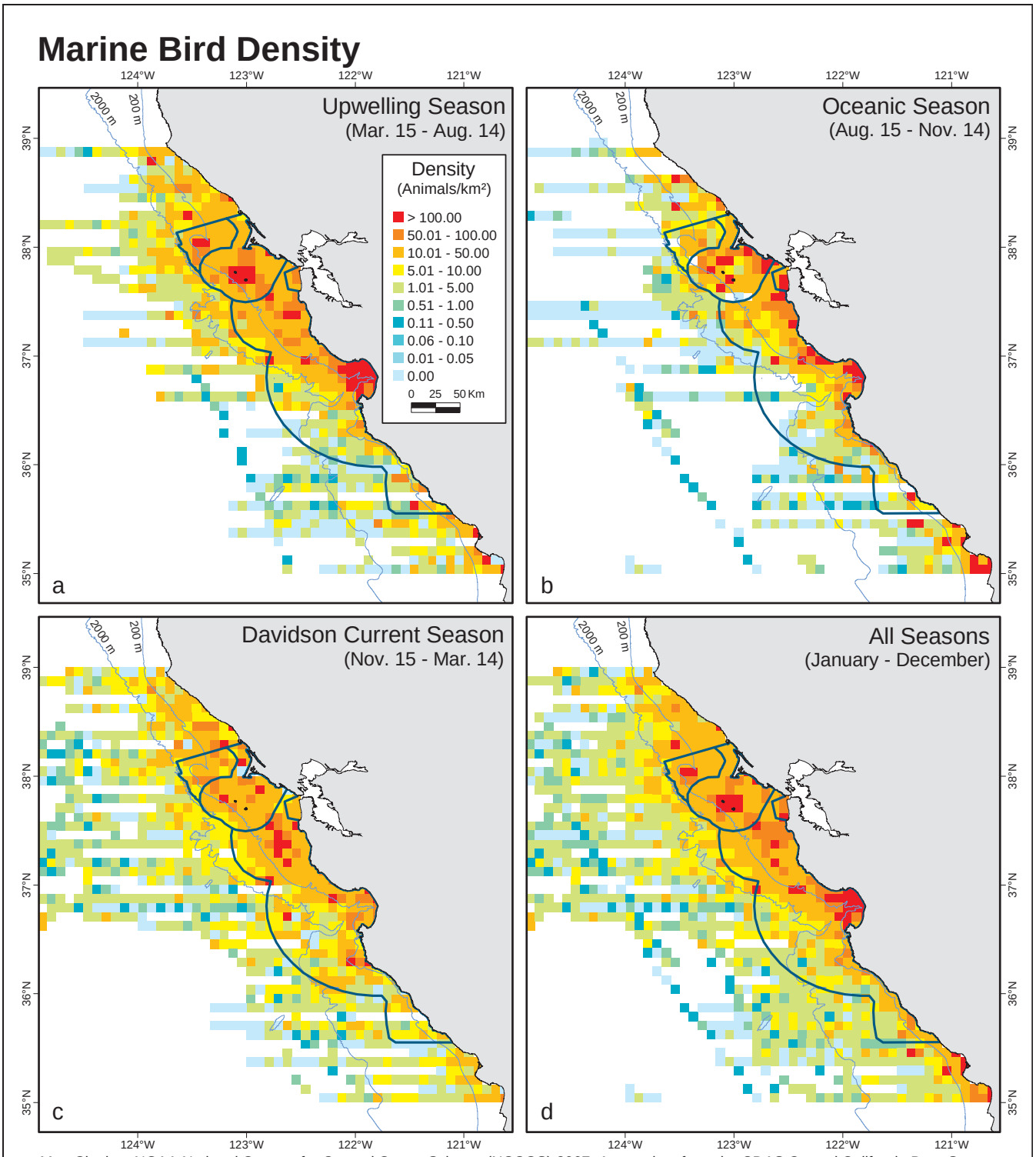


Map Citation: NOAA National Centers for Coastal Ocean Science (NCCOS) 2007. At-sea data from the CDAS Central California Data Set (1980-2001), 2003.

Figure 3.39. 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.

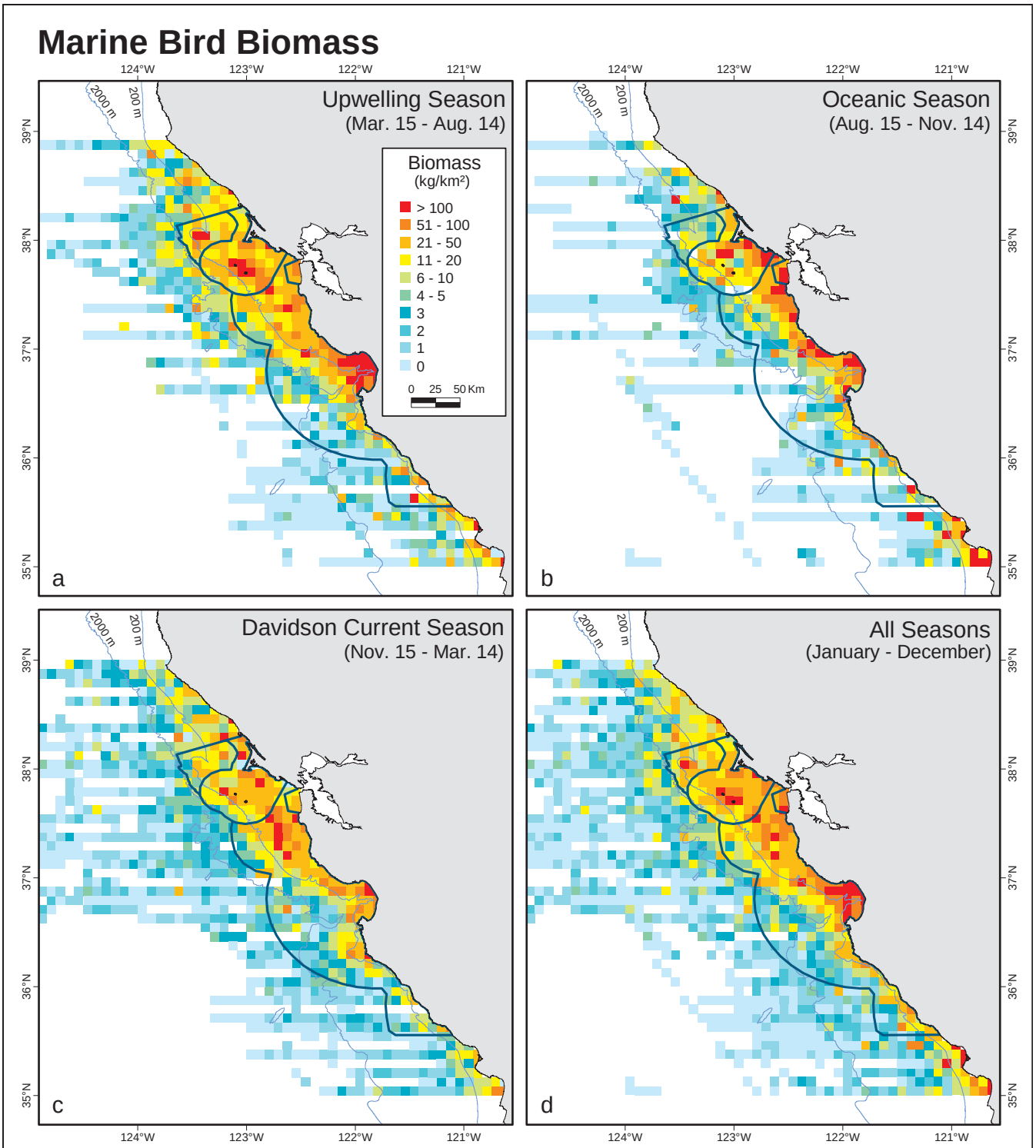
RESULTS AND DISCUSSION

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.

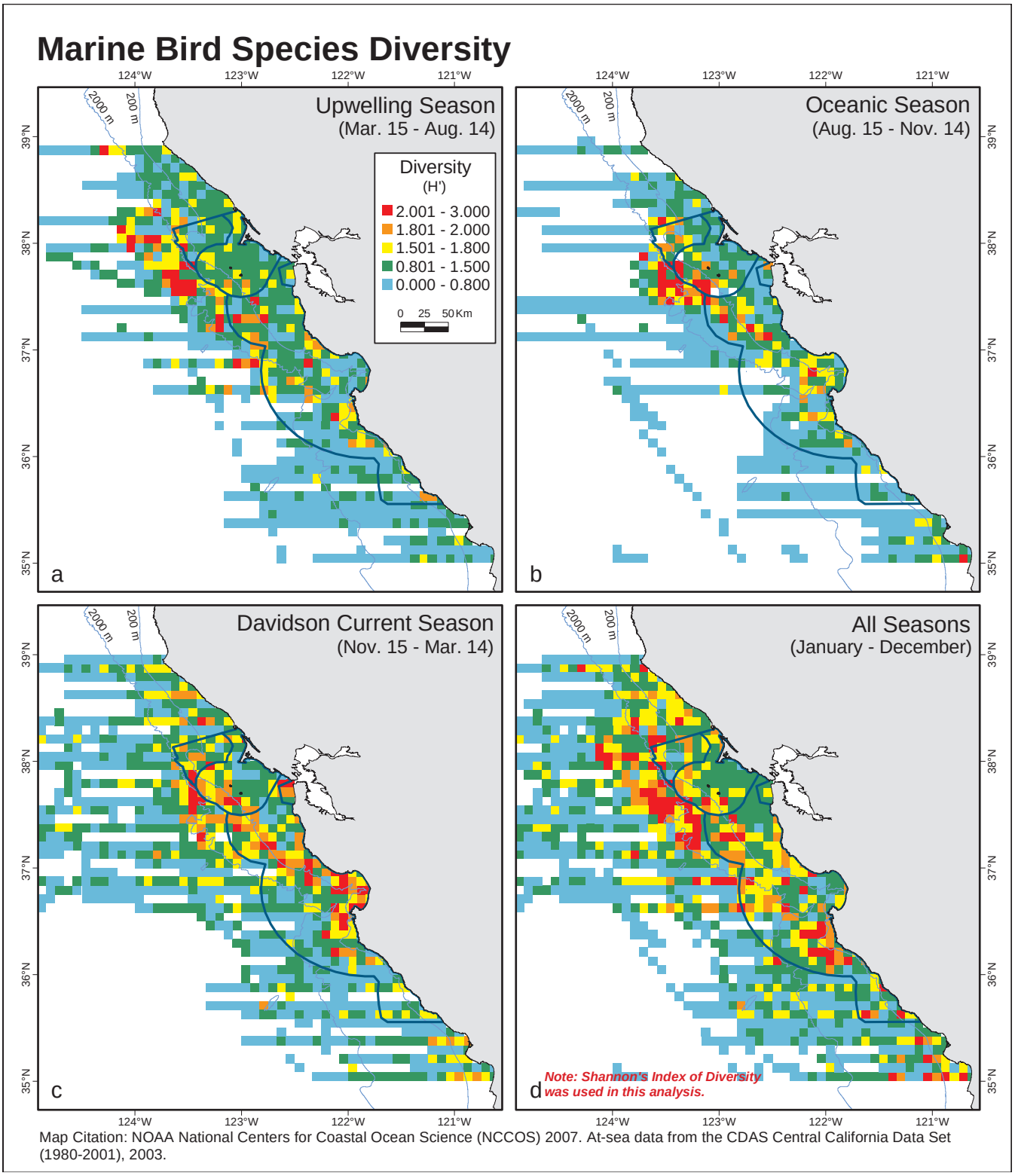


Figure 3.41. Marine bird diversity, by season and for all seasons.

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.

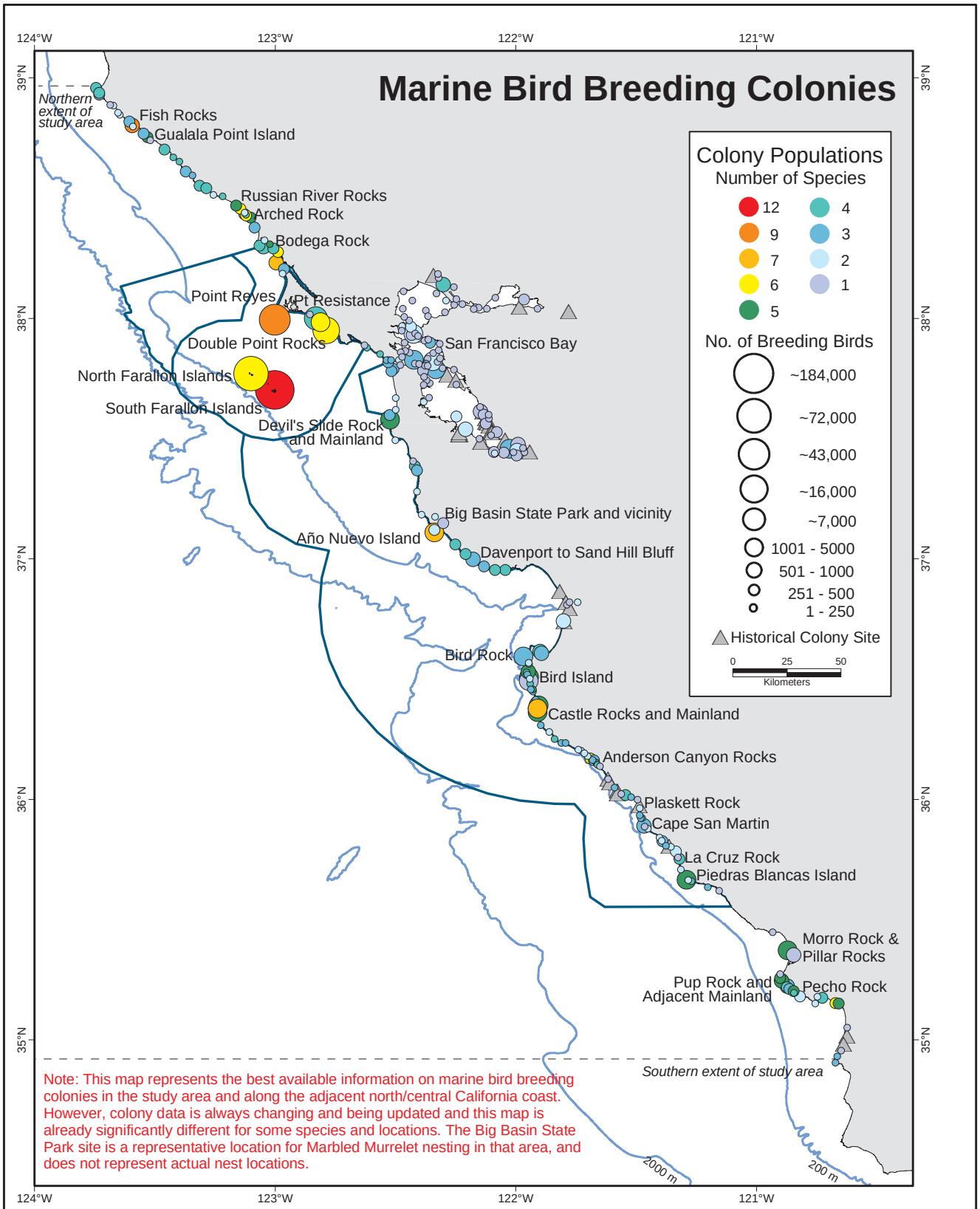


Figure 3.42. Marine bird breeding colonies along the coast of north/central California.

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.

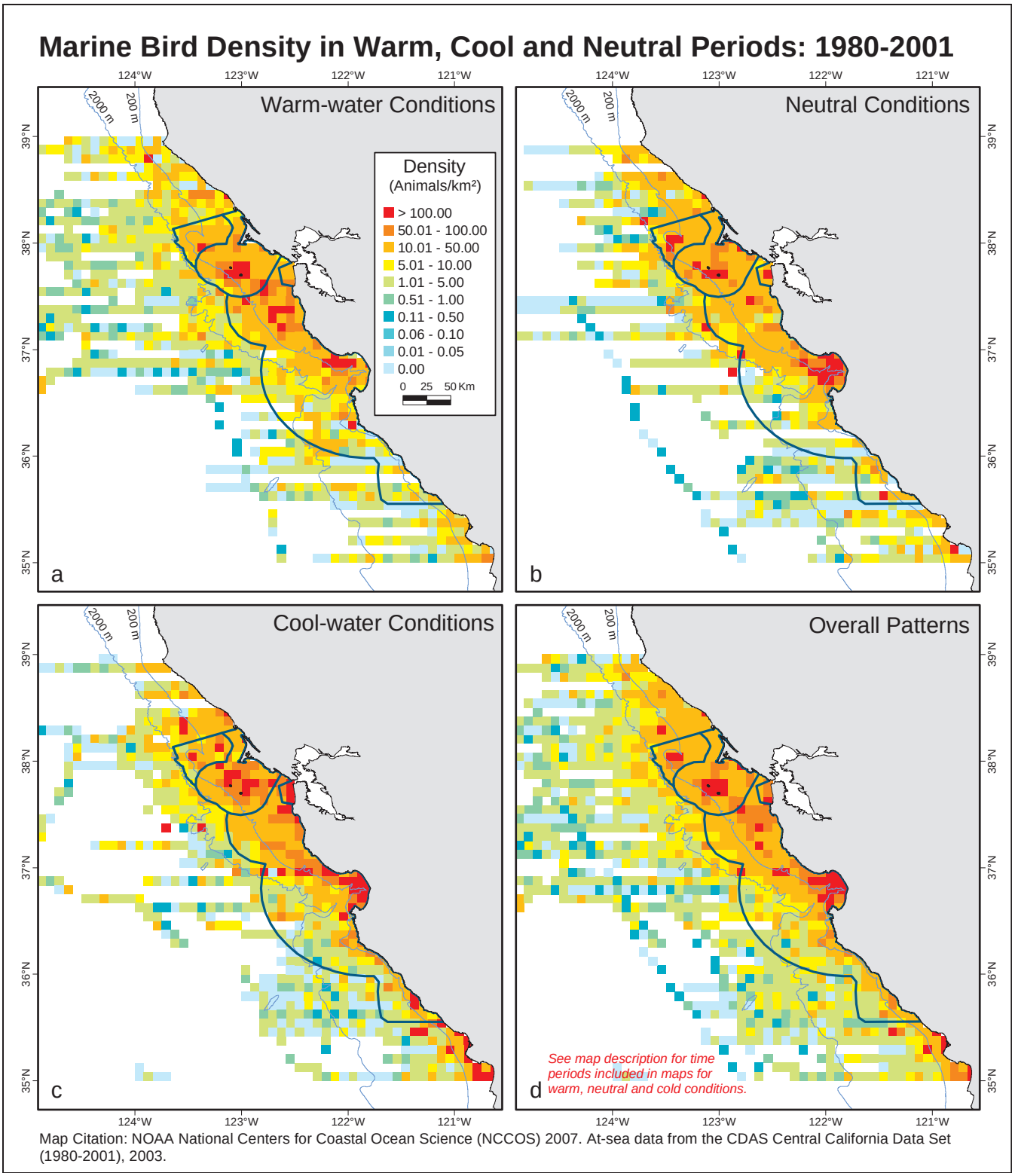


Figure 3.43. Marine bird density in warm, cold and neutral periods: 1980-2001.

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.

Calculating Marine Bird Density for Different Temperature Periods. 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.

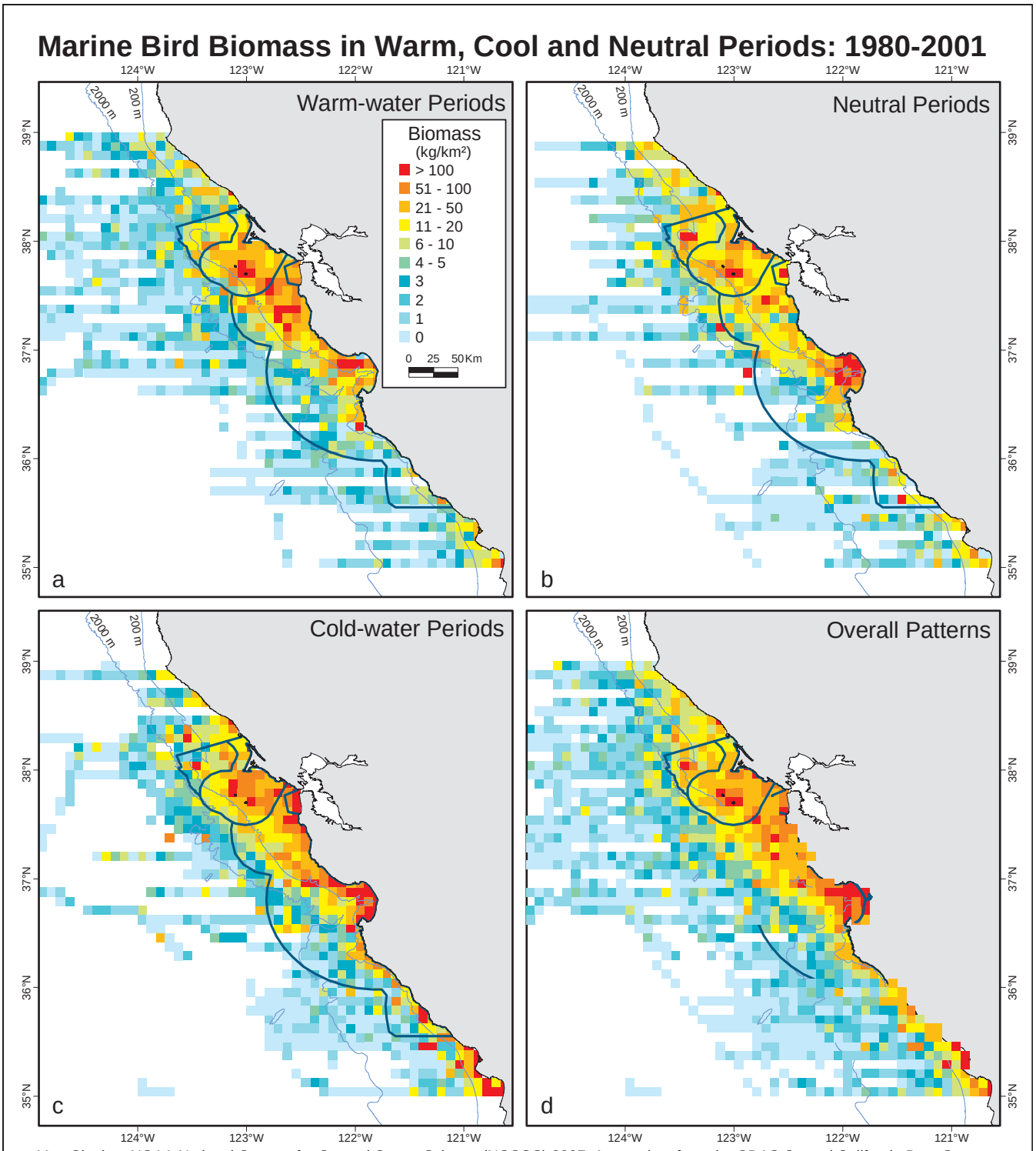
For the warm-water conditions (including El Niño) map, the following seasons and years were used: Davidson Current Season - 1981, 1983, 1984, 1992, 1993, 1994, 1996, and 1998; Upwelling Season - 1985, 1987, 1992, 1993, 1995, and 1998; and Oceanic Season - 1983 and 1997. For the "neutral" conditions map, 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.



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 3.44. 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.

Calculating Marine Bird Biomass Density for Different Temperature Periods. 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.

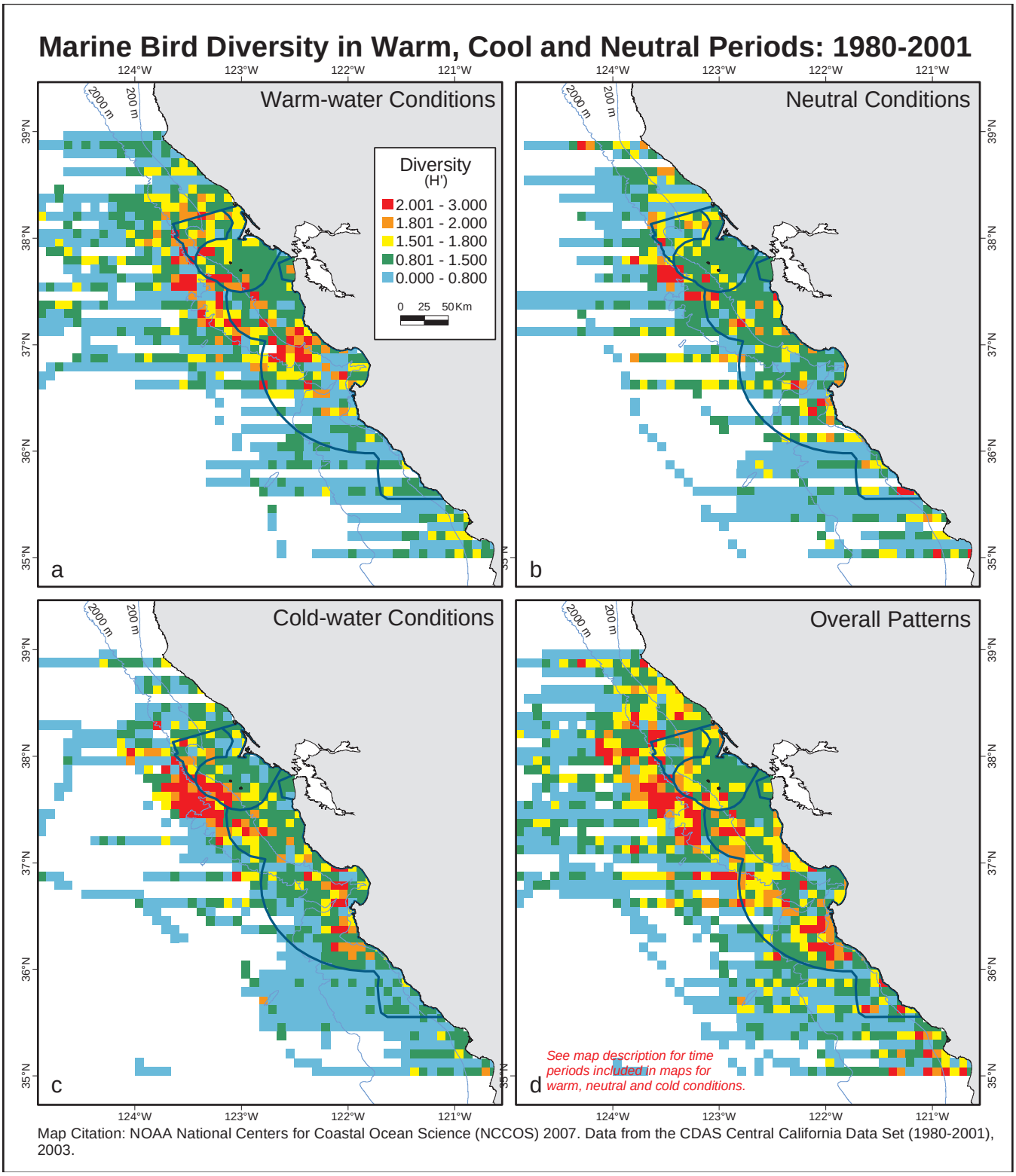


Figure 3.45. Marine bird diversity in warm, cold and neutral periods: 1980-2001.

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.

Calculating Marine Bird Diversity during Different Temperature Conditions. 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.

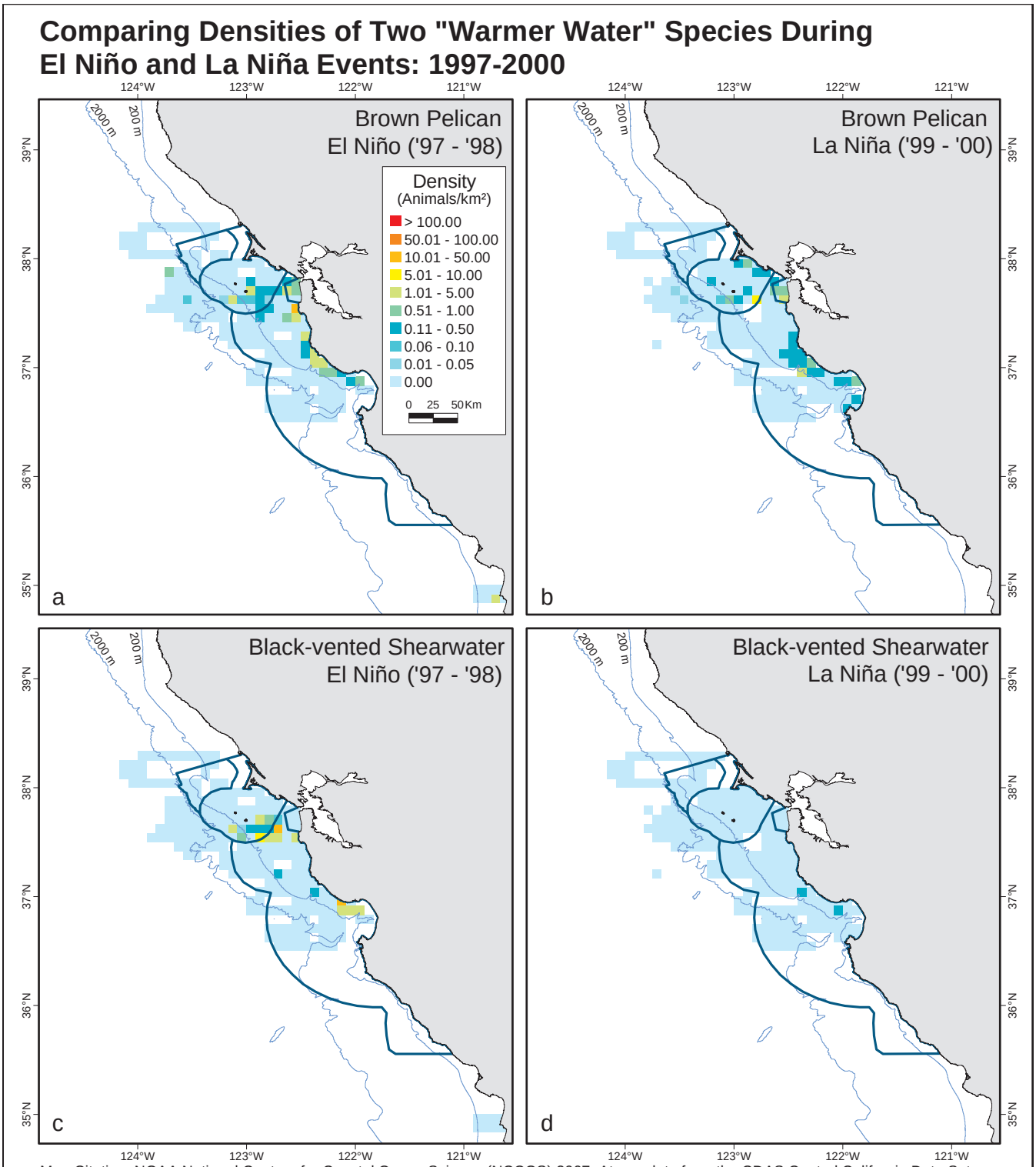


Figure 3.46. Comparing densities of two “warmer water” marine bird species during El Niño and La Niña events: 1997-2000.

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.

Estimating Density for the Two Temperature Periods. 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.

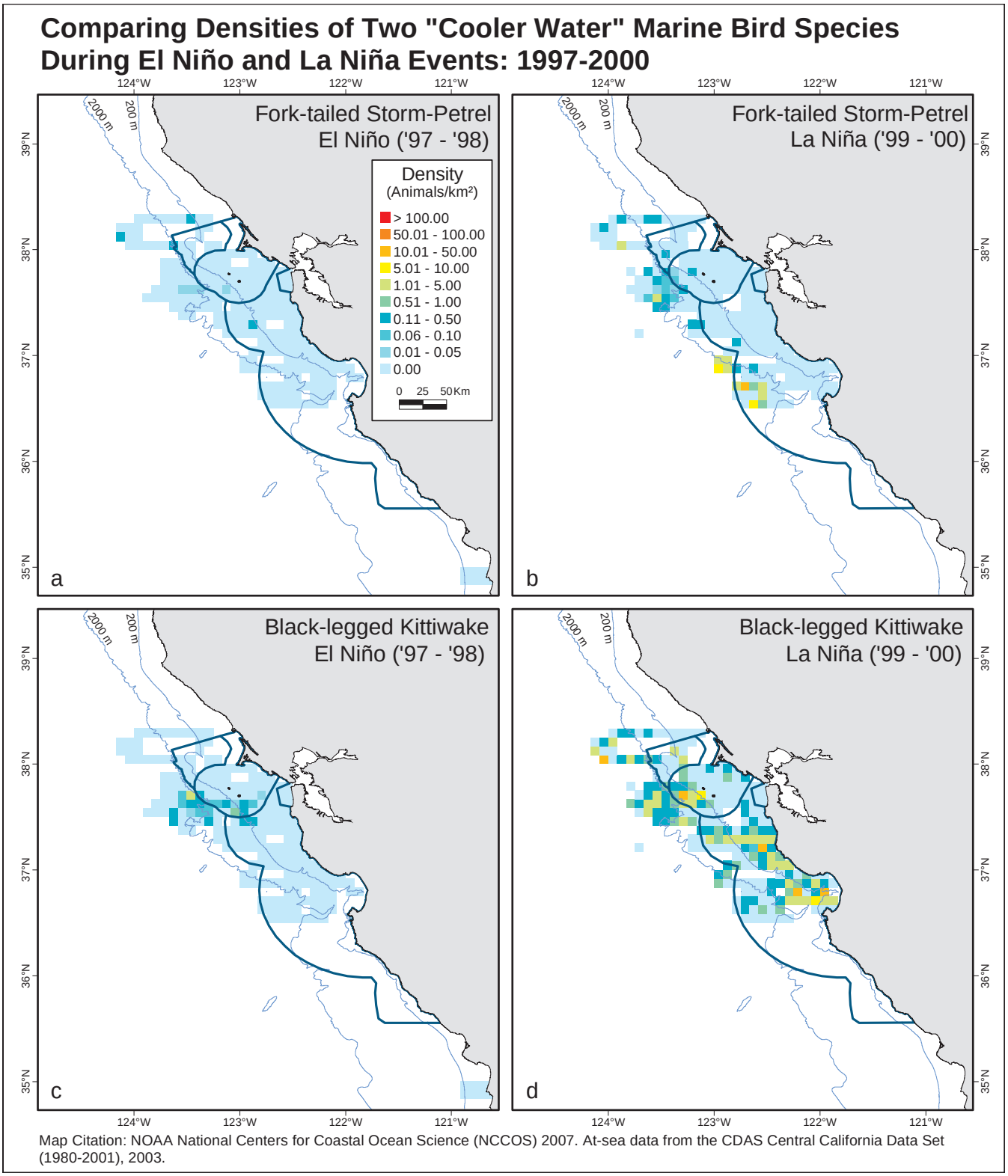


Figure 3.47. Comparing densities of two “cooler water” marine bird species during El Niño and La Niña events: 1997-2000.

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.

Estimating Density for the Two Temperature Periods. 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 Sanc-tuaries	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 Escarp-ment	Farallon Ridge	San Fran-cisco Bay Plume	Pioneer Sea mount	Pioneer Canyon	Ascen-cion, Cabrillo, & Año Canyons	Pt. Ano Nuevo	Mon-terey Canyon	Mon-terey Bay Inshore	Carmel Canyon	Pt. Sur Slope	Pt. Sur Shelf	David-son Sea mount	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.

	Biomass/Density			Diversity		
Area	**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.

Human Impacts to Marine Birds in the Study Area. 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.

MAJOR CHAPTER CONTRIBUTORS

David Ainley, H.T. Harvey and Associates (lead)
Janet Casey, R.G. Ford Consulting Co.
Tracy Gill, NCCOS, NOS, NOAA
R. Glenn Ford, R.G. Ford Consulting Co.
Jamie Higgins, NCCOS, NOAA
Wendy Willams, R.G. Ford Consulting Co.
Gerry McChesney, U.S. FWS, San Francisco Bay National Wildlife Refuge Complex
Lisa Ballance, SWFSC, NOAA
Harry Carter, Carter Biological Consulting
Larry Spear, H.T. Harvey and Associates
Ken Buja, NCCOS, NOAA

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.

Phase I Map Development Workshop: Participants/Reviewers:

David Ainley, H.T. Harvey and Associates
Sarah Allen, Point Reyes National Seashore, U.S. National Park Service
Lisa Ballance, Southwest Fisheries Science Center, NOAA
Janet Casey, R.G. Ford Consulting Co.
Glenn Ford, R.G. Ford Consulting Co.
Carol Keiper, Oikonos Ecosystem Knowledge
Nora Rojek, formerly of California Department of Fish and Game
Jan Roletto, Gulf of the Farallones National Marine Sanctuary Program, NOS, NOAA

Ed Ueber, NOAA, Gulf of the Farallones National Marine Sanctuary Program, NOS, NOAA
And several other members of the NOAA project team and sanctuary programs.

Reviewers of the Phase I Bird Section:
Sarah Allen, Point Reyes National Seashore, U.S. National Park Service
Scott Benson, Southwest Fisheries Science Center, NMFS, NOAA
Karin Forney, Southwest Fisheries Science Center, NMFS, NOAA
Doug Forsell, Chesapeake Bay Program, U.S. Fish and Wildlife Service
Laird Henkle, H.T. Harvey and Associates
David Hyrenbach, Duke University Marine Lab
Hannah Nevins, Oikonos Ecosystem Knowledge
Jan Roletto, Gulf of the Farallones NOAA's Marine Sanctuary Program, NOS, NOAA
Franklin Schwing, Southwest Fisheries Science Center, NMFS NOAA
And several other members of the NOAA project team and sanctuary programs.

Reviewers of the Phase II Marine Bird Chapter:
W. Breck Tyler, University of California, Santa Cruz
Hannah Nevins, Oikonos Ecosystem Knowledge
Gerry McChesney, U.S. FWS, San Francisco Bay National Wildlife Refuge Complex
And several other members of the NOAA project team.

PERSONAL COMMUNICATIONS

Harry R. Carter, U.S. Geological Survey
Gerry McChesney, San Francisco Bay National Wildlife Refuge Complex, U.S. FWS
Laird Henkel, H.T. Harvey and Associates,
Michelle Hester, Oikonos
Deborah Jaques, Pacific Eco Logic,
Steve Hampton, California Department of Fish and Game
Bill Sydeman, PRBO Conservation Science
Joelle Buffa, Farallon National Wildlife Refuge, U.S. FWS
C. Harrison, Hunton and Willams

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