

The California Current Marine Bird Conservation Plan Chapter 3

Seabird Habitats of the California Current and Adjacent Ecosystems



Photo: Dave Gardner, PRBO Conservation Science

THE David &
Lucile Packard
Foundation



A publication of PRBO Conservation Science
www.prbo.org



The California Current Marine Bird Conservation Plan Chapter 3

Seabird Habitats of the California Current and Adjacent Ecosystems

Version 1.0

**Edited By:
Kyra L. Mills, William J. Sydeman
and Peter J. Hodum**

Marine Ecology Division
PRBO Conservation Science
4990 Shoreline Highway
Stinson Beach, CA 94970

April 2005

CHAPTER 3. SEABIRD HABITATS OF THE CALIFORNIA CURRENT AND ADJACENT ECOSYSTEMS

The coastal and offshore areas of the California Current region provide a variety of feeding, roosting, and nesting habitat for seabirds. The abundant food in the California Current, resulting from high ocean primary productivity, attracts millions of seabirds that breed and/or migrate throughout this region annually, with the non-breeders outnumbering the breeders year-round (1, 2).

Marine habitat characteristics and “quality” vary spatially and temporally, within and between seasons, years, and decades. Naturally occurring climate cycles in the world’s oceans and atmosphere operate at several scales and strongly influence the CCS and, therefore, the ocean habitats that seabirds depend on for their survival, including habitat-specific productivity and predator-prey relationships. While the mechanisms of climate change are not well understood, it seems clear that climate cycles and change in ocean habitats, prey availability, and prey quality are critically linked to changes in seabird demography.

In this section we summarize both terrestrial and marine habitat used by seabirds for breeding, roosting, and feeding in the CCS region. Oceanographic and atmospheric processes leading to marine climate variability on multiple temporal scales, and the response of seabirds to this variability, are discussed in detail in Chapter 5.

3.1 TERRESTRIAL HABITAT

(A1). General Habitat Description

The coastal and offshore areas of the West Coast provide a variety of roosting and nesting habitat, including islands, rocks, cliffs, headlands, beaches, estuaries, and even human-made structures such as bridges, dikes, dredge spoil islands, jetties, and breakwaters. Islands, however, are disproportionately important sites for roosting and nesting.

There are numerous islands off the west coast of North America, several of which contain seabird colonies exceeding 100,000 breeding birds. Numerous bays and estuaries along the mainland coast also provide critical habitat for many seabird species. The largest of these are Puget Sound in northern Washington, the Columbia River estuary on the border between Oregon and Washington, and San Francisco Bay in California.

These protected coastal areas provide important breeding habitat, especially for coastal terns and gulls. East Sand Island in the Columbia River estuary supports the largest Caspian Tern colony in the world and the largest Double-crested Cormorant colony in the Pacific.

a. Islands - - Islands, by their very nature, are isolated and typically provide seabirds with a protected habitat where they can breed and roost with little danger and few disturbances. The largest seabird colonies and the vast majority of breeding seabirds are found on islands, especially on those that are small to medium-sized. Islands are quite variable and have defining features that affect the species and number of seabirds that utilize them, such as size, shape, height, geological composition, micro-habitat characteristics, distance from shore, distance to feeding areas, presence or absence of soil, extent and depth of soil, plant communities, animal communities, and history of bird use.

The smaller islets and rocks often support larger numbers of seabirds. Smaller islands are often uninhabited and free of mammalian predators such as rats, cats, dogs, foxes, and coyotes, although this is not always the case. Included in the island category, but unique, are the low islands found in bays and estuaries. These islands form naturally when sediments fall out of suspension in the slower moving waters of the estuary. They are much more dynamic in shape, size, and composition than the rocky, marine islands and in a natural system islands appear, disappear, and continually change shape. Scoured by

winter floods, these islands often support little or no vegetation and provide important nesting and roosting habitat for coastal species, especially terns, gulls, and Double-crested Cormorants.

b. Cliffs and Headlands - The relatively inaccessible cliffs and headlands along the mainland coast and on larger islands are also an important habitat for seabirds. It is difficult for predators and humans to access these sites, so disturbance and predation are low. This habitat is most important for cormorants, Common Murres, and Pigeon Guillemots.

c. Old Growth Forests - The old growth forests of the Pacific Northwest are the primary breeding habitat for Marbled Murrelets.

d. Wetlands and Estuaries - This type of habitat provides critical nesting and feeding opportunities to numerous resident and migrant plant and animal species.

e. Artificial Structures - Artificial structures can create usable habitat for both nesting and roosting. Caspian Terns are remarkably adaptable and can nest on artificial dredge-spoil islands and other artificial structures (3). The California Least Tern is also very opportunistic; one colony breeds on the former Naval Air Station, Alameda, California on an airplane runway (M. Elliott, pers. comm.). Double-crested Cormorants are another good example of a species that can thrive on human structures. In the San Francisco Bay area, this species breeds on several of the most heavily used bridges (4).

(A2). Habitat Characteristics by Region

a. California

For characterization purposes the state can be divided into three sections: the north coast is typified by rugged headlands, steep cliffs, and exposed beaches; in the central coastal area, rocky shorelines and sandy beaches dominate the landscape; and in the south, the most developed and heavily populated segment, sandy beaches predominate. Large islands are found off southern California (Channel Islands), and thousands of smaller rocks and islands dot the coastline in central and northern California. Major embayments, which provide key nesting, roosting, and feeding habitat, include Humboldt, Tomales, San Francisco, Morro, and San Diego bays.

Carter et al. (5) estimated approximately 643,000 breeding seabirds in the state and identified several important areas, based on high concentrations of breeding birds. The most important breeding areas in the state are Castle Rock (19% of the state breeding population), Farallon Islands (24%), and the northern Channel Islands (13%).

Castle Rock National Wildlife Refuge (NWR) is a 5.7-hectare island situated less than 1 km off the northern California coast. This sparsely vegetated island, ringed with steep cliffs, has a large grassy area with thick soil which is used extensively by five species of burrow nesters (6).

Habitat heterogeneity on the Farallon Islands NWR, a group of offshore granitic islands 42 km west of the Golden Gate Bridge in central California, also allows for a diverse avifauna. The Farallones, at only 85 hectares, are home to the largest and most diverse assemblage of breeding seabirds in the state. Twelve species breed on the islands (5), including the largest colonies of Western Gull and Brandt's Cormorant in the world (7) and one of the largest Ashy Storm-Petrel colonies.

The Channel Islands, located within the highly productive Southern California Bight, are a group of eight large islands, ranging in size from 260-24,910 hectares (91,093 hectares total). The four northern islands (San Miguel, Santa Rosa, Santa Cruz¹, and Anacapa) and Santa Barbara Island are part of the Channel Islands National Park. The islands have a variety of habitats: shrub and grass-covered hills, steep canyons, sandy and rocky beaches, gentle sloping faces, steep cliffs, and some relatively flat areas. All except Anacapa have associated islets and rocks.

These islands support 12 breeding species, including the state's entire population of Brown Pelicans, Xantus's Murrelets, and Black Storm-Petrels, and a large proportion of the global Ashy Storm-Petrel population (5).

¹ Only the eastern 24% of Santa Cruz Island is included in the National Park, the western 76% is owned and managed by The Nature Conservancy

b. Oregon

The Oregon coastline is a fairly direct north/south line extending nearly 1,000 km, and, compared to Washington and California, has few large bays or inland waters, with the exception of the Columbia River estuary.

Coos Bay, in the southern portion, is the largest bay in the state, followed by Tillamook Bay in the north. The coastline consists of rocky and sandy beaches interspersed with rocky headlands and steep cliffs. Two extensive stretches of sand beaches with associated dune systems are found in the central and northern regions of the state: Oregon Dunes National Recreation Area between Coos Bay and Florence and the Clatsop Plains located between Tillamook Bay and the Columbia River. These sandy stretches of coastline with few offshore rocks support very few nesting seabirds but provide important beach roost habitat.

The Columbia River estuary has both natural and human-made dredge-spoil islands that provide ample nesting and roosting habitat for seabirds. The largest Caspian Tern colony in the world and the largest Double-crested Cormorant colony along the Pacific coast are found here. In the Columbia River estuary, East Sand Island is a low, natural island that has been augmented with dredge spoils and is owned by the Army Corps of Engineers.

Oregon has approximately 1,400 offshore islands, rocks, and reefs (R. Lowe, pers. comm.). These rocks and islands are mostly rocky with steep cliffs. The relatively few islands that have well-developed soils are where large numbers of burrow-nesting Leach's Storm-Petrels breed. Major colonies with greater than 100,000 nesting seabirds include: Three Arch Rocks, Goat Island, Whaleshead Island Complex, and Crook Point Complex. Leach's Storm-Petrels and Common Murres are the most abundant species at these colonies.

c. Washington

Washington is home to approximately 300,000 seabirds belonging to 16 species (8). Seabird colonies are mostly found along the outer coast of the Olympic Peninsula, from Copalis Beach to Cape Flattery (9).

Washington has two distinct coastlines: the outer coast, from Cape Flattery to the Oregon border, and the inner coast, which includes the Strait of Juan de Fuca, the San Juan Islands, and the Puget Sound. Habitat along Puget Sound consists of primarily low elevation and relatively flat rocks and islands. The San Juan Islands are large, rocky, and have human inhabitants.

Along the outer coast, the two large bays, Willapa and Grays Harbor, are located in the southern half of the state. Sand beaches with associated dunes dominate this southern coastline.

The majority of the nesting seabirds are found in the northern half of the state on the islands of the Maritime National Wildlife Refuge and the San Juan Islands. This northern coast is more rugged and rocky with numerous offshore rocks. Washington has 600-800 offshore rocks and islands, approximately 550 of which are in the National Wildlife Refuge system (K. Ryan, pers. comm.).

d. Mexico's Baja California

There are 19 main islands off the Pacific coast of Baja California that support breeding seabirds and provide roosting habitat (10) (Figure 3.1). There are an unknown number of islets and rock stacks associated with these islands, some of which provide additional roosting and nesting habitat. All of the Pacific islands of Baja California provide roosting habitat for marine birds.

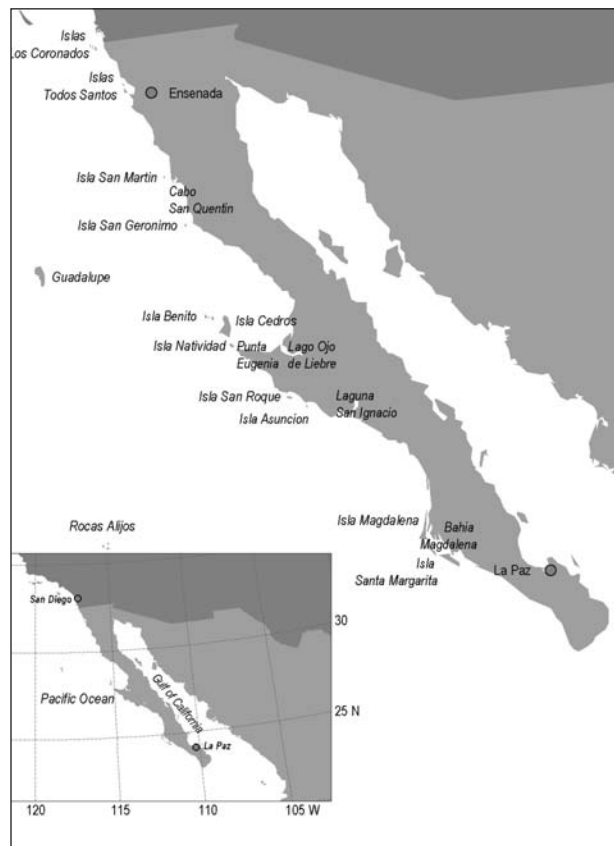


Figure 3.1 – Map of Pacific Baja California islands. Main offshore islands, cities, and geographic features are shown.

In general, numbers and distribution of roosting birds are poorly documented as the focus for researchers has been quantifying numbers of breeding birds. San Martin, San Jeronimo, Asunción, and San Roque islands all support several thousand or more roosting Brown Pelicans, with over 5,000 roosting pelicans recorded on San Martin in September 2002 (B. Keitt, pers. obs.). San Martin, Natividad, Asunción and San Roque islands support large numbers of roosting Double-crested and Brandt's Cormorants.

The main types of seabird nesting habitat on the Baja California Pacific islands are scree and boulder slopes for crevice nesters, sandy flats for burrow nesters and surface nesters, open slopes and ridges for surface nesters, and shrubs and mangrove trees for above ground nesters. Steep cliffs and caves also provide marine bird habitat on some islands, but not to the extent seen on the California Channel Islands. A brief description of each habitat follows:

Scree and boulder slopes – These slopes provide habitat for Least and Black Storm-Petrels, Xantus's and Craveri's Murrelets, Cassin's Auklets, and Black-vented Shearwaters. This is the main habitat type on Los Coronados Islands and is in short supply on Todos Santos Islands. Virtually all of San Martin Island is scree/lava boulder habitat; however, for unknown reasons, few seabirds occupy this habitat. There is no evidence of storm-petrels using the island and Xantus's Murrelet populations are thought to be very small. San Jeronimo has very limited crevice habitat, restricted to the sandstone bluffs at the top of the island. The San Benito Islands provide extensive scree habitat on all three islands. Although Guadalupe Island and its associated islets have extensive scree habitat, its use by seabirds is only documented on Afuera Islet, where Black-vented Shearwaters, Xantus's Murrelets, and Leach's Storm-Petrels breed. Natividad, Asunción, San Roque, Magdalena, and Margarita all have very little scree habitat.

Sand and soil habitat – Natividad, San Jeronimo, San Benito, and parts of Guadalupe Island provide vast expanses of sandy or soil habitat for burrow nesters. Black-vented Shearwaters on Natividad nest almost exclusively in stabilized sand dunes, now covered by the introduced iceplant, *Mesembryanthemum crystallinum*. Cassin's Auklets on San Jeronimo and San Benito, and Leach's Storm-Petrels on San Benito use sandy soil for digging burrows. On Guadalupe, the Guadalupe Storm-Petrel and Leach's Storm-Petrel dug burrows in the soil beneath the once extensive cypress forests. It is unknown whether Leach's still utilize this habitat on the main island.

Shrub habitat – This type of habitat is available primarily on San Martin and Todos Santos Islands. Large numbers of Double-crested Cormorants and Brown Pelicans use the atriplex bushes along the north and east sides of San Martin Island. Double-crested Cormorants also use the atriplex habitat to a lesser extent on Todos Santos South. The only tree habitats in the region are the vast mangrove areas in Magdalena Bay, encompassing parts of Margarita and Magdalena islands. Magnificent Frigatebirds utilize these trees as nesting habitat on Margarita Island. About 1,500 Double-crested Cormorants breed in the mangrove areas around the islands and throughout Magdalena Bay.

Table 3.1 – List of islands in Pacific Baja California, their main habitat, and seabird species that use the island. (BLSP = Black Storm-Petrel, BRPE = Brown Pelican, BVSH = Black-vented Shearwater, CAAU = Cassin’s Auklet, CRMU = Craveri’s Murrelet, DCCO = Double-crested Cormorant, GUSP = Guadalupe Storm-Petrel, LESP = Leach’s Storm-Petrel, XAMU = Xantus’s Murrelet, MAFR = Magnificent Frigatebird).

Island or Group of Islands	Main Habitat Types	Species
Los Coronados	scree and boulder slopes	LESP, BLSP, XAMU, CRMU, CAAU, BVSH
Todos Santos	shrub	DCCO
San Martin	scree/lava boulder, shrub	DCCO, BRPE
San Jeronimo	sand and soil	CAAU
San Benito	scree; sand and soil	CAAU, LESP
Guadalupe	scree; sand and soil	GUSP, LESP
Islote Afuera	scree	BVSH, XAMU, LESP
Natividad	sand and soil	BVSH
Asunción*	scree and boulder slopes	LESP, BLSP, XAMU, CRMU, CAAU, BVSH
San Roque*	scree and boulder slopes	LESP, BLSP, XAMU, CRMU, CAAU, BVSH
Magdalena*	mangrove	DCCO
Margarita*	mangrove	MAFR, DCCO

* Indicates south of the CCS boundary as defined in this plan

Table 3.2 - Status and number of breeding individuals on the Channel Islands. The most recent population estimates available are given with the citation in the superscript. Un-italicized font indicates that the estimate is based on a direct nest count or standard sampling method. Italicized font indicates that the estimate is based on an incomplete or preliminary census. Where extirpated populations are listed (E), citations for historic breeding records are given. PE, possibly extirpated, possibly occurred historically; B, breeder, no population estimate available; P, probable breeder, breeding suspected but not confirmed.

	San Miguel	Santa Rosa	Santa Cruz	Anacapa	Santa Barbara	Santa Catalina	San Nicolas	San Clemente	Total Extirpated	populations
Leach's Storm-Petrel (<i>Oceanodroma leucorhoa beali</i>)	114 ^a				204 ^a				318	0
Ashy Storm-Petrel (<i>Oceanodroma homochroa</i>)	1354 ^a		281 ^a		1460 ^a	<50 ⁱ		50 ⁱ	3195	0
Black Storm-Petrel (<i>Oceanodroma melania</i>)	P ^a				274 ^a			P ^a	274	0
Brown Pelican (<i>Pelecanus occidentalis</i>)	E ^{b,c,d}		E ^g	10680 ^a	1236 ^a				11916	2
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)	552 ^a		E ^a	720 ^a	1191 ^a	E ^a			2463	2
Brandt's Cormorant (<i>Phalacrocorax penicillatus</i>)	15700 ^a	4650 ^a	3140 ^a	63 ^a	667 ^a		5089 ^a	56 ^a	29365	0
Pelagic Cormorant (<i>Phalacrocorax pelagicus</i>)	691 ^a	1162 ^a	460 ^a	328 ^a	46 ^a				2687	0
Western Gull (<i>Larus occidentalis</i>)	1892 ^a	170 ^a	1236 ^a	10274 ^a	7678 ^a	156 ^a	6038 ^a	218 ^a	27662	0
Common Murre (<i>Uria aalge</i>)	E ^{a,b,c}								0	1
Pigeon Guillemot (<i>Cepphus columba</i>)	1114 ^a	287 ^a	1459 ^a	74 ^a	284 ^a				3218	0
Rhinoceros Auklet (<i>Cerorhinca moncerata</i>)	19 ^a				PE ^a				19	0-1
Tufted Puffin (<i>Fratercula cirrhata</i>)	10 ^a		E ^{a,g}	E ^{a,b,d,g}	E ^{a,g}				10	3
Xantus's Murrelet (<i>Synthliboramphus hypoleucus scrippsi</i>)	150 ^{a,f}		26 ^a	100-400 ^h	1544 ^a	P ^j		B ^j	1970	0
Cassin's Auklet (<i>Ptychoramphus aleuticus aleuticus</i>)	11584 ^a		736 ^a	2 ^{+,h}	156 ^a				12478	0
Total breeding individuals¹	33180	6269	7338	22391	14740	206	11127	324	95575	
Total breeding taxa (species/subspecies)	11-12	4	7	8	11	2-3	2	4-5	14	
Total extirpated taxa (species/subspecies)³	2	0	3	1	1-2	1	0	0	8-9	

- 1 Total breeding individuals calculated by adding estimates from all islands using the mean of the range where ranges of individuals are given.
- 2 Does not include historical extirpations where species/subspecies has since recolonized.
- 3 U.S. Fish and Wildlife Service, Endangered Species Program, <http://endangered.fws.gov/wildlife.html>.
- 4 California Department of Fish and Game, Natural Diversity Data Base, Species of Special Concern Reports, June 1999.
- 5 IUCN Red List of Threatened Species, Hilton-Taylor (2000). Sources: a (Carter et al. 1992), b (Willet 1910), c (Hunt et al. 1980), d (Grinnell 1915), e (Wright and Snyder 1913), f (Hunt et al. 1979), g (Howell 1917), h (McChesney et al. 2000), i (Nur et al. 1999), j (Drost and Lewis 1995).

There are five main wetland areas on the Baja peninsula that support breeding and roosting marine birds (11). In addition to being dominated by shorebirds and ducks that over-winter and some of these wetland areas support significant breeding and roosting colonies of seabirds. All information on peninsular sites is summarized from Massey and Palacios (11):

Punta Banda is a wetland located southeast of the town of Ensenada and primarily consists of a shallow estuary lined with pickleweed. It covers 2100 hectares and provides nesting habitat for Least Terns along its sandy beaches and wintering habitat for loons, grebes, gulls, terns, and shorebirds.

San Quintin Bay covers 12,060 hectares and provides breeding habitat for Least Terns. This large wetland is located west of the town of San Quintin and has extensive mud flats with low-lying flood plains extending to the east of the main bay. Laguna Figueroa, located about 15 km north of San Quintin Bay, once supported breeding Caspian and Forster's Terns until human activities in 1992 destroyed the marsh habitat.

Laguna Ojo de Liebre (Scammon's Lagoon) is actually three separate wetlands with an area of 39,300 hectares adjacent to Vizcaino Bay. Double-crested Cormorants, Western Gulls, Least Terns, Caspian Terns, and Royal Terns are known to breed here.

Laguna San Ignacio covers 28,000 hectares and supports breeding colonies of Brown Pelicans, Double-crested Cormorants, Western Gulls, and Least, Royal, and Caspian Terns. The lagoon is the northern range of the red mangrove, which provides habitat for shrub nesters such as Double-crested Cormorants and Brown Pelicans.

Bahía Magdalena is formed by a series of long, narrow sand dune islands, stretching for 250 km along the west coast of the Baja peninsula. Large groves of mangroves thrive in the lagoons on the east sides of the islands. Brown Pelicans, Brandt's Cormorants, Double-crested Cormorants, and Least Terns all breed in the region. The mangroves to the southeast of Margarita Island support 20,000 pairs of Magnificent Frigatebirds.

(A3). Breeding Habitat

Nesting habitat of marine birds can be segregated into three categories: sub-surface, surface, and above-ground shrub or tree nesters. Nesting habitat preference, by species, is shown in Table 3.3.

Table 3.3 – Seabird species that breed in the CCS and typical breeding habitat (listed in alphabetical order).

COMMON NAME	SCIENTIFIC NAME	BREEDING HABITAT
Ancient Murrelet	<i>Synthliboramphus antiquus</i>	crevice, burrow
Arctic Tern	<i>Sterna paradisaea</i>	flat, rocky
Ashy Storm-Petrel	<i>Oceanodroma homochroa</i>	rocky crevices
Black Skimmer	<i>Rynchops niger</i>	flat, sandy
Black Storm-Petrel	<i>Oceanodroma melania</i>	crevice on talus/rock
Black-vented Shearwater	<i>Puffinus opisthomelas</i>	rock crevices, sandy burrows
Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>	cliff tops/slopes
Brown Pelican	<i>Pelecanus occidentalis</i>	mangroves/shrubs
California Gull	<i>Larus californicus</i>	rocky islands
Caspian Tern	<i>Sterna caspia</i>	open, sparse vegetation
Cassin's Auklet	<i>Ptychoramphus aleuticus</i>	soil burrows, rocky crevices
Common Murre	<i>Uria aalge</i>	cliff tops/slopes
Craveri's Murrelet	<i>Synthliboramphus craveri</i>	rocky islands, crevice
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	trees, ground, bridges, etc.
Elegant Tern	<i>Sterna elegans</i>	flat, sandy
Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	crevice on rocky islands
Forster's Tern	<i>Sterna forsteri</i>	ground in marshes
Glaucous-winged Gull	<i>Larus glaucescens</i>	rocky islands
Gull-billed Tern	<i>Sterna nilotica</i>	flat, sandy
Heermann's Gull	<i>Larus heermanni</i>	open ground
Horned Puffin	<i>Fratercula corniculata</i>	burrow/crevice on steep slopes/cliffs
Laysan Albatross	<i>Diomedea immutabilis</i>	open ground
Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>	soil burrows, rocky crevices
Least Storm-Petrel	<i>Oceanodroma microsoma</i>	crevice on talus/rock
Least Tern	<i>Sterna antillarum</i>	flat, sandy
Magnificent Frigatebird	<i>Fregata magnificens</i>	mangroves/shrubs
Marbled Murrelet	<i>Brachyramphus marmoratus</i>	old growth forests
Mew Gull	<i>Larus canus</i>	ground, rocky islands
Northern Fulmar	<i>Fulmarus glacialis</i>	cliffs
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	steep, rocky cliffs
Pigeon Guillemot	<i>Cephus columba</i>	rocky crevices on islands or coast
Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	soil burrows, rocky crevices
Ring-billed Gull	<i>Larus delawarensis</i>	ground, rocky islands
Royal Tern	<i>Sterna maxima</i>	flat, sandy
Thick-billed Murre	<i>Uria lomvia</i>	cliff tops/slopes
Tufted Puffin	<i>Fratercula cirrhata</i>	burrow/crevice on steep slopes/cliffs
Western Gull	<i>Larus occidentalis</i>	open ground
Xantus's Murrelet	<i>Synthliboramphus hypoleucus</i>	crevice

All of the procellariiforms (albatrosses, petrels, shearwaters, storm-petrels) and alcids (murrees, auklets, puffins) are sub-surface (crevice or burrow) nesters except the Laysan Albatross, a surface breeder; Common Murres, which breed on the relatively flat tops and ledges of offshore rocks and islands; and Marbled Murrelets, which nest in trees in old growth forests, up to 100 km inland from the coast.

Burrowing seabirds have limited nesting habitat given their restriction to coastal or offshore areas that are secure from predators and have an adequate supply of soil, allowing for burrow excavation. Smaller rocks and islands are often devoid of this habitat; therefore, these species are in greatest abundance on slightly larger islands. Of the burrow and cavity-nesting alcids, Tufted Puffins, Horned Puffins, Rhinoceros Auklets, Ancient Murrelets, and Cassin's Auklets typically excavate burrows.

In areas where little soil is available, several of the "burrowing" species (Cassin's Auklets, Rhinoceros Auklets, and Tufted Puffins) will occupy crevices in talus or in rock walls of old foundations; such is the case on the Farallon Islands (7). Pigeon Guillemots and Xantus's Murrelets are cavity nesters. However, guillemots will also utilize artificial cavities such as the underside of abandoned wooden piers and Xantus's Murrelets often nest under vegetation.

Of the burrow/cavity-nesting procellariiforms, Black and Ashy Storm-Petrels rarely excavate their own burrows, nesting instead in rocky cavities and crevices. Leach's and Fork-tailed Storm-Petrels prefer to excavate burrows but will nest in cavities, especially when soil is limited.

Cormorants, frigatebirds, pelicans, gulls, and terns are surface and above-surface nesters. Brown Pelicans and Magnificent Frigatebirds nest on vegetation, often small bushes in ravines or slopes of islands. Frigatebirds also often nest in mangroves. Double-crested Cormorants nest in a wide range of marine, estuarine, and inland habitats including vegetation, the barren surface of offshore islands, ledges of steep cliffs, low-lying estuarine islands and artificial habitats such as the San Francisco Bay bridges (4).

Brandt's Cormorants utilize similar cliff-top and slope habitats to Common Murres and nests of the two species are often interspersed, while Pelagic Cormorants typically nest on small ledges of steep cliff faces. The terns and gulls typically nest on low, flat, open habitats, such as islands in bays and estuaries or isolated beaches and dunes along the mainland coast. With the enormous loss and degradation of west coast beach and estuarine habitats, this group of species has increasingly used artificial

habitats, especially dredge spoil islands, salt pond dikes, levees, airstrips, rooftops, and parking lots.

Western and Glaucous-winged gulls are more marine, nesting primarily on offshore rocks and islands, although small colonies and individual pairs also nest along the mainland coast and on low islands and artificial habitats in bays and estuaries.

(A4). Roosting Habitat

Roosting allows birds to rest, preen and dry their plumage. Communal roosts may also serve social functions such as locations for mate selection and extra pair copulations and facilitate finding prey and increasing foraging efficiency. In addition, the plumage of some seabird species, such as pelicans and cormorants, is not waterproof and roosting on dry land is necessary for drying their feathers (12, 13).

Although most seabirds roost at colony sites, typical roost sites away from the colony differ by species group and include offshore rocks and islands, sand bars in estuaries and river mouths, and human-made structures such as pilings, jetties, and breakwaters (14). Gulls and terns tend to congregate on open sandy beaches, sandy islands, and sand bars. Cormorants also utilize sandy islands and sand bars but they rarely roost in large numbers on mainland beaches subject to frequent disturbance. They are also commonly found on rocky headlands, offshore rocks, coastal trees, and human-made structures such as jetties and transmission towers.

Some seabirds, especially pelicans, cormorants, gulls, and terns return to land regularly to roost, during both the breeding and non-breeding seasons. Pelicans and cormorants roost in similar habitats. Post-breeding pelicans migrate as far north as British Columbia and tend to roost in large numbers, congregating in roosts of up to thousands of individuals (15), with numbers peaking in the late summer and fall (16, 17). Currently, the largest known fall roost site in Oregon is at East Sand Island in the Columbia River estuary. In early September 2002, 10,852 pelicans were counted roosting on this low estuarine island (18).

Other important pelican roost sites include Marina del Rey Harbor, Purisima Colony (near Vandenberg Air Force Base), Año Nuevo Island, Southeast Farallon Island, Point San Pedro, and Elkhorn Slough in California and Grays Harbor in Washington (16-20).

Storm-petrels and alcid generally roost on land during the breeding season, but then remain at sea during the non-breeding season. There are two exceptions to this pattern: Ashy Storm-Petrels return to the Farallon Islands and occupy burrows during all months, although numbers are significantly lower during the non-breeding season (7), and Common Murres return to the breeding colonies in late fall or early winter to roost, but their attendance is intermittent (7).

By monitoring roost sites over a number of years, managers can develop a more complete picture of the health, status, and trends of some seabird populations. For example, when Brown Pelican populations were being affected by chlorinated hydrocarbons (i.e., DDT) in the 1960s and early 1970s, there were declines in roosting numbers throughout their range (21, 22). In addition, juveniles of many seabird species can be distinguished from adults during roost surveys, thereby giving an indication of breeding success (20).

3.2 MARINE HABITAT

The ocean is deceptively heterogeneous. To the layperson, the ocean appears as a featureless seascape, but in reality it is composed of distinct, interacting habitats. The oceanic habitats of seabirds are often associated with physical features, such as currents (e.g., the North and South Equatorial and California currents), fronts, and convergences.

Frontal zones are associated with hydrographic gradients in temperature and salinity (e.g., upwelling plumes, current edges) or bathymetric (e.g., islands and seamounts, canyons and shelf-slope regions) and coastal topographic attributes (e.g., headlands and promontories). These features promote the production and aggregation of prey for upper-trophic level predators such as foraging seabirds (23-27).

Upwelling, the vertical mixing of waters from above and below the thermocline, is an important mechanism supporting the production of seabird prey (macro-zooplankton and fish) in all regions of the Pacific Ocean and especially the CCS (28).

In this section, we provide (1) a general description of the North Pacific Ocean habitats utilized by seabirds and (2) a more detailed account of the California Current System. Naturally occurring climate cycles in the world's oceans and atmosphere strongly influence the California Current System (CCS) and central North Pacific Ocean (NPO) ecosystems and, therefore, the ocean habitats that seabirds depend on for their survival.

A description of large-scale oceanographic and atmospheric processes, operating at short and long timescales, which affect ocean habitats of seabirds and a review of the responses of seabirds to marine climate variability on multiple temporal scales will be discussed in more detail in Chapter 5.

(B1). General Description of Pacific Ocean Habitats

The geographic region broadly considered in this review is the North Pacific Ocean south of the Bering Sea with emphasis placed on the upwelling, coastal domain off the west coast of North America (British Columbia, Washington, Oregon, California, and Baja California).

The clockwise North Pacific subtropical gyre is the principal current gyre in the North Pacific Ocean. Four distinct biogeographic regions, with distinct temperature-salinity records, have been identified: (1) Bering Sea - coastal subarctic, (2) subarctic current - transition zone, (3) North Pacific central water, and (4) the upwelling domain (29).

High temperature and high salinity waters characterize the North Pacific central water; in general, ocean productivity in this region is low. The upwelling domain of the U.S. West Coast is dominated by the California Current System, which is one of five eastern boundary currents worldwide. All of these boundary currents are known for their diverse and abundant marine fish, mammal, and bird communities.

The oceanic habitats used by marine birds vary spatially with latitude, longitude, and distance from land. It is convenient to consider the ocean habitats of seabirds as (1) those associated with static bathymetric and land-based coastal structures, and (2) those associated with hydrography, where waters of varying characteristics converge and diverge. The scale of these habitats varies greatly from tens of kilometers for many static habitats to thousands of kilometers for large-scale hydrographic habitats (26).

a. Ocean Habitats Defined by Static Features

Along the U.S. West Coast, the continental shelf provides relatively shallow (<100 m) habitat for many coastal species such as terns, cormorants, and murre. It is widest (>75 km) in the Southern California Bight and relatively narrow (~15 km) off Washington and Oregon (30).

At the continental shelf break and slope, water depth increases from about 100 m to 2,000 m. Along the outer continental shelf, a frontal convergence zone often appears due to the transition from colder, less saline coastal waters to the warmer and saltier offshore waters; this change also leads to localized upwelling along the shelf break. The shelf break/slope fronts and convergences are important habitats for seabirds due to physical processes that promote productivity and/or concentrate prey. Many species of alcids (e.g., auklets) and shearwaters forage within the shelf break/slope convergences (31). Moreover, the shelf break/slope habitat is a complex region interspersed with submarine canyons, tables, sills, and seamounts.

These structures diversify the underwater topography, and provide additional features upon which the hydrographic environment interacts. Increased numbers of seabirds in the vicinity of seamounts and submarine canyons are likely caused by physical and biological processes that promote the aggregation of macro-zooplankton and fish (32). Beyond the continental shelf break and slope, the California Current flows in a southerly direction; the fastest currents are found 200 km to 500 km offshore (15). Beyond the California Current is the North Pacific central water bioregion.

b. Ocean Habitats Defined by Dynamic Features

Dynamic hydrographic habitats are those created when waters of varying thermohaline (salinity and temperature) characteristics converge and diverge. We refer to these habitats as “dynamic” because they change in size, shape, magnitude, and location through time. Some, such as the edges of major currents (California Current, North and South Equatorial), are persistent, but others are unpredictable and even ephemeral.

In the North Pacific Ocean, major, persistent ocean currents include the Kuroshio and Oyashio currents off Japan and Russia, the North Pacific and Subarctic currents, the California Current, and the North and South Equatorial currents. Along the edges of major currents, fronts form where seabird prey is concentrated by various mechanisms, such as concentrating planktonic prey or nutrients that enhance primary production.

The intensity (strength and flow rate) of major currents leads to the development of smaller-scale (10s - 100s km) meanders, eddies, and rings along the margins of currents. Offshore eddies are important habitats for some pelagic fish (e.g., sardines), but the importance of these habitats for foraging seabirds is unclear. Some eddies, like the Haida eddies off British Columbia, may calve from their parent currents and persist for years in the central North Pacific. Relatively large, persistent eddies in the northeastern Pacific Ocean are known to influence the migration of salmon (33); salmon and seabirds often occupy the same trophic level and feed on similar prey in the eastern North Pacific Ocean.

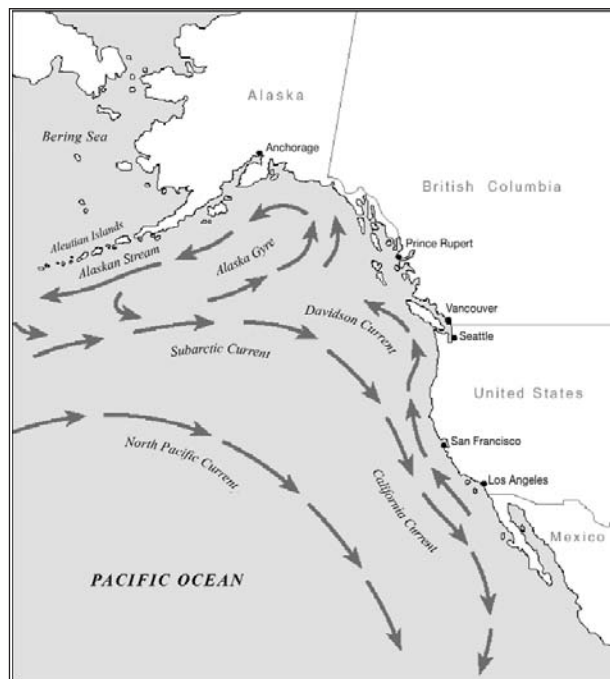
(B2). The Upwelling Domain: the California Current System

The California Current System (CCS) is one of the most biologically productive regions in the world. The main components of the CCS are the southward-flowing California Current, the northward-flowing (in the fall and winter) California Undercurrent (or Davidson Current), the northward-flowing Southern California Undercurrent, and the Southern California Countercurrent/Eddy (Figure 3.3).

Surface flow along the coast (north of Pt. Conception) is generally northward during the fall and winter, but there is a dramatic reversal or “spring transition,” as the current shifts to predominantly southward during the early spring and summer (74). Upwelling of cold, nutrient-rich waters along the coast is greatest in spring and summer, generally reaching a peak in May each year, but this varies substantially between years and with latitude.

Bathymetry, coastal topography, and weather all contribute to spatial and temporal variability in the system (e.g., change in upwelling intensity, formation of eddies and jets, etc.), and the conditions generalized above often reverse for short periods in response to environmental fluctuations (74).

Figure 3.3 – Map of the eastern Pacific, highlighting main ocean currents.



There are a number of upwelling “centers” in the CCS, regions where upwelling is persistent and unusually strong. Point Conception, Point Reyes, and Point Mendocino in California, and Cape Blanco, Oregon, are locales where upwelling is enhanced by coastal promontories and headlands (Figure 3.4).

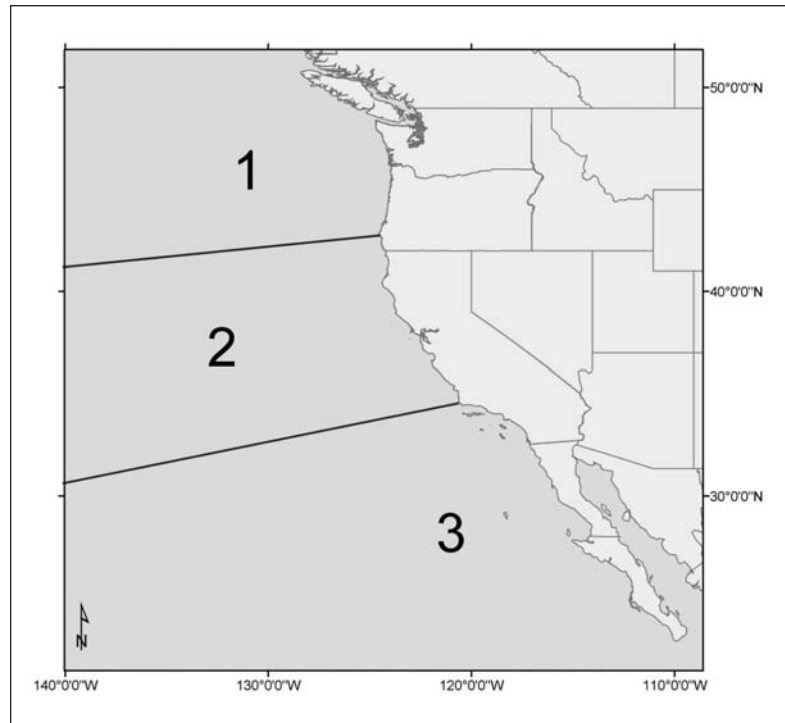
The resulting enrichment of surface waters leads to high levels of productivity in these regions. Moreover, because upwelling occurs in distinct areas, “plumes” of cold, nutrient-enriched waters intersect warmer waters offshore, creating convergence zones and fronts. Where upwelling fronts occur, plankton and fish are trapped, and seabird predators concentrate.

The CCS may be subdivided into three regions, each showing differences in physical and biological attributes (34) (Figure 3.5). In the northern California Current, extensive coastal downwelling in winter is associated with intense winter storms that pass through this region; upwelling occurs, but generally is restricted to the late spring and summer months. In the central CCS, from Pt. Conception, California, to Cape Blanco, Oregon, coastal upwelling occurs year-round (35). Off southern California and northern Baja California, the Southern California Bight represents a physical oceanographic and faunal barrier, separating the cold California Current subarctic waters from warmer subtropical waters to the south. This dynamic ecotone delineates the ranges of many subarctic and subtropical marine bird species (15).

This region is also characterized by substantial seasonal, interannual, and interdecadal variability in oceanographic conditions, which also may lead to changes in the seabird community structure. This variable oceanographic regime produces a convergence of range limits of seabird species with northern and southern affinities. The bight marks the southern range limit of four species with northern boreal affinities (Common Murre, Pigeon Guillemot, Tufted Puffin, and Rhinoceros Auklet) and the northern range limit of the Xantus’s Murrelet and two subtropical species (Black Storm-Petrel and California Brown Pelican). Relatively more subtropical taxa are also found in this region under warm ocean conditions (36).

Figure 3.4 – California Current Subdivisions based on physical and biological attributes.

1. Northern region: extensive coastal downwelling in winter; upwelling in late spring and summer.
2. Central region: coastal upwelling occurs year-round.
3. Southern region: Southern California Bight represents a barrier separating the cold subarctic California Current waters from warmer subtropical waters to the south.



The Southern California Bight region, which includes the Channel Islands, Los Coronados, Todos Santos, and San Martín islands, extends from Point Conception to Punta Baja (35° to 30° N) (37). The bight is formed by an eastward bend in the coastline south of Point Conception and is characterized by a wide continental shelf over which the cooler southerly-flowing California Current water merges with warmer northerly-flowing surface water of the California Countercurrent in a large retaining counter-clockwise eddy (38).

The Channel Islands and Pacific Mexican islands are positioned within the southern portion of the CCS, and are characterized by seasonal upwelling of cold, nutrient-rich water, periodic El Niño Southern Oscillation events, and decadal climate shifts (reviewed in Hickey (39)).

Specifically, the Channel and Mexican islands are encompassed within the two southern regions of the CCS characterized by different intensities and durations of upwelling, wind stress, coastal topography, bathymetry, and fresh water flow that influence the seasonal abundance and availability of prey resources (40) and the seabird assemblage in each region (41).

The western Channel Islands and San Nicolas are influenced by the cooler California Current waters and nutrient-rich upwelled waters off Point Conception during spring and summer (38). The southern and eastern Channel Islands are surrounded by warmer, subtropical waters carried north by the California Countercurrent (38). Wind-generated upwelling is most persistent off Point Conception and in the region between San Diego and Punta Baja where the coast is parallel to the along-shore southeast winds (42).

The southernmost region of the CCS, which includes the islands from San Jerónimo southward, is located between Punta Baja and Cabo San Lucas (30° to 23° N). Upwelling-favorable winds persist year-round and peak in spring (43). Upwelling is most intensive at the coastal prominences of Punta Baja, Punta Eugenia, and Punta Abreojos (42) and between Punta Eugenia and Cabo San Lazaro (41), where many seabird colonies are located. Coastal filaments are often formed near coastal promontories where upwelling jets diverge from the shelf, sending narrow streams of colder water seaward often several hundred kilometers across the warmer California Current flow (44).

The region south of Punta Eugenia is characterized by warmer surface waters resulting from thermal heating due to low cloud cover (43). At the southern tip of the Baja California peninsula, subarctic, subtropical, equatorial, and Gulf of California water masses converge to form the temperate/subtropical transition zone (45). Higher sea surface temperatures and the increasing influence of subtropical waters help to define the southern range limits of Brandt's Cormorants and Western Gulls and the beginning of a tropical seabird assemblage marked by nesting Magnificent Frigatebirds.

Differences in coastal topography and in upwelling intensity influenced by wind stress curl further divide the southernmost region into three subregions with different oceanographic characteristics: (a) a zone of maximal upwelling centered at Point Baja, (b) Vizcaino Bay with limited circulation and a seasonal anticyclonic eddy, and (c) the region south of Point Eugenia, marked by advection of warm subtropical and Gulf of California water, cyclonic eddy circulation, and the presence of a more tropical marine prey assemblage (46).

South of 30°N, persistent negative wind stress curl dominates the offshore region year-round (46). While positive wind stress curl can create open ocean upwelling away from the coast that enhances coastal upwelling, negative wind stress curl offshore creates downwelling of surface water (46). Therefore, in this region, nearshore coastal upwelling is dominant and is rarely enhanced by open-ocean upwelling.

In a unique region between Point Baja to Point Eugenia, the lobe of typically offshore negative wind stress curl extends inshore to within 10-20 km of the coast, and Vizcaino Bay effectively separates the water masses along the peninsula into distinct northern and southern components (46). Vizcaino Bay itself forms a semicircle 110 km in diameter and encompasses the broadest portion of the continental shelf, which narrows and breaks steeply west of Cedros Island to Point Abreojos (47). Anticyclonic eddy circulation in the bay is important for the retention and growth of larval fish and plankton, which might otherwise be advected offshore, thereby providing important prey resources for seabirds (46, 48).

(B3). Distribution and Abundance of Seabirds at Sea

Seabirds spend most of their life at sea, and it is from the sea that they derive their food; however, most seabird research has been conducted at colonies. Information on seabird distribution, abundance, and behavior at sea is fundamental to understanding seabird ecology and the formulation of scientifically sound solutions to conservation issues and threats. In addition, this at-sea information is essential for identifying actual or potential conflicts with fisheries activities.

Studies of seabirds at sea have revealed a number of important patterns, including both spatial and temporal changes in species distribution and abundance. Such information should be considered when developing long-term conservation strategies, including the design and establishment of marine protected areas.

In addition, knowledge of seabirds at sea is key to understanding and interpreting the important factors that influence seabird behavior, ecology, and population dynamics. This type of information is valuable to marine bird conservation as it contributes to the determination of species/community vulnerability to oil spills, fisheries interactions, and other anthropogenic factors that may affect seabird populations in the California Current.

In this section, we review information concerning the abundance, distribution, and diversity of seabirds at sea in the Pacific coastal upwelling domain of the West Coast, and how patterns of community organization and individual species dispersion vary seasonally and at longer timescales.

Seabird Patterns, Communities, and Assemblages

The distribution and abundance of seabirds at sea is influenced by oceanographic and biological processes operating at multiple temporal and spatial scales (26). At large spatial scales, greater than 1000s of kilometers, distinct seabird communities are associated with water masses characterized by different temperatures and salinities (29, 32, 49, 50). At smaller spatial scales, 1s to 100s of kilometers, marine birds are influenced by the locations of breeding colonies, distance from land, and physical and biological processes that aggregate prey and make it accessible to foraging seabirds (51-54).

Within the upwelling domain of the west coast of North America, the greatest ocean productivity occurs over the continental shelf, with moderate productivity over the shelf break/slope, and lowest productivity in offshore waters > 2000 m deep. Seabird biomass follows the same general pattern (2).

The high abundance of prey over the continental shelf attracts millions of seabirds that breed in, winter in, or migrate through this region annually (2, 15, 55). Seabird diversity and biomass are greatest during spring and fall migrations. In the winter, when birds found in offshore pelagic waters are mainly local breeders and visitors from northern and inland colonies, overall avifaunal density and diversity are lower (Table 3.4). Such onshore-offshore gradients in seabird assemblages have been documented off California and Washington (Table 3.4) (15, 56, 57).

Seabird communities and assemblages vary considerably within distinct oceanographic domains. In general, highly productive coastal regions sustain greater overall seabird densities than less productive pelagic waters (15, 50, 58). Greater numbers of diving seabirds, which often have high energetic requirements (59), are found in coastal areas along the U.S. West Coast, with the diving alcids and cormorants preferentially inhabiting areas of cool ocean temperatures and high chlorophyll concentrations (53).

In contrast, areas of lower ocean productivity of the equatorial Pacific Ocean sustain less diverse and abundant avifauna, dominated by species that often feed in flocks and procure food by surface-picking and plunge-diving (Table 3.4) (54, 58, 60). Moreover, many of these taxonomic groups (e.g., boobies, shearwaters, and terns) are surface or near-surface feeders (shallow divers) and they rely on underwater predators (tunas, dolphins, etc.) to drive prey to the surface where they become available to near-surface feeding seabirds (Table 3.4) (54, 58, 61, 62).

Individual Species

On the continental shelf, gulls, murre, and shearwaters are the dominant seabird taxa. The coastal avifauna is dominated by locally breeding species, such as Common Murres, Brandt's and Pelagic Cormorants, and Cassin's Auklets, but migratory visitors from the Southern Hemisphere are numerically dominant during much of each year.

The most abundant breeding seabird along the U.S. West Coast is the Common Murre, although it is second in abundance and biomass to Sooty Shearwaters, a Southern Hemisphere migrant which is the most abundant species overall (Table 3.5). Phalaropes migrate to the continental shelf in large numbers in spring and Laysan and Black-footed Albatrosses forage in these waters even when feeding chicks on the Hawaiian colonies. Short-tailed Albatrosses also forage in these cool productive waters.

Many seabirds, including shearwaters, phalaropes, and auklets appear to be attracted to thermal fronts (63), some associated with upwelling centers (2, 15). Moreover, several species that primarily breed inland and several others from more northerly regions (e.g., kittiwakes) move to the coastal region to over-winter. Migrants from inland include several gull species (California, Ring-billed, Bonaparte's, Mew, Herring), and Double-crested Cormorants (64). Migrant waterfowl from the north include loons (Common and Arctic), grebes (Eared, Red-necked), and scoters (Black and White-winged); these species are often found in nearshore areas. Beyond the shelf and slope region, Pterodroma petrels and storm-petrels (primarily Leach's) are the numerically dominant species in the summer, while Cassin's Auklets and phalaropes, along with Leach's Storm-Petrels, are dominant during the winter (Table 3.4).

During the breeding season, California Current seabirds are often found relatively close to their colonies, as they are limited in their foraging range by incubation and chick-feeding duties (53). After the breeding season, the majority of breeding seabirds along the U.S. West Coast remain in this region, although their distributions may shift north or south. Such species include Brown Pelicans, Ashy Storm-Petrels, Brandt's, Pelagic, and Double-crested Cormorants, and all of the alcids (Common Murres, Tufted Puffins, Rhinoceros Auklets, Pigeon Guillemots, and Cassin's Auklets).

Several species migrate out of this region after breeding, including most of the terns (Caspian, Elegant, Gull-billed, and Least). Forster's Terns disperse south to Mexico and Central America, although some remain in southern California. The majority of Black Storm-Petrels disperse to Central and South America, with a small portion remaining in California (64).

Temporal Variability in Seabirds at Sea

Variability in seabird community structure and individual species dispersion results from oceanographic variability. Short-lived increases in abundance of subtropical species, for example, are common during warming episodes off southern and central California. During the 1992 and 1997-98 El Niño events, southern species, such as the Black-vented Shearwater and the Pink-footed Shearwater, shifted their distributions northwards (36, 57).

At larger temporal scales, analyses of long-term (1980s - present) surveys have revealed shifts in the prevalence of subtropical versus subarctic species off the west coast of North America (36, 53, 64, 65). In particular, Sooty Shearwaters (36, 64) and other species with subarctic affinities, including Common Murres and Cassin's Auklets (53), have declined since the mid-1980s. These pervasive changes suggest that the avifauna of the West Coast indicate a shift from a "high-productivity" assemblage typical of eastern boundary upwelling systems to a "low-productivity" community similar to those inhabiting subtropical gyres (66, 67).

At sea, changes in seabird communities and populations in the CCS may be related to variability in the PDO, although results are unclear. Veit et al. (68), in studying the seabird community off southern California, reported that overall seabird abundance decreased by 40% between 1987-1994, mostly due to the 90% decline in the dominant cold-water species, the Sooty Shearwater. Hyrenbach and Veit (57) have extended these observations, noting that, since 1994, total seabird abundance and Sooty Shearwater numbers have remained consistently lower than during 1987-1994, suggesting that long-term changes to the ecosystem persist.

In central California, Ainley et al. (69) and Oedekoven et al. (53) demonstrated interannual and long-term avifaunal changes and declines in many cold-water, locally breeding species, including Common Murres and Cassin's Auklets.

The most parsimonious explanation for changes in seabirds at sea in southern and north-central California in the late 1980s is probably a response to ecosystem change at that time (-1989-1990), rather than a lagged response to the 1976-1977 regime shift. Wahl and Tweit (70) studied decadal trends in seabird populations off the coast of Washington, and demonstrated a decline in cold-water species and a concomitant increase in warm-water species over the past three decades.

Finally, in recent reports on the state of the California Current developed as part of the California Cooperative Oceanic Fisheries Investigation (71-73), combined colony and at-sea datasets have been used to investigate seabird response to a purported shift in the PDO in 1998-1999.

Colony data from the Farallon Islands clearly demonstrate an increase in productivity for six species of seabirds after 1998. Moreover, Schwing et al. (73) demonstrate not only an increase in mean reproductive performance after 1998 but also a decrease in variance. In contrast, the overall abundance of seabirds at sea in southern California has not changed simultaneously; numbers remain low when compared with the seabird communities of the late 1980s. However, in both 1999 and 2001, coldwater, subarctic species comprised a greater proportion of the avifauna. Future surveys will reveal if this represents a consistent long-term change in seabird community composition or an intermittent change associated with coldwater intrusions during these years.

Table 3.4 - Comparison of seabird assemblages of the North Pacific central water mass and the upwelling domain off the west coast of North America during summer (July - Aug.) and winter (Jan. - Feb.). Three feeding methods are considered: Surface-feeding (S), diving (D), and plunging (P).

<i>Variable</i>	Upwelling Domain		North Pacific Central Water		References
<i>Mean Bird Density (Birds / km 2)</i>	<u>Summer</u> 23	<u>Winter</u> 11	<u>Summer</u> < 2	<u>Winter</u> < 1	Wahl et al. 1989 Gould 1983 Tyler et al. 1993
<i>Prevalent Feeding Method (% Total Birds)</i>	Divers (80%) Surface Feeders (20%)		Plungers (55%) Surface Feeders (45%)		Wahl et al. 1989
<i>Numerically Dominant Species (Feeding Method)</i>	<u>Summer</u> SOSH (D) PFSH (S) WEGU (S)	<u>Winter</u> CAGU(S) NOFU (S) RHAU (D)	<u>Summer</u> BRNO (P) WTSH (S) SOTE (P)	<u>Winter</u> BFAL (S) BWPT (S) RTTR (P)	Gould 1983 Wahl et al. 1989 Tyler et al. 1993

BFAL – Black-footed Albatross

BRNO – Brown Noddy

BWPT – Black-winged Petrel

CAGU – California Gull

NOFU – Northern Fulmar

PFSH – Pink-footed Shearwater

RHAU – Rhinoceros Auklet

SOSH – Sooty Shearwater

SOTE – Sooty Tern

WEGU – Western Gull

WTSH – Wedge-tailed Shearwater

RTTR – Red-tailed Tropicbird

Table 3.5 - Comparison of conditions within offshore (depth > 2000 m) and onshore (depth < 2000 m) domains of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) grid in summer (July-Aug.) and winter (Jan.–Feb.), between May 1987 and Sept. 1998. Percent importance is defined as the proportional contribution to overall bird abundance. Table modified from Hyrenbach and Veit 2003.

<i>Variable</i>	Onshore		Offshore	
Chlorophyll Concentration (0 – 200 m) (mg chl / m ³)	<u>Summer</u> 41.20	<u>Winter</u> 41.67	<u>Summer</u> 27.89	<u>Winter</u> 27.54
Macrozooplankton Biomass (0 – 200m) (ml / 1000 m ³)	<u>Summer</u> 470.82	<u>Winter</u> 56.71	<u>Summer</u> 30.56	<u>Winter</u> 42.33
Seabird Density (Birds / km ²)	<u>Summer</u> 6	<u>Winter</u> 4	<u>Summer</u> 0.6	<u>Winter</u> 0.4
Numerically Dominant Bird Species (1987 – 98)	<u>Summer</u> SOSH PHAL WEGU	<u>Winter</u> CAGU CAAU BVSH	<u>Summer</u> LESP SOSH COPT	<u>Winter</u> LESP PHAL CAAU

BVSH – Black-vented Shearwater

CAGU – California Gull;

CAAU – Cassin’s Auklet;

COPT – Cook’s Petrel; **LESP**: Leach’s Storm-Petrel;

PHAL – Red and Red-necked Phalaropes;

SOSH – Sooty Shearwater;

WEGU – Western Gull

Table 3.6 - Mean at-sea density (birds/km²) of seabirds in the CCS during July and December, designation of breeding status (breeder or visitor), and total density (Sum Total). Species are ranked from highest overall (July and Dec.) density to lowest density. Table modified from Tyler et al. 1993.

Rank	Common Name	Scientific Name	Breeder/ Visitor	July	Dec.	SUM TOTAL
1	Sooty Shearwater	<i>Puffinus griseus</i>	V	33.8	0	33.8
2	California Gull	<i>Larus californicus</i>	V/B	0.1	14.1	14.2
3	Common Murre	<i>Uria aalge</i>	B	7.0	5.1	12.1
4	Phalarope spp.	<i>Phalaropus spp.</i>	V	5.6	0.9	6.5
5	Northern Fulmar	<i>Fulmarus glacialis</i>	V	3.0	3.4	6.4
6	Cassin's Auklet	<i>Ptychoramphus aleuticus</i>	B	3.3	2.7	6.0
7	Western Gull	<i>Larus occidentalis</i>	B	4.5	1.1	5.6
8	Rhinoceros Auklet	<i>Cerorhinca monocerata</i>	B	0.2	4.2	4.4
9	Pink-footed Shearwater	<i>Puffinus creatopus</i>	V	2.5	0	2.5
10	Herring Gull	<i>Larus argentatus</i>	V	0.1	2.4	2.5
11	Black-legged Kittiwake	<i>Rissa tridactyla</i>	V	0	2.4	2.4
12	Leach's Storm-Petrel	<i>Oceanodroma leucorhoa</i>	B	2.4	0.1	2.5
13	Fork-tailed Storm-Petrel	<i>Oceanodroma furcata</i>	B	1.8	0.2	2.0
14	Brandt's Cormorant	<i>Phalacrocorax penicillatus</i>	B	1.8	0.2	2.0
15	Pacific Loon	<i>Gavia pacifica</i>	V	0	1.4	1.4
16	Glaucous-winged Gull	<i>Larus glaucescens</i>	B	0	0.8	0.8
17	Black-footed Albatross	<i>Phoebastria nigripes</i>	V	0.9	0.1	1.0
18	Bonaparte's Gull	<i>Larus philadelphia</i>	V	0	0.9	0.9
19	Heermann's Gull	<i>Larus heermanni</i>	V	0.1	0.7	0.8
20	Brown Pelican	<i>Pelecanus occidentalis</i>	B	0.3	0.3	0.6
21	Tufted Puffin	<i>Fratercula cirrhata</i>	B	0.3	0	0.3
22	Buller's Shearwater	<i>Puffinus bulleri</i>	V	0.2	0	0.2
23	Common/Arctic Tern	<i>Sterna hirundo /S. paradisaea</i>	V	0.2	0	0.2
24	Ashy Storm-Petrel	<i>Oceanodroma homochroa</i>	B	0.1	0	0.1
25	Pomarine Jaeger	<i>Stercorarius pomarinus</i>	V	0	0.1	0.1
26	Xantus's Murrelet	<i>Synthliboramphus hypoleucus</i>	B	0	0.1	0.1
27	Ancient Murrelet	<i>Synthliboramphus antiquus</i>	V/B	0	0.1	0.1
28	Black-vented Shearwater	<i>Puffinus opisthomelas</i>	B	0	0.1	0.1
29	Laysan Albatross	<i>Phoebastria immutabilis</i>	V	0	0	0

3.3 RESEARCH AND MONITORING RECOMMENDATIONS

1. Work in cooperation with agencies to protect important seabird habitats from human disturbance and introduction of non-native species.
2. Develop and implement programs to eradicate introduced predators and prevent further predatory mammal introductions on islands.
3. Restore colonies that have been damaged by human disturbance and mammalian introductions. Develop a plan to restore and expand breeding populations on islands from which seabirds have been extirpated or reduced.
4. Regulate areas with high boat traffic, such as ferries, recreational boaters and kayakers, that affect seabird colonies.
5. Increase enforcement of airplane and helicopter ceiling regulations.
6. Monitor and evaluate effectiveness of artificial habitat (e.g., nest boxes) on populations of select species.
7. Continue to use social attraction methods as needed for restoration and management. Identify and monitor locations and species for which this technique may increase population size.
8. Facilitate projects that involve vegetation restoration for burrow-nesting seabirds.
9. Work to decrease attraction of egg and chick predators to seabird nesting habitats (e.g., the interaction of campgrounds with corvids and Marbled Murrelets in coastal forests).

3.4 CONSERVATION AND MANAGEMENT RECOMMENDATIONS

1. Identify important roosting and breeding habitats within the CCS, and their protection status.
2. Identify important historic breeding and roosting sites, the causes for change in use of these areas, and whether restoration is warranted.
3. Identify locations where introduced plants and animals limit seabird breeding opportunities.
4. Identify cases where seabird breeding is limited by interactions with overabundant species (e.g., gulls).
5. Identify areas of high boat or air traffic that cause potential or actual disturbance to seabird colonies.
6. Identify the principle predators at colonies, and those colonies that are most threatened by predators.
7. Identify major threats to seabirds during their migration through the CCS and/or at their wintering grounds.
8. Investigate the effects of native animal disturbance at seabird colonies (e.g., pelicans, geese, eagles, pinnipeds).
9. Evaluate the effects of reintroduction of eagles and falcons on seabird populations.

CHAPTER 3 LITERATURE CITED

1. Briggs, K. T. and E. W. Chu, 1986. Sooty shearwaters off California: distribution, abundance and habitat use. *Condor* 88: 355-364.
- 2., Tyler, V. B., et al., 1990. Seabird distribution and abundance in relation to oceanographic processes in the California Current System in *The Status, Ecology and Conservation of Marine Birds of the North Pacific*. Canadian Wildlife Service Special Publication, Ottawa, ON, Canada.
3. Wires, L.R. and F.J. Cuthbert, 2000. Trends in Caspian Tern numbers and distribution in North America: a review. *Waterbirds* 23: 388-404.
4. Rauzon, M. J., et al., 2001. *Population Size and Breeding Success of Double-crested Cormorants (Phalacrocorax auritus) on the Richmond-San Rafael Bridge, California, in 2000*. Unpublished Report. PRBO Conservation Science, Stinson Beach, CA.
5. Carter, H. R., et al., 1992. *Breeding populations of seabirds in California, 1989-1991*. US Fish and Wildlife Service.
6. Osborne, T., 1971. *Survey of seabird use of the coastal rocks of northern California from Cape Mendocino to the Oregon line*. Administrative Report No. 71-4. California Department of Fish and Game.
7. Ainley, D.G. and R.J. Boekelheide (eds.), 1990. *Seabirds of the Farallon Islands*. Stanford University Press, Palo Alto, CA.
8. Speich, S.M. and T.R. Wahl, 1989. *Catalog of Washington seabird colonies*. U. S. Fish and Wildlife Service Biological Report.
9. Briggs, K. T., et al., 1992. Seabirds of the Oregon and Washington OCS, 1989-1990 in *Oregon and Washington Marine Mammal and Seabird Surveys*. Final Report to the Pacific OCS Region, Minerals Management Service, U.S. Dept. of the Interior, Los Angeles, CA.
10. Wolf, et al., 2000. *Population size, phenology, and productivity of seabirds on Santa Barbara Island, 1999*. Final Report to Channel Islands National Park, Ventura, CA. Point Reyes Bird Observatory, Stinson Beach, CA.
11. Massey, B.W. and E. Palacios, 1994. Avifauna of the wetlands of Baja California, México: current status. *Studies in Avian Biology* 15: 45-57.
12. Rijke, A.M., 1970. Wettability and phylogenetic development of feather structure in water birds. *Journal of Experimental Biology* 52: 469-479.
13. Johnsgard, P. A., 1993. *Cormorants, darters, and pelicans of the world*. Smithsonian Institution Press, Washington D.C.
14. Pereska, D., 1996. *California Brown Pelican roost site and coast utilization survey at Vandenberg Air Force Base, Santa Barbara County, California*. Unpublished report.
15. Briggs, K., et. al., 1987. Bird communities at sea off California 1975- 1983. *Studies in Avian Biology* 11: 1-74.
16. Jaques, D. and C. S. Strong, 1998. *Seabird research and monitoring at Castle Rock National Wildlife Refuge, 1997*. Report to the Humboldt Bay NWR, U.S. Fish and Wildlife Service.
17. Collier, N., et. al., 2002. *Brown Pelican roost utilization along the coastal margin of Vandenberg Air Force Base, 1995, 2000, 2001*. Unpublished report. Point Reyes Bird Observatory, Stinson Beach, CA.
18. Wright, S.K., 2003. *BRPE on ESI 2002*. Unpublished Report. Oregon State University.
19. Briggs, K.T., et al., 1983. Brown pelicans in central and northern California. *Journal of Field Ornithology* 54: 353-373.

20. Capitolo, P.J., et. al., 2002. *Protocol for identification of areas used for counting seabirds from aerial photographs at the Southeast Farallon Islands*. Unpublished report. Humboldt State University, Arcata, CA.
21. Briggs, K.T., et al., 1981. Brown Pelicans in southern California: habitat use and environmental fluctuations. *Condor* 83: 1-15.
22. Anderson, D.W. and F. Gress, 1983. Status of a northern population of California Brown Pelicans. *Condor* 85: 79-88.
23. Pocklington, R., 1979. An oceanographic interpretation of seabird distributions in the Indian Ocean. *Marine Biology* 51: 9-21.
24. Schneider, D.C., 1982. Fronts and Seabird Aggregations in the Southeastern Bering Sea. *Marine Ecology Progress Series* 10: 101-103.
25. Schneider, D.C., 1990. Seabirds and fronts: a brief overview. *Polar Research* 8: 17-21.
26. Hunt, G.L.J. and D.C. Schneider, 1987. Scale-dependent processes in the physical and biological environment of marine birds. In *Seabirds: feeding Ecology and Role in Marine Ecosystems*. J.P. Croxall, (ed.). Cambridge University Press. Cambridge, MA.
27. Ribic, C.A. and D.G. Ainley, 1997. The relationship of seabird assemblages to physical habitat features in Pacific equatorial waters during spring 1984-1991. *ICES Journal of Marine Science* 54: 593-599.
28. Mann, K.H. and J.R.N. Lazier, 1996. *Dynamics of marine ecosystems*. Blackwell Science. Cambridge, MA.
29. Wahl, T.R., et al., 1989. Associations between seabirds and water-masses in the northern Pacific Ocean in summer. *Marine Biology* 103: 1-11.
- 30., Huyer, A., 1983. Coastal upwelling in the California system. *Progress in Oceanography* 43: 12: 259-284.
- 31., Oedekoven, C.S., et. al., 2001. Variable responses of seabirds to change in marine climate: California Current, 1985-1994. *Marine Ecology Progress Series* 212: 265-281.
32. Hunt, G.L. Jr., 1991. Marine ecology of seabirds in polar oceans. *American Zoology* 31: 131-142.
33. Hamilton, K. and L.A. Mysak, 1986. Possible effect of the Sitka eddy on sockeye and pink salmon migration off southeastern Alaska. *Canadian Journal of Fisheries and Aquatic Science* 43: 498-504.
- 34., Globec, U. S., 1992. Eastern Boundary Current Program. Report on Climate Change and the California Current
37. Ecosystem. *Global Ocean Ecosystems Dynamics*.
35. Bakun, A. 1975. Daily and weekly upwelling indices, West Coast of North America, 1967-73. U.S. Department of Commerce, NOAA Technical Report NMFS SSRF-693.
- 36., Veit, R. R., et al., 1996. Ocean warming and long-term change in pelagic bird abundance within the California
68. current system. *Marine Ecology Progress Series* 139: 11-18.
38. Hunt, G.L. Jr., et. al., 1980. Distribution and abundance of seabirds breeding on the California Channel Islands. In *The California Islands: Proceedings of a Multidisciplinary Symposium*. Santa Barbara Museum of Natural History. Santa Barbara, CA.
39. Hickey, B.M., 1998. Coastal oceanography of Western North America from the tip of Baja California to Vancouver Island. In *The Global Coastal Ocean: Regional Studies and Syntheses*. K.H. Brink (ed.). John Wiley and Sons. New York, NY.
40. Lavaniegos, B.E., et al., 1998. Long-term changes in zooplankton volumes in the California Current System: The Baja California region. *Marine Ecology Progress Series* 169: 55-64.

Chapter 3. Literature Cited

- 42., 46. Parrish, R.H., et. al., 1981. Transport mechanisms and reproductive success of fishes in the California Current. *Biological Oceanography* 1: 175-203.
44. Miller, A.J., et al., 1999. Observing and modeling the California Current System. EOS Transactions. *American Geophysical Union* 80: 533-539.
45. Roden, G. I., 1971. Large-Scale upwelling off Northwestern Mexico. *Journal of Physical Oceanography* 2: 184-189.
- 47., Lavaniegos, B.E., 1994. Dispersion and development patterns in larvae of *Nyctiphanes simplex* (*Euphausiacea*) in the upwelling region off Baja California. *Marine Ecology Progress Series* 106: 207-225.
- 48.
49. Jespersen, D., 1924. On the frequency of birds over the high Atlantic Ocean. *Nature* 114: 281-283.
50. Ashmole, N.P., 1971. Seabird ecology and the marine environment. In *Avian Biology*. D.S. Farner and J.R. J.R. King (eds.) Academic Press. New York, NY.
51. Schneider, D.C., 1997. Habitat selection by marine birds in relation to water depth. *Ibis* 139: 175-178.
52. Hunt, G.L. Jr., et al., 1999. *Physical processes, prey abundance, and the foraging ecology of seabirds*. Proceedings of the 22nd International Ornithological Congress. Johannesburg, South Africa.
54. Spear, L.B., et. al., 2001. Responses of seabirds to thermal boundaries in the tropical Pacific: the thermocline versus the Equatorial Front. *Marine Ecology Progress Series* 219: 275-289.
55. Ainley, D.G., 1976. The occurrence of seabirds in the coastal region of California. *Western Birds* 7: 33-68.
56. Wahl, T.R., et. al., 1990. Seabird distribution off British Columbia and Washington. In *The status, ecology and conservation of marine birds of the North Pacific*. Canadian Wildlife Service Special Publication, Ottawa, ON, Canada.
57. Hyrenbach, K.D. and R.R. Veit, 2003. Ocean warming and seabird assemblages of the California Current System (1987-1998): Response at multiple temporal scales. *Deep Sea Research II* 50: 2537-2565.
58. Ballance, L.T., et. al., 1997. Seabird community structure along a productivity gradient: importance of competition and energetic constraint. *Ecology* 78: 1502-1518.
59. Ellis, H.I. and G.W. Gabrielsen, 2002. Energetics in free-ranging seabirds. In *Biology of Marine Birds*. E.A. Schreiber and J. Burger (eds.) CRC Press. Boca Raton, FL.
60. Ainley, D.G., 1977. Feeding methods in seabirds: a comparison of polar and tropical nesting communities in the Eastern Pacific Ocean. In *Adaptations within Antarctic Ecosystems*. E. Llano (ed). Gulf Publishing Co., Houston, TX.
61. Harrison, C.S., 1990. *Seabirds of Hawaii*. Cornell University Press. Ithaca, NY.
62. Gould, P. J. and J. F. Piatt, 1990. Seabirds of the central North Pacific. In *The Status, Ecology, and Conservation of Marine Birds of the North Pacific*. K. Vermeer, K. T. Briggs, K. H. Morgan and D. Siegel-Causey (eds.). Canadian Wildlife Service Special Publication, Ottawa, ON, Canada.
63. Hoefel, C.J., 2000. Marine bird attraction to thermal fronts in the California Current System. *Condor* 102: 423-427.
64. Harrison, P., 1983. *Seabirds: an identification guide*. Houghton Mifflin Company. Boston, MA.
- 65., Wahl, T.R. et al., 2000. Seabird abundances off Washington, 1972-1998.
70. *Western Birds* 31: 69-88.
- 66., McGowan, J.A., et. al., 1996. *Plankton patterns, climate, and change in the California Current*. CalCOFI Report 67: 37:45-68.

69. Ainley, D.G., 1995. Ashy Storm-Petrel. In *The Birds of North America: Life Histories for the 21st Century*. The American Ornithologist's Union.
71. Bograd, S.J., et al., 2000. The State of the California Current 1999-2000: Forward to a new regime? *California Cooperative Oceanic Fisheries Investigation Reports*.
72. Durazo, R., et al., 2001. The state of the California Current, 2000-2001: a 3rd straight La Niña year? *California Cooperative Oceanic Fisheries Investigation Reports*.
73. Schwing, F., et al., 2002. The state of the California Current, 2001-2002: does the new climate regime continue or is El Niño looming? *California Cooperative Oceanic Fisheries Investigation Reports*.
74. Hickey, B. M. and T. C. Royer. 2001. California and Alaska Currents. In *Encyclopedia of Ocean Sciences*. Academic Press. London, UK.