# CHAPTER 5 – BIOGEOGRAPHY OF MARINE BIRDS

Olaf Jensen, Harry Carter, Glenn Ford, Julie Kellner, John Christensen

Over 195 species of marine birds use open water, shore, or island habitats in the Southern California Bight south of Point Conception (Baird, 1993). As many as 10 additional species use the coast along Vandenberg Air Force Base. The region of interest is located along the Pacific Flyway, a major migratory route for birds, and acts as a stopover during both north (April through May) and south (September through December) migrations. The months of June and July are peak months for transient shorebirds (Lehman, 1994). The Channel Islands and the Southern California mainland coast provide breeding and nesting sites for many species of seabirds and shorebirds, including several listed as threatened or endangered. The status and distribution of the 11 requested bird species within the study area are summarized in Table 5.0.1. This chapter is divided into a single species analysis of the 11 requested species (Chapter 5.1), and a community analysis of all bird species sampled in at-sea surveys (Chapter 5.2).

## 5.1 MARINE BIRD SINGLE SPECIES ANALYSIS

### Data and Methods

Data sources for this section are summarized in Table 5.1.1 and discussed in greater detail below. Three types of georeferenced survey data for marine birds (the term marine birds is used to encompass both seabirds and shorebirds) were available for this report: shipboard and aerial at-sea surveys, breeding colony surveys, and Xantus's murrelet telemetry data. Although no data were available in any of these surveys for snowy plover (*Charadrius alexandrinus*) or western snowy plover (*Charadrius alexandrinus nivosus*), the critical habitat delineations published in the Federal Register (USFWS, 1999) allow for some spatial analysis of the distribution of important snowy plover habitat. Scientific names and spellings of common names follow the Patuxent Bird Identification Infocenter (Gough *et al*., 1998). For display purposes, all maps were classified by quintile (five intervals, each of which contains approximately 20% of the data), except where fewer than five discrete values occurred. For discussion in this chapter, northern Channel Islands are: San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands.

A recent comprehensive survey of marine birds in the Southern California Bight was conducted in 1999-2002; however georeferenced data from these surveys were not available at the time of publication. From May 1999 to January 2002, aerial at-sea surveys were conducted by Humboldt State University (HSU) and the U.S. Geological Survey (USGS) for seabirds and marine mammals from Point Piedras Blancas to the U.S.-Mexico border, including the entire Southern California Bight (McChesney *et al*. 2000, 2001; Capitolo *et al*. 2003). Surveys were funded mainly by USGS, with additional support from the Minerals Management Service (MMS), U.S. Navy (USN) and California Department of Fish and Game (Office of Spill Prevention and Response; CDFG-OSPR). At-sea and shoreline roosting surveys were conducted: May and September 1999; January, May, and September 2000; January, May, and September 2001; and January 2002. These efforts used the same methods and essentially covered the same areas of the continental shelf examined by surveys during 1975-1977 below Point Conception and by surveys during 1980-1983 north of Point Conception (Briggs *et al*. 1987). Higher at-sea survey effort and greater coverage of coastline areas (on shore and at sea) occurred for each survey in 1999-2002, but they were conducted less frequently than in earlier surveys. Databases from 1999-2002 HSU/USGS surveys were not available for this report but will be available in the near future.

*Computer Database Analysis System (CDAS)*

At-Sea Surveys

Five at-sea surveys from the period 1975-1997 were compiled in CDAS v2.1 (MMS, 2001) and used to derive density maps for eight of the requested bird species:

Ashy storm-petrel (*Oceanodroma homochroa*)
California brown pelican (*Pelecanus occidentalis californicus*)
Double-crested cormorant (*Phalacrocorax auritus*)
Brandt's cormorant (*Phalacrocorax penicillatus*)
Pelagic cormorant (*Phalacrocorax pelagicus*)

**Figure 5.0.1.** Status, habitat locations, and seasonal use of the requested marine birds in the region of interest (Source: Working Draft Environmental Impact Statement for Channel Islands National Marine Sanctuary: Affected Environment Section, 2000).

| | Common Name | Scientific Name | Status / Season | Federal / State Status | Habitat Type | Habitat Location within Study Area | Breeding (location) |
|---|---|---|---|---|---|---|---|
| Shorebirds | Western snowy plover | *Charadrius alexandrinus nivosus* | Fairly common/winter<br>Fairly common to Uncommon /summer | Federally listed as Threatened | Beaches, sandy and rocky shores, Jetties | Vandenberg Air Force Base, Hollster Ranch, Ormond Beach, Point Mugu Lagoon, Coal Oil Point | Vandenberg Air Force Base, Hollster Ranch, Ormond Beach, Point Mugu Lagoon, Coal Oil Point, Channel Islands |
| | Black oystercatcher | *Haematopus bachmani* | Uncommon/year-round | | Beaches, sandy and rocky shores, jetties | Vandenberg Air Force | Vandenberg Air Force Base, Channel Islands |
| Seabirds | Ashy storm-petrel | *Oceanodroma homochroa* | Common/spring, winter, fall<br>Casual/winter | California Department of Fish and Game species of special concern | Open ocean | Channel Islands | San Miguel, Santa Cruz, Anacapa, Santa Barbara, San Clemente Islands |
| | California brown pelican | *Pelecanus occidentalis californicus* | Common/year-round | Federally listed as Endangered | Inshore ocean waters, bays and harbors | Most areas | Anacapa, Santa Barbara Islands |
| | Double-crested cormorant | *Phalacrocorax auritus* | Common/winter<br>Uncommon/summer | California's Department of Fish and Game species of special concern | Open ocean, lakes, reservoirs, large streams, creeks and rivers | Santa Ynez River, Hollster Ranch, Devereux Slough, UCSB Lagoon, Goleta Slough, Ormond Beach | Anacapa, San Miguel, Santa Barbara, San Clemente Islands, San Diego Bay |
| | Brandt's cormorant | *Phalacrocorax penicillatus* | Uncommon to adundant/ winter | | Fresh and/or salt water marshes, estuaries, mudflats, tidal lagoons, and brackish water, lakes, reservoirs, large streams, creeks and rivers, inshore ocean waters, bays and harbors | Vandenberg Air Force Base, Hollster Ranch, Channel Islands | Vandenberg Air Force Base,San Miguel, Santa Rosa, Santa Cruz, Santa Barbara, Anacapa, San Nicolas, San Clemente Islands |
| | Pelagic cormorant | *Phalacrocorax pelagicus* | Fairly common to common/winter<br>Rare to fairly common/ summer | | Open ocean, beaches, sand and rocky shores, jetties | Vandenberg Air Force Base, Hollster Ranch, Channel Islands | Vandenberg Air Force Base, San Miguel, Santa Rosa, Santa Cruz, Anacapa, Santa Barbara Islands |
| | California least tern | *Stena antillarum browni* | Rare to Common/year-round | Federally and State-listed as Endangered | Beaches, sandy and rocky shores, jetties, inshore ocean waters, bays and harbors | Vandenberg Air Force Base, Devereux Slough, UCSB Lagoon, Carpinteria Marsh, Ormond Beach, Point Mugu Lagoon | Vandenberg Air Force Base, Devereux Slough, Ormond Beach, Point Mugu Lagoon |
| | Pigeon guillemot | *Cepphus columba* | Common/summer | | Beaches, sandy and rocky shores, jetties, inshore ocean waters, bays and harbors | Vandenberg Air Force Base, Hollster Ranch, Channel Islands | Vandenberg Air Force Base, San Miguel, Santa Rosa, Santa Cruz, Anacapa, Santa Barbara Islands |
| | Xantus's murrelet | *Synthliiboramphus hypoleucus* | Uncommon/spring, summer<br>Rare/fall, winter | | Open ocean | Channel Islands | San Miguel, Santa Cruz, Anacapa, Santa Barbara, San Clemente, Santa Catalina Islands |
| | Cassin's auklet | *Ptychoramphus aleuticus* | Fairly common/year-round | | Open ocean | Channel Islands | San Miguel, Santa Cruz, Anacapa, Santa Barbara Islands |

Pigeon guillemot (*Cepphus columba*)
Xantus's murrelet (*Synthliboramphus hypoleucus*)
Cassin's auklet (*Ptychoramphus aleuticus*)

**Table 5.1.1.** Data used for the analysis of marine bird distributions presented in this chapter.

| Survey | Source | Dates | Platform | Months |
|---|---|---|---|---|
| CDAS- Minerals Management Service Aerial Surveys | R.G. Ford | 1980-1983 | airplane (low altitude) | Year-round |
| CDAS-California Department of Fish and Game, Office of Spill Prevention and Response | R.G. Ford | 1994-1997 | airplane (low altitude) | Year-round |
| CDA3-Southern California Bight Low Aerial Survey | R.G. Ford | 1975-1978 | airplane (low altitude) | Year-round |
| CDAS-Seabird Ecology Study | R.G. Ford | 1985 | ship and airplane | March and May |
| CDA3-Southern California Bight, Minerals Management Service Survey | R.G. Ford | 1995-1997 | airplane (low altitude) | Year-round |
| Breeding Colony Surveys-Humbolt State University and U.S. Fish and Wildlife Service | H.R. Carter | 1989-1991 | various | April-August |
| Xantus's Murrelet Breeding Colony Surveys-Humbolt State University | H.R. Carter | 1991-2002 | various | April-May |
| Xantus's Murrelet Telemetry Study-U.S. Geological Survey and Humbolt State University | H.R. Carter | 1995-1997 | Airplane and fixed station radio receivers | April-June |
| Snowy plover critical habitat-U.S. Fish and Wildlife Service | Federal Register | 1999 | | |
| DRAFT California least tern breeding survey-California Department of Fish and Game | Lyann Comrack | 2001-2003 | | |

A sixth survey, the Southern California Bight ship survey, which is used in the calculation of bird diversity (Chapter 5.2) was not used in the calculation of individual species densities because of the difficulties of reconstructing survey effort for this survey. This was not problematic for the calculation of diversity for the reasons discussed in that chapter, but it precludes the calculation of density.

Bird densities were calculated for five minutes of latitude by five minutes of longitude cells. Densities were calculated as the number of individuals sighted divided by the area searched for each species in each five-minute cell. Areas searched were calculated as the total length of survey track in each cell multiplied by the effective strip width. Cells in which fewer than 5 km of survey track occurred were dropped from this analysis. For calculation of total individuals and density within the boundary concept, all grid cells which intersect the boundaries of a concept are included in calculations for that concept. This method is required because effort in the CDAS data set is summarized by cells. Consequently, any analysis involving effort is limited in spatial resolution by this five-minute cell size.

Breeding Colony Surveys
Surveys of marine bird breeding colonies were conducted in 1989-1991 by researchers from Humboldt State University (HSU) and the U.S. Fish and Wildlife Service (USFWS), and were funded by the Minerals Management Service (MMS) (Carter *et al*., 1992, 1995a). The survey counted birds, nests, and potential nesting sites for most breeding species. Additionally, the size of the breeding population at each site was estimated based on adjustments to the counts mentioned above or by capture-recapture methods. Details of the population estimates are given in Carter *et al*. (1992). All analysis of the breeding colony survey in this report is based on these site-specific population estimates. Breeding colony survey data were available for:

Ashy storm-petrel (*Oceanodroma homochroa*)
California brown pelican (*Pelecanus occidentalis californicus*)
Double-crested cormorant (*Phalacrocorax auritus*)
Brandt's cormorant (*Phalacrocorax penicillatus*)
Pelagic cormorant (*Phalacrocorax pelagicus*)

Black oystercatcher (*Haematopus bachmani*)
California least tern (*Sterna antillarum browni*)
Pigeon guillemot (*Cepphus columba*)
Xantus's murrelet (*Synthliboramphus hypoleucus*)
Cassin's auklet (*Ptychoramphus aleuticus*)

More recent surveys of California least tern nesting areas were provided by Lyann Comrack (CDFG, draft data). The maximum number of least tern breeding pairs observed at each site was complied from these CDFG surveys conducted in 2001, 2002, and 2003. Additionally, recent colony survey data for Xantus's murrelet were provided by H. Carter (HSU, unpubl. data). These data were compiled from surveys conducted from 1991-2002 and are summarized in Burkett *et al*., (2003). Because these data are available as summaries for individual shoreline segments rather than point counts they are presented for each island individually.

*Xantus's Murrelet Telemetry Study*
Data presented in this section represent the results of a radio telemetry survey of Xantus's murrelet in the Southern California Bight conducted by the U.S. Geological Survey (USGS) and HSU from 1995 to 1997 (Whitworth *et al*., 2000; Carter *et al*., 2000). Murrelets were captured at sea near Santa Barbara Island and 153 individuals were fitted with radio transmitters. Marked individuals were relocated mainly by aerial telemetry surveys conducted between April and June of 1995, 1996, and 1997. A receiving station on North Peak, Santa Barbara Island was also used to relocate marked individuals within a few km of the island. A raster density map of re-locations was created for visualization purposes using the kernel density function of ArcView Spatial Analyst (ESRI, 2003) with a radius of 15 km and a cell size of 2 km. Analysis of the boundary concepts was conducted on the re-location points not the density map.

**Broad-scale Patterns and Analysis of Boundary Concepts**

**Ashy storm-petrel** (*Oceanodroma homochroa*)
Ashy storm-petrel is a small procellariiform (Family Hydrobatidae) whose year round range extends from Cape Mendocino, California to northern Baja California, Mexico. CINMS is at the southern end of their core breeding and feeding distribution. This species nests mainly in cavities in rock piles and cliffs on offshore California islands with only one known nesting site outside of California on Islas Los Coronados, Mexico. Small numbers nest on small rocks near the coast at Point Reyes, south of Monterey, and possibly on the mainland at Vandenberg AFB (McChesney *et al*., 2000; Whitworth *et al*., 2002; Brown *et al*., 2003). Due to their widely dispersed and offshore foraging habits, ashy storm-petrels are likely to be underestimated by at-sea surveys, and their cryptic nests make it difficult to census colonies. Breeding colony surveys from 1989-1991 estimated a worldwide breeding population of 7,207 birds with 43% of the breeding population found in the northern Channel Islands (Carter *et al*., 1992). Although this estimate is greater than previous estimates, differences in survey sites and methods preclude any inference of a trend. Due to pollutant impacts and other factors, numbers may be declining in the northern Channel Islands (H. Carter, unpubl. data). Numbers have declined at the Farallon Islands due to high predation (Sydeman *et al*., 1998). Ashy storm-petrel is listed as a California "Species of Special Concern," but is not federally endangered or threatened.

At-sea sightings indicate that areas of high ashy storm-petrel density occur along the continental slope off Central California, with notable concentrations between Point Arena and Monterey Bay (including the deep waters of the Monterey Canyon), and in the Southern California Bight. Sightings also occur on the shelf between Point Buchon and Point Conception.

Analysis of the observed patterns of ashy storm-petrel sightings (Figure 5.1.1) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in both sightings (absolute metric) and mean density (relative metric) for its relative size compared to the current boundary (NAC; Table 5.1.2). Most of the additional sightings within the study area but outside of the current sanctuary boundaries occur in the Santa Barbara Channel. It should be noted that most of the increase in sightings and density observed in Concept 3 relative to the next smallest concept (Concept 4) is due to inclusion of one additional grid cell in which 55 ashy storm-petrels were observed.

In 1989-1991, breeding colonies of ashy storm-petrel (Figure 5.1.2) were found on San Miguel, Santa Cruz, and Santa Barbara Islands. More recent surveys (H. Carter, unpubl. data) have found greater numbers on Santa

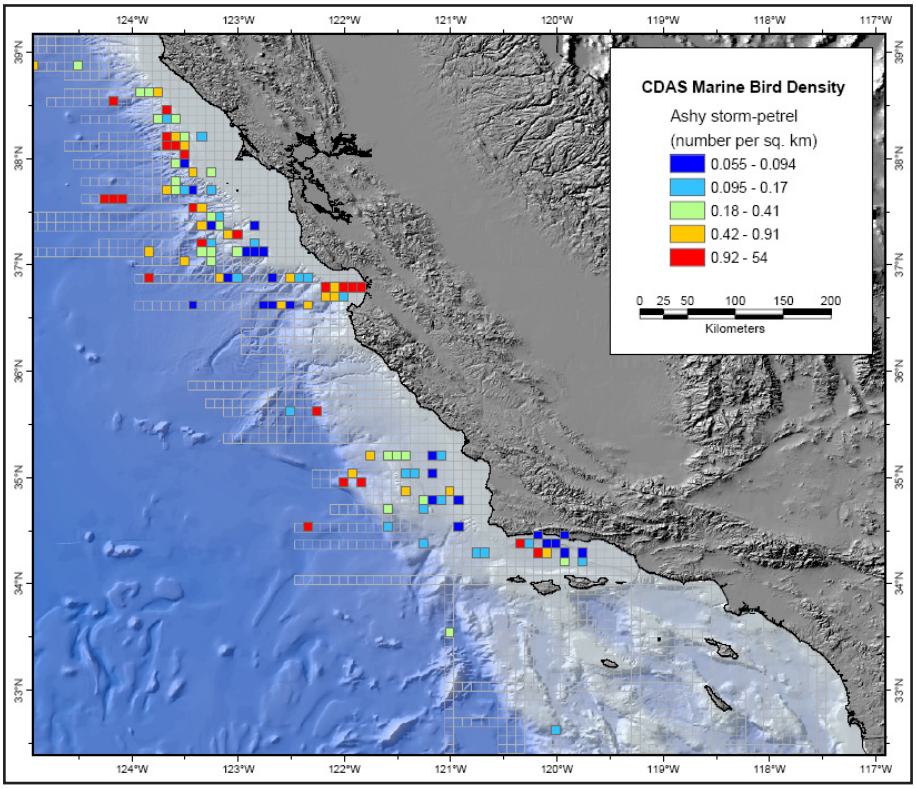


**Figure 5.1.1.** Ashy storm-petrel. At-sea densities (individuals/km$^2$) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

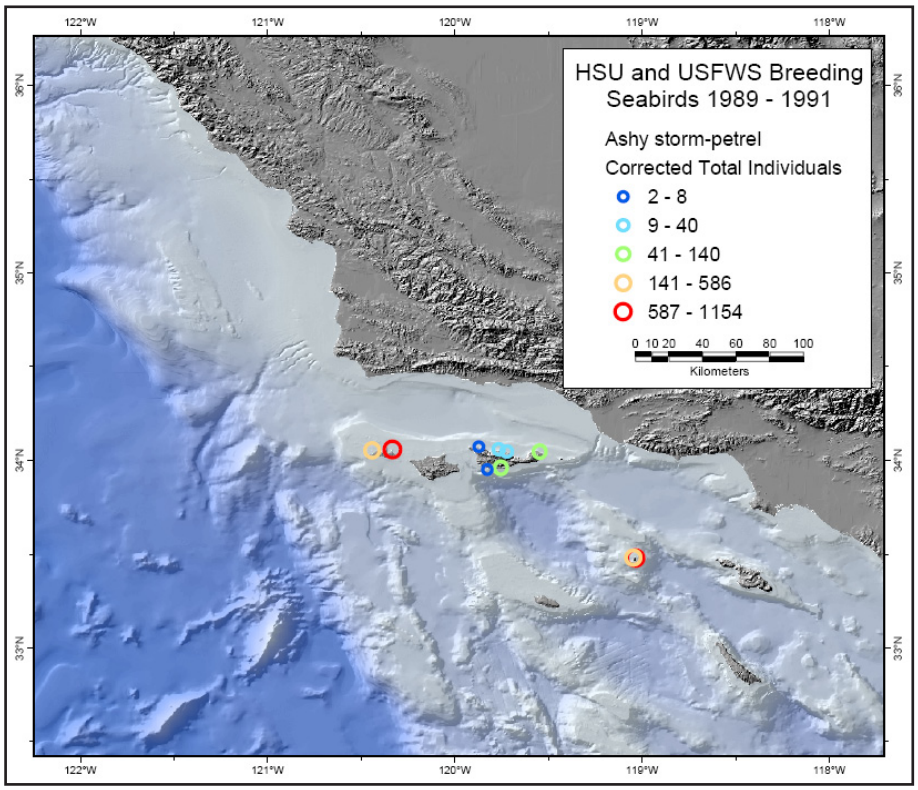


**Figure 5.1.2**. Ashy storm-petrel. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al.*, 1992).

Cruz Island and colonies on Anacapa and San Clemente Island. Most colonies are within the current sanctuary boundaries as well as the boundaries of all of the concepts, and consequently no Optimal Area Index (OAI) analysis was done for the ashy storm-petrel colony data.

**Table 5.1.2.** Ashy storm-petrel. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km$^2$) | Density (Individuals per km$^2$) | Area (km$^2$) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 2 | 448.2 | 0.004 | 3745 | - | - | - | - | - |
| 5 | **3** | 492.3 | **0.006** | 4538 | 50 | 36.56 | 21.12 | 2.37 | 1.73 |
| 4 | **38** | 748.3 | **0.051** | 7981 | 1800 | 1038.02 | 113.11 | 15.91 | 9.18 |
| 3 | **95** | 984.6 | **0.096** | 9044 | 4650 | 2062.25 | 141.50 | 32.86 | 14.57 |
| 2 | **106** | 1589.1 | **0.067** | 13736 | 5200 | 1394.85 | 266.78 | 19.49 | 5.23 |
| 1a | **128** | 2460.3 | **0.052** | 22613 | 6300 | 1065.91 | 503.82 | 12.50 | 2.12 |
| 1 | **128** | 2460.3 | **0.052** | 22591 | 6300 | 1065.91 | 503.23 | 12.52 | 2.12 |
| *SA* | *107* | *2115.2* | *0.051* | *17093* | *5250* | *1033.64* | *356.42* | *14.73* | *2.90* |

**California brown pelican** (*Pelecanus occidentalis californicus*)
California brown pelicans (Family Pelecanidae) range from southern British Columbia to northern South America with the California subspecies breeding from California to the Pacific coast of southern Mexico. The CINMS is at the northern edge of this subspecies breeding range and feeding distribution. They nest in a variety of habitats on offshore islands. The 1991 breeding colony survey resulted in an estimate of 11,916 breeding birds in California with all of the breeding population of California occurring in the northern Channel Islands (Carter *et al*., 1992). This survey indicated a continued increase in abundance of pelicans since the low of 76 nests in 1977, reflecting partial recovery from pollutant impacts. Since 1991, pelicans have oscillated in numbers between years (F. Gress, pers. comm.). However, much larger numbers of pelicans occur in late summer and fall in the Santa Barbara Channel and the Southern California Bight when many disperse northward from large colonies in the Gulf of California (Jaques *et al*., 1996; Capitolo *et al*., 2003). The California brown pelican is a state and federally listed endangered species.

At-sea sightings indicate that areas of high brown pelican density can be found on the north side of Santa Cruz Island, and along the coast from Point Sal to Point Mugu. Much of the eastern half of the Santa Barbara Channel also exhibits high brown pelican density.

Analysis of the observed patterns of brown pelican sightings (Figure 5.1.3) and density relative to the proposed boundary concepts indicates that Concepts 1 and 1a provide the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.3). The density-based OAI, however, favors Concept 5, the smallest concept other than the NAC. The smaller concepts (3-5) fail to capture the region of high pelican density along the mainland coast and in the eastern Santa Barbara Channel, while the largest concepts (1 and 1a) include large areas of low pelican density along the shelf. Concept 2 exhibits both of these flaws in relation to brown pelican distributions.

Only two breeding colonies of brown pelican (Figure 5.1.4) were recorded in California in the 1989-1991 breeding colony survey. The larger colony (10,680 individuals) is found on West Anacapa Island, and a smaller colony (1,236 individuals) is found on Santa Barbara Island.

No analysis of boundary concepts was conducted for brown pelican breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

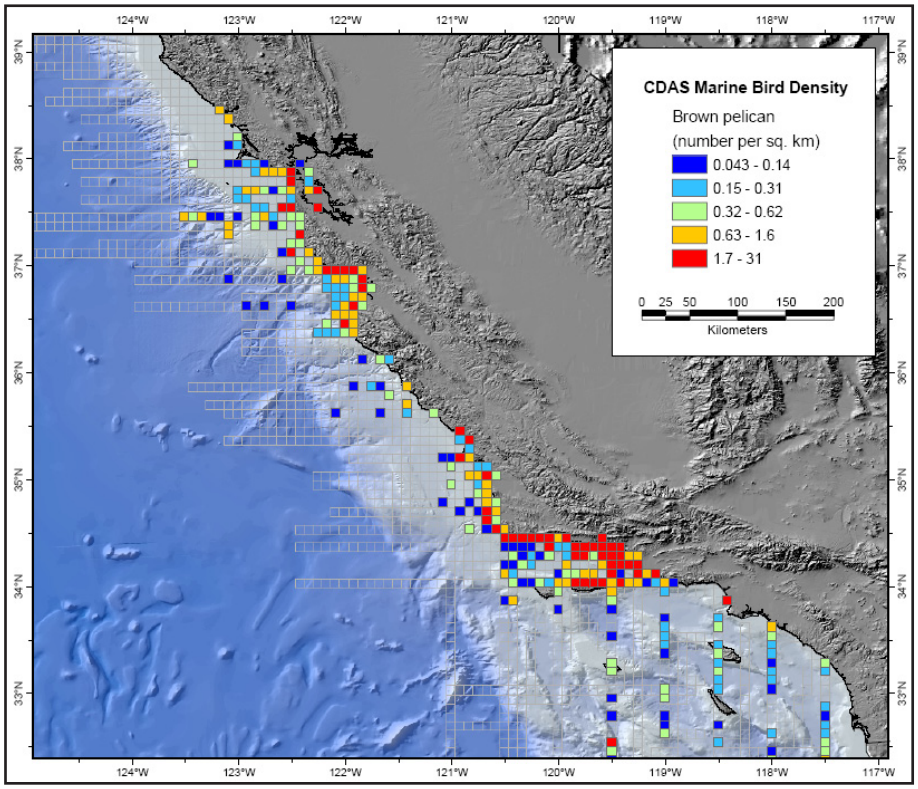


**Figure 5.1.3.** California brown pelican. At-sea densities (individuals/km$^2$) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

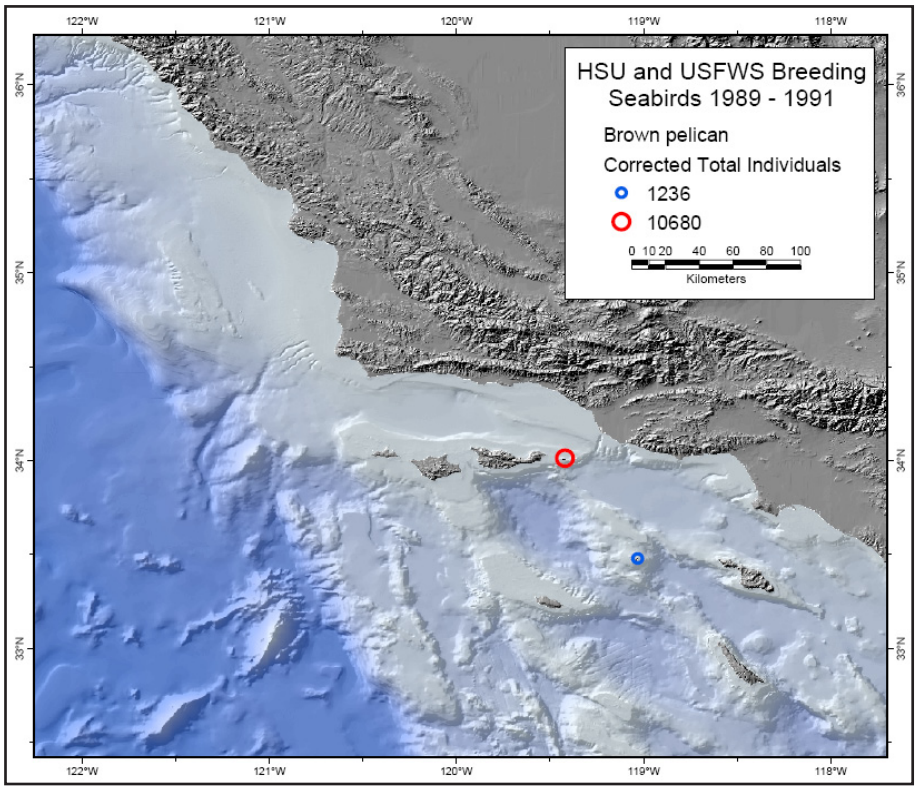


**Figure 5.1.4.** California brown pelican. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

**Table 5.1.3.** California brown pelican. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km$^2$) | Density (Individuals per km$^2$) | Area (km$^2$) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 374 | 448.2 | 0.834 | 3745 | - | - | - | - | - |
| 5 | **452** | 492.3 | **0.918** | 4538 | 20.88 | 10.03 | 21.12 | 0.99 | 0.47 |
| 4 | **540** | 748.3 | 0.722 | 7981 | 44.39 | -13.52 | 113.11 | 0.39 | -0.12 |
| 3 | **913** | 984.6 | **0.927** | 9044 | 144.12 | 11.12 | 141.50 | 1.02 | 0.08 |
| 2 | **1355** | 1589.1 | **0.853** | 13736 | 262.30 | 2.19 | 266.78 | 0.98 | 0.01 |
| 1a | **2546** | 2460.3 | **1.035** | 22591 | 580.75 | 24.01 | 503.23 | 1.15 | 0.05 |
| 1 | **2546** | 2460.3 | **1.035** | 22613 | 580.75 | 24.01 | 503.82 | 1.15 | 0.05 |
| *SA* | *2546* | *2115.2* | *1.204* | *17093* | *580.75* | *44.25* | *356.42* | *1.63* | *0.12* |

**Double-crested cormorant** (*Phalacrocorax auritus*)
Double-crested cormorant (Family Phalacrocoracidae) is found in marine, estuarine, and freshwater habitats throughout most of North America. CINMS is within the core breeding range of the *P. a. albociliatus* subspecies. In California, they nest in a variety of habitats including flat, sloping, and cliff areas of the mainland coast and offshore rocks and islands, as well as trees and artificial habitats. The 1989-1991 breeding colony survey resulted in an estimate of 10,037 breeding birds in marine and estuarine habitats of California with 25% of the breeding population of California occurring in the northern Channel Islands (Carter *et al*., 1992). The survey showed an increase in abundance of double-crested cormorant in the northern Channel Islands since earlier (1975-1980) surveys (Carter *et al*., 1995a, b). This increase reflected some recovery from pollutant impacts, but recent surveys have shown declines (Capitolo *et al*., 2004). The northern Channel Islands are one of the few areas in North America where double-crested cormorants are declining (Carter *et al*., 1995b). The double-crested cormorant is listed as a California "Species of Special Concern," but is not federally endangered or threatened.

At-sea sightings showed the highest densities of double-crested cormorant in San Francisco Bay, well to the north of the CINMS study area. However, an additional region of relatively high densities exists in nearshore waters along both sides of the Santa Barbara Channel. The highest densities in Southern California were found in nearshore waters from Point Conception to Point Hueneme.

Analysis of the observed patterns of double-crested cormorant sightings (Figure 5.1.5) and density relative to the proposed boundary concepts indicates that Concepts 1 and 1a provide the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.4). The density-based OAI favors Concept 3, which includes a region of high density around Point Conception. As with brown pelican, the smaller concepts (4 and 5) fail to capture the region of high double-crested cormorant density along the mainland coast, while the largest concepts (1 and 1a) include large areas of low density along the shelf. Again, Concept 2 exhibits both of these flaws.

Breeding colonies of double-crested cormorant (Figure 5.1.6) exist on San Miguel, West Anacapa, and Santa Barbara Islands, with the two largest colonies (720 and 768 individuals) in Southern California found on West Anacapa and Santa Barbara Islands respectively. A small colony was recently found at San Clemente Island (H. Carter, unpubl. data). Mainland colonies exist at Morro Bay and San Diego Bay.

No analysis of boundary concepts was conducted for double-crested cormorant breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

**Brandt's cormorant** (*Phalacrocorax penicillatus*)
Brandt's cormorant (Family Phalocrocaracidae) is the most abundant cormorant in California, ranging along the Pacific coast from southern Vancouver Island, Canada to southern Baja California, Mexico. CINMS is within the core of their breeding range and feeding distribution. Nesting habitat for this species is variable and includes flat or sloping surfaces of offshore islands as well as mainland cliffs. Surveys of all known large (>100) breeding col-

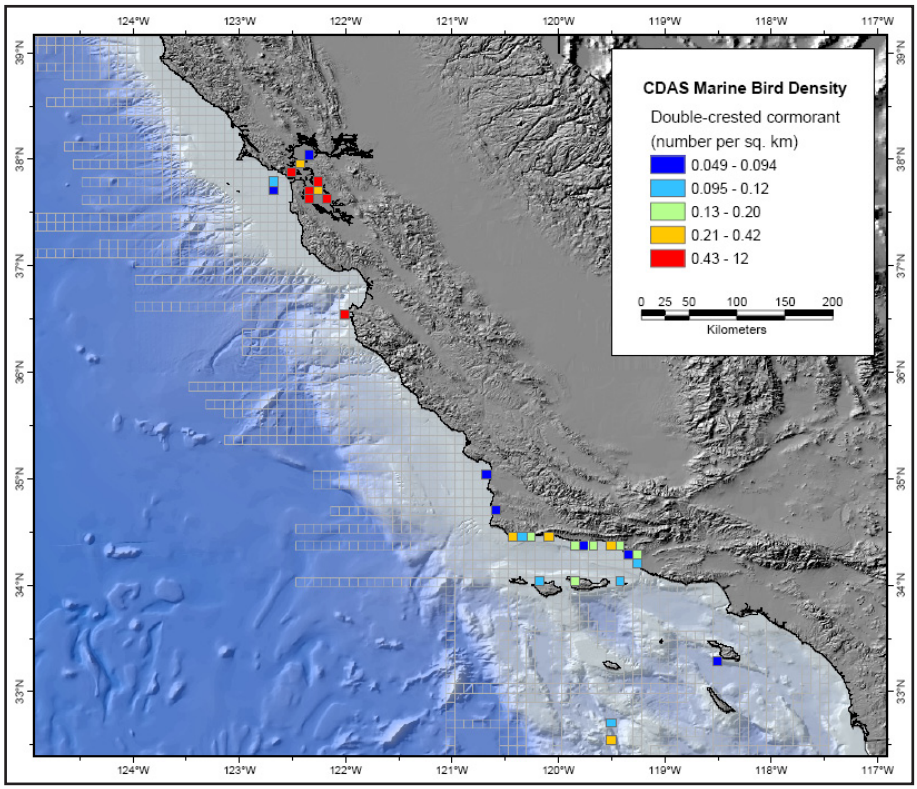


**Figure 5.1.5.** Double-crested cormorant. At-sea densities (individuals/km$^2$) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

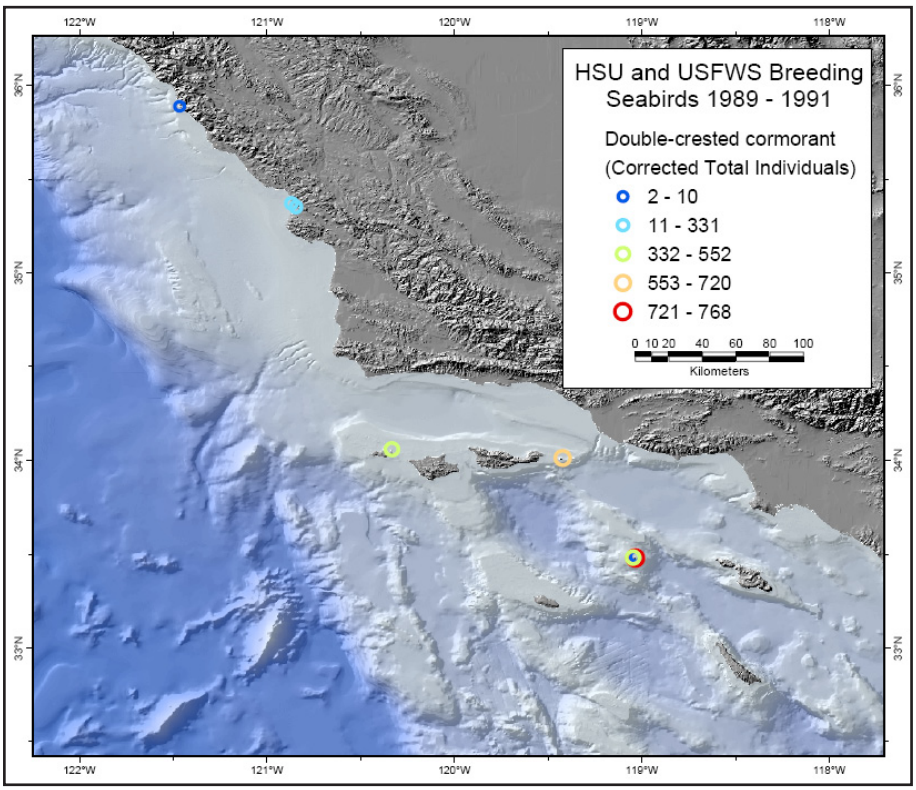


**Figure 5.1.6.** Double-crested cormorant. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

**Table 5.1.4.** Double-crested cormorant. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km²) | Density (Individuals per km²) | Area (km²) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 3 | 448.2 | 0.007 | 3745 | - | - | - | - | - |
| 5 | 3 | 492.3 | 0.006 | 4536 | 0.00 | -8.96 | 21.12 | 0.00 | -0.42 |
| 4 | 3 | 748.3 | 0.004 | 7981 | 0.00 | -40.10 | 113.11 | 0.00 | -0.35 |
| 3 | **11** | 984.6 | **0.011** | 9044 | 266.67 | 66.91 | 141.50 | 1.88 | 0.47 |
| 2 | **18** | 1589.1 | **0.011** | 13736 | 500.00 | 69.23 | 266.78? | 1.87 | 0.26 |
| 1a | **40** | 2460.3 | **0.016** | 22591 | 1233.33 | 142.90 | 503.23 | 2.45 | 0.28 |
| 1 | **40** | 2460.3 | **0.016** | 22613 | 1233.33 | 142.90 | 503.82 | 2.45 | 0.28 |
| *SA* | *40* | *2115.2* | *0.019* | *17093* | *1233.33* | *182.53* | *356.42* | *3.46* | *0.51* |

onies in 1989-1991 resulted in an estimate of 83,394 breeding birds in California with 29% of this population occurring in the northern Channel Islands (Carter *et al*., 1992). This survey indicated a notable increase in abundance of Brandt's cormorants in the northern Channel Islands since surveys in 1975-1980. However, more recent surveys have shown a decline since 1991 (Capitolo *et al*., 2004). Brandt's cormorant is not a federal endangered or threatened species.

At-sea survey data suggest that Brandt's cormorant is widely distributed in nearshore waters of central and southern California with notable concentrations in the Gulf of the Farallones, near Point Sur, Morro Bay, Point Conception, and the northern Channel Islands (with the exception of Santa Barbara Island).

Analysis of the observed patterns of Brandt's cormorant sightings (Figure 5.1.7) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.5). Density (relative metric), however, was highest for Brandt's cormorant within the NAC and consequently the density-based OAI is negative for all of the concepts. Much of the increase in density for Concept 3 relative to the smaller concepts (4, 5, and the NAC) is due to the inclusion of two additional grid cells near Point Conception.

Breeding colonies of Brandt's cormorant (Figure 5.1.8) exist on seven Channel Islands (all except Santa Catalina), with major colonies (top quintile, 1,548-5,606 individuals) on San Miguel, Santa Rosa, Santa Cruz, and San Nicolas Islands. Mainland colonies in Southern California exist at Point Buchon, Morro Bay, Vandenberg AFB, Santa Barbara, La Jolla, and along the coast between Point Piedras Blancas and Cape San Martin.

No analysis of boundary concepts was conducted for Brandt's cormorant breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

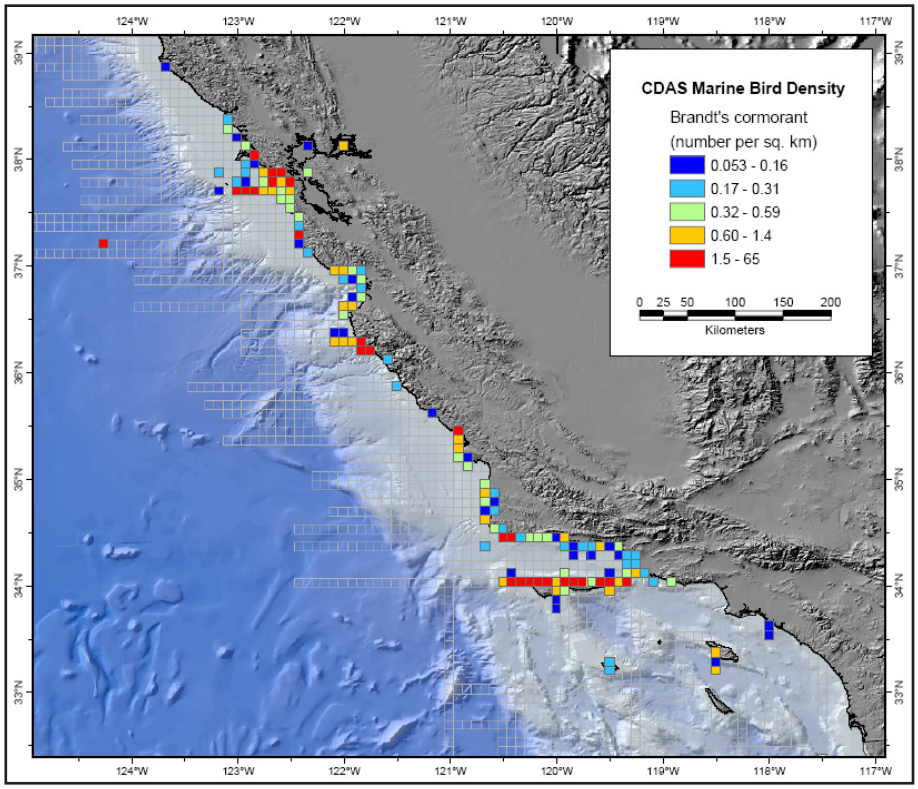


**Figure 5.1.7.** Brandt's cormorant. At-sea densities (individuals/km²) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

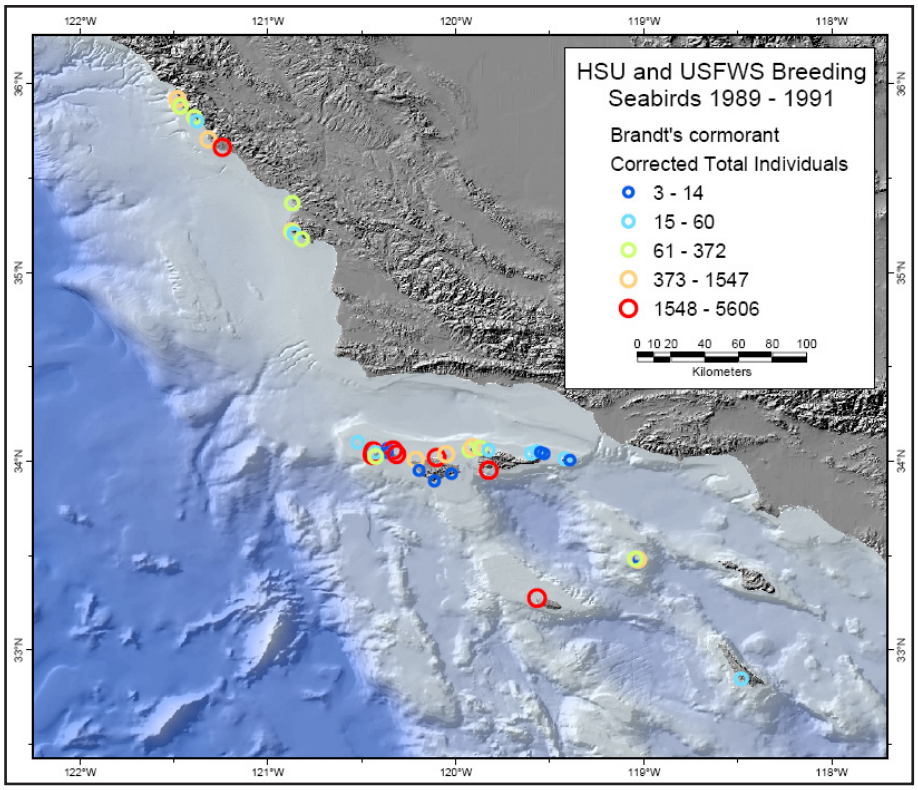


**Figure 5.1.8.** Brandt's cormorant. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

**Table 5.1.5.** Brandt's cormorant. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km$^2$) | Density (Individuals per km$^2$) | Area (km$^2$) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 377 | 448.2 | 0.841 | 3745 | - | - | - | - | - |
| 5 | 377 | 492.3 | 0.766 | 4538 | 0.00 | -8.96 | 21.12 | 0.00 | -0.42 |
| 4 | **378** | 748.3 | 0.505 | 7981 | 0.27 | -39.95 | 113.11 | 0.00 | -0.35 |
| 3 | **477** | 984.6 | 0.484 | 9044 | 26.53 | -42.40 | 141.50 | 0.19 | -0.30 |
| 2 | **526** | 1589.1 | 0.331 | 13736 | 39.52 | -80.85 | 266.78 | 0.15 | -0.23 |
| 1a | **589** | 2460.3 | 0.239 | 22591 | 56.23 | -71.54 | 503.23 | 0.11 | -0.14 |
| 1 | **589** | 2460.3 | 0.239 | 22613 | 58.23 | -71.54 | 503.82 | 0.11 | -0.14 |
| *SA* | *589* | *2115.2* | *0.278* | *17093* | *56.23* | *-66.89* | *356.42* | *0.16* | *-0.19* |

**Pelagic cormorant** (*Phalacrocorax pelagicus*)

The pelagic cormorant (Family Phalacrocoracidae) ranges along the north Pacific coast with the southern end of their breeding range in North America occurring at Santa Barbara Island, with occasional nesting of a few individuals at Islas Los Coronados, Mexico. Nesting habitat includes cliffs on the coast and on islands. The 1989-1991 breeding colony survey resulted in an estimate of 14,345 breeding birds in California with 19% of the breeding population of California occurring in the northern Channel Islands (Carter *et al*., 1992). The survey showed a small decrease in abundance of pelagic cormorant since earlier (1975-1980) surveys (Carter *et al*., 1995b). Somewhat greater abundance was found in southern California. While this is likely due to greater survey effort, numbers at Anacapa Island have increased (F. Gress, pers. comm.). Pelagic cormorant is not a endangered or threatened species.

At-sea sightings indicate that pelagic cormorant are widely distributed in the nearshore waters of central and southern California, with high densities observed near many of the major points, including; Point Buchon, Point Sal, Point Arguello, and Point Conception. Additional high density areas exist near San Miguel, Santa Rosa, and Santa Cruz Islands.

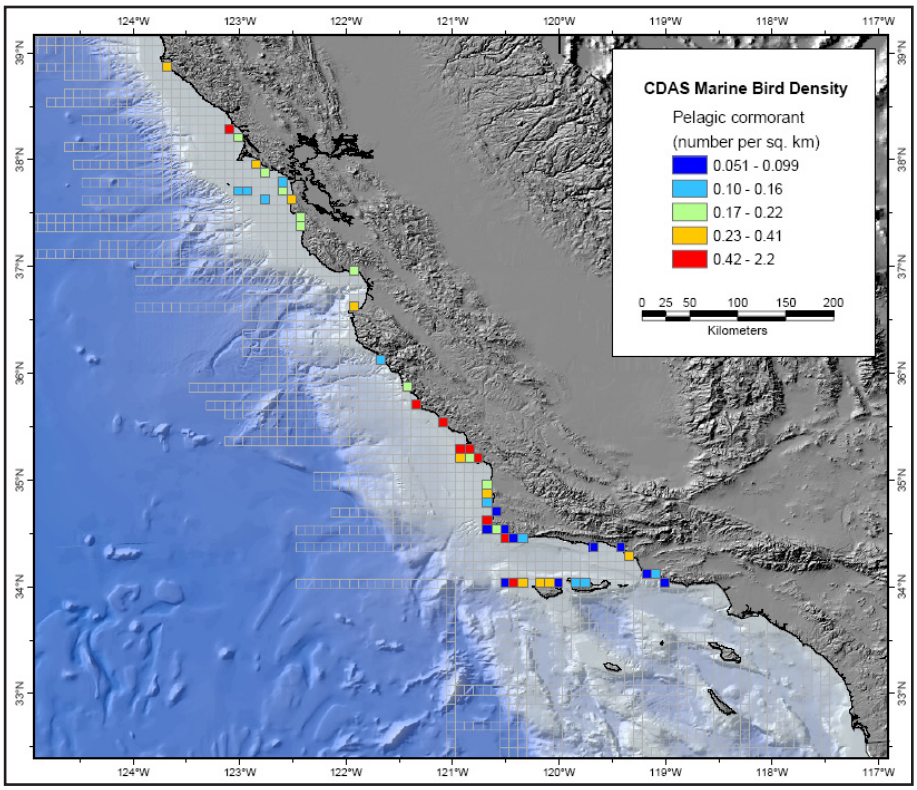


**Figure 5.1.9.** Pelagic cormorant. At-sea densities (individuals/km$^2$) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

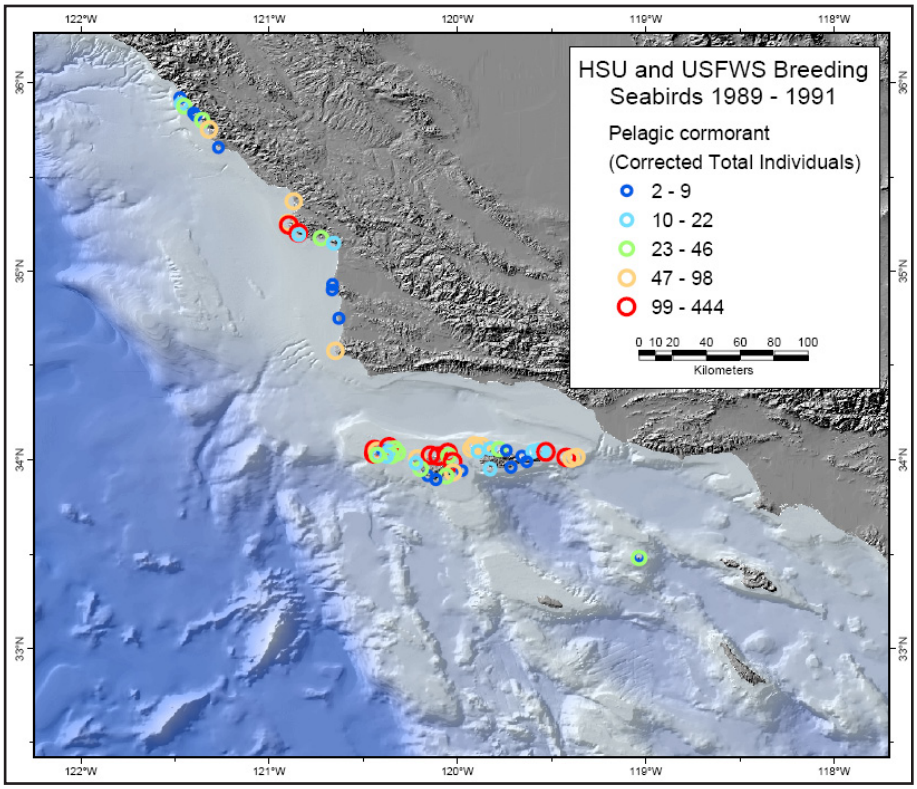


**Figure 5.1.10.** Pelagic cormorant. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Analysis of the observed patterns of pelagic cormorant sightings (Figure 5.1.9) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.6). Density (relative metric), however, was highest for pelagic cormorant within the NAC and consequently the density-based OAI is negative for all of the concepts. Much of the increase in sightings for Concept 3 relative to the smaller concepts (4, 5, and the NAC) is due to the inclusion of one additional high density grid cell near Point Conception. Concepts 1, 1a, and 2 encompass additional high density grid cells off Point Sal and Point Arguello.

Breeding colonies of pelagic cormorant (Figure 5.1.10) exist on San Miguel, Santa Rosa, Santa Cruz, Anacapa (West, Middle, and East), and Santa Barbara Islands, with major colonies (top quintile, 99-444 individuals) found on San Miguel, Santa Rosa, and Santa Cruz Islands. Southern California mainland colonies exist from Point Arguello north to Cape San Martin.

Analysis of the distribution of pelagic cormorant breeding colonies within the proposed boundary concepts suggests that Concept 2 provides the greatest increase in breeding individuals for its relative size compared to the NAC (Table 5.1.7). The increase in breeding individuals for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to the inclusion of three additional colonies on Points Arguello, Purisima, and Sal. Concepts 1 and 1a also encompass these colonies and one additional colony of 4-5 pairs, but their larger areas result in lower values for the OAI.

**Table 5.1.6.** Pelagic cormorant. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km²) | Density (Individuals per km²) | Area (km²) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 20 | 448.2 | 0.045 | 3745 | - | - | - | - | - |
| 5 | 20 | 492.3 | 0.041 | 4536 | 0 | -8.96 | 21.12 | 0.00 | -0.42 |
| 4 | 20 | 748.3 | 0.027 | 7981 | 0 | -40.10 | 113.11 | 0.00 | -0.35 |
| 3 | **33** | 984.6 | 0.034 | 9044 | 65 | -24.88 | 141.50 | 0.46 | -0.18 |
| 2 | **41** | 1589.1 | 0.026 | 13736 | 105 | -42.18 | 266.78 | 0.39 | -0.16 |
| 1a | **57** | 2460.3 | 0.023 | 22591 | 185 | -48.08 | 503.23 | 0.37 | -0.10 |
| 1 | **57** | 2460.3 | 0.023 | 22613 | 185 | -48.08 | 503.82 | 0.37 | -0.10 |
| *SA* | *57* | *2115.2* | *0.027* | *17093* | *185* | *-39.61* | *356.42* | *0.52* | *-0.11* |

**Table 5.1.7.** Pelagic cormorant. Colony counts (total individuals) and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Area (km²) | Δ Individuals (%) | Δ Area (%) | OAI Individuals (absolute metric) |
|---|---|---|---|---|---|
| NAC | 2687 | 3745 | - | - | - |
| 5 | 2687 | 4536 | 0.00 | 21.12 | 0.000 |
| 4 | 2687 | 7981 | 0.00 | 113.11 | 0.000 |
| 3 | 2687 | 9044 | 0.00 | 141.50 | 0.000 |
| 2 | **2790** | 13736 | 3.83 | 266.78 | 0.014 |
| 1a | **2799** | 22591 | 4.17 | 503.23 | 0.008 |
| 1 | **2799** | 22613 | 4.17 | 503.82 | 0.008 |
| *SA* | *2799* | *17093* | *4.17* | *356.42* | *0.012* |

## Western snowy plover

(*Charadrius alexandrinus nivosus*)

Western snowy plover is a shorebird (Family Charadriidae) which nests in sand, gravel, and salt pans on coastal beaches from southern Washington to southern Baja California, Mexico. CINMS is in the southern half of their core breeding range and feeding distribution. No information was available on population status or distribution within the study area; however, some individuals are known to nest on Santa Rosa, San Miguel, and San Nicolas Islands (P. Martin and G. Smith, pers. comm.).

Along the U.S. Pacific coast of Washington, Oregon, and California, 290 km of coastline have been designated as critical habitat for the western snowy

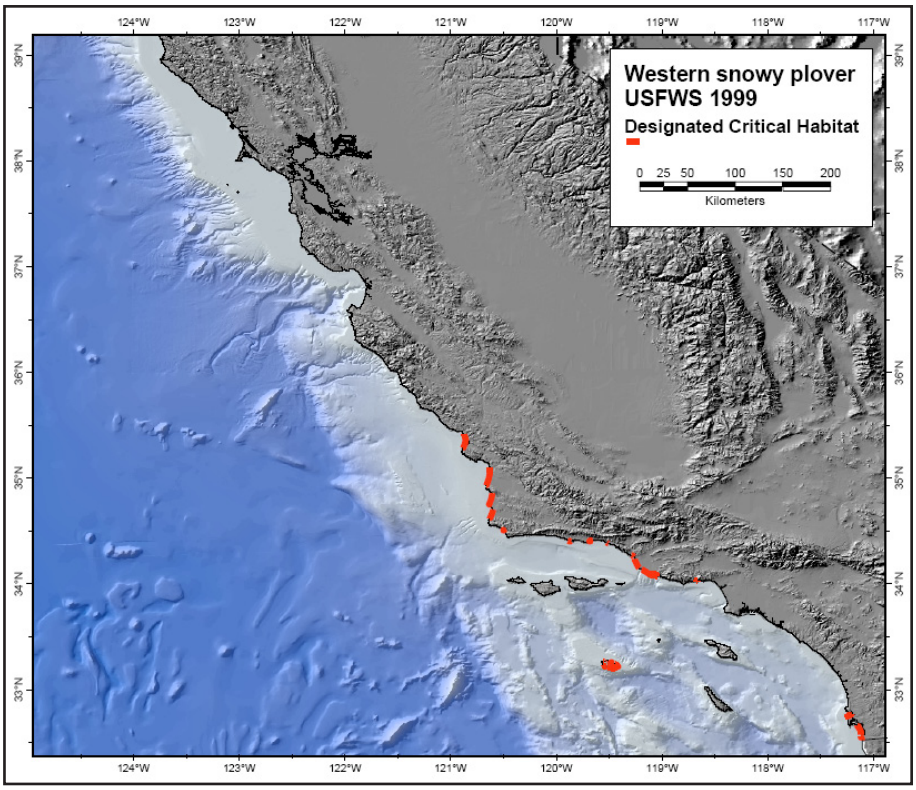


**Figure 5.1.11.** Western snowy plover. Designated critical habitat for the Pacific coast population of western snowy plover (Source: USFWS, 1999). Designated critical habitat is mapped for locales in the vicinity of CINMS; this map is not inclusive of all designated snowy plover critical habitat.

plover (USFWS, 1999). The current CINMS sanctuary boundary (NAC) and Concepts 4 and 5 do not include any designated critical habitat (Figure 5.1.11; Table 5.1.8). Concept 3 includes 2.3 km of critical habitat shoreline, less than 1% of the total designated habitat. Concept 2 encompasses 27.4 km (9.4%). The largest concepts (1 and1a) and the Study Area include 70 km (24%) of the designated western snowy plover critical habitat. Because there was no critical habitat designated within the NAC, it is not possible to calculate the OAI for western snowy plover critical habitat.

**Table 5.1.8.** Western snowy plover. Critical habitat for the Pacific coast population of western snowy plover.

| Concept | Area ($km^2$) | Critical Habitat Length of Shoreline (km) |
|---|---|---|
| NAC | 3745 | 0.00 |
| 5 | 4536 | 0.00 |
| 4 | 7981 | 0.00 |
| 3 | 9044 | 2.29 |
| 2 | 13736 | 27.35 |
| 1a | 22591 | 69.85 |
| 1 | 22613 | 69.85 |
| *SA* | *17093* | *69.85* |

**Black Oystercatcher** (*Haematopus bachmani)*

Black oystercatcher is a large shorebird (Family Haemotopidae), ranging along the Pacific coast from the Aleutian Islands to central Baja California, Mexico. CINMS is at the southern end of their core breeding and feeding distribution. The black oystercatcher nests along rocky shorelines in mixed aggregations with other marine birds, and is known to hybridize with American oystercatcher in the Channel Islands. The 1989-1991 breeding colony surveys resulted in an estimate of 888 breeding birds in California, with 30% of the breeding population occurring in the northern Channel Islands (Carter *et al*., 1992). The cryptic, solitary nests make this a rough estimate, and population trends could not be determined from this survey. However, recent population declines are suspected in parts of Alaska. The black oystercatcher is not a endangered or threatened species. No at-sea sightings were available for this shorebird.

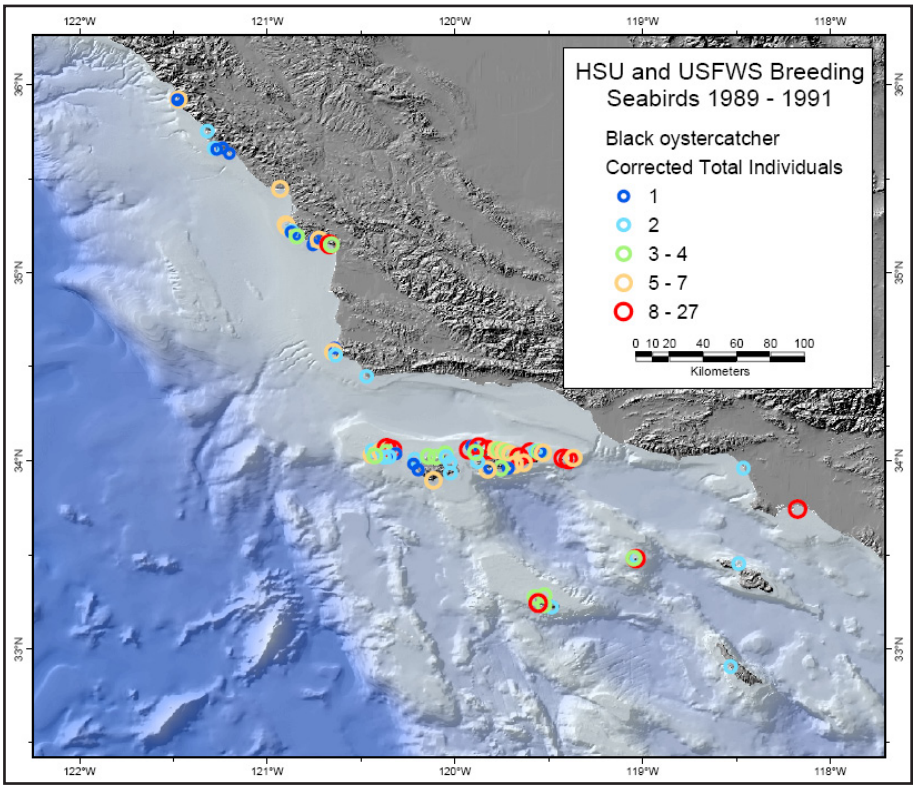


**Figure 5.1.12.** Black oystercatcher. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

Breeding colonies of black oystercatcher (Figure 5.1.12) exist on all eight of the Channel Islands with major colonies (top quintile, 8-27 individuals) occurring on San Miguel, Santa Cruz, Anacapa, Santa Barbara, and San Nicolas Islands. Numerous smaller colonies (less than 8 individuals each) exist on Santa Rosa Island.

Analysis of the distribution of black oystercatcher breeding colonies within the proposed boundary concepts suggests that Concept 2 provides the greatest increase in breeding individuals for its relative size compared to the NAC (Table 5.1.9). The increase in breeding individuals for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to

**Table 5.1.9.** Black oystercatcher. Colony counts (total individuals) and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Area ($km^2$) | Δ Individuals (%) | Δ Area (%) | OAI Individuals (absolute metric) |
|---|---|---|---|---|---|
| NAC | 267 | 3745 | - | - | - |
| 5 | 267 | 4536 | 0.00 | 21.12 | 0.000 |
| 4 | 267 | 7981 | 0.00 | 113.11 | 0.000 |
| 3 | **269** | 9044 | 0.75 | 141.50 | 0.005 |
| 2 | **278** | 13736 | 4.12 | 266.78 | 0.015 |
| 1a | **278** | 22591 | 4.12 | 503.23 | 0.008 |
| 1 | **278** | 22613 | 4.12 | 503.82 | 0.008 |
| *SA* | *278* | *17093* | *4.12* | *356.42* | *0.012* |

the inclusion of three additional colonies at Point Arguello. Concepts 1 and 1a also encompass these colonies, but their larger areas result in lower values for the OAI.

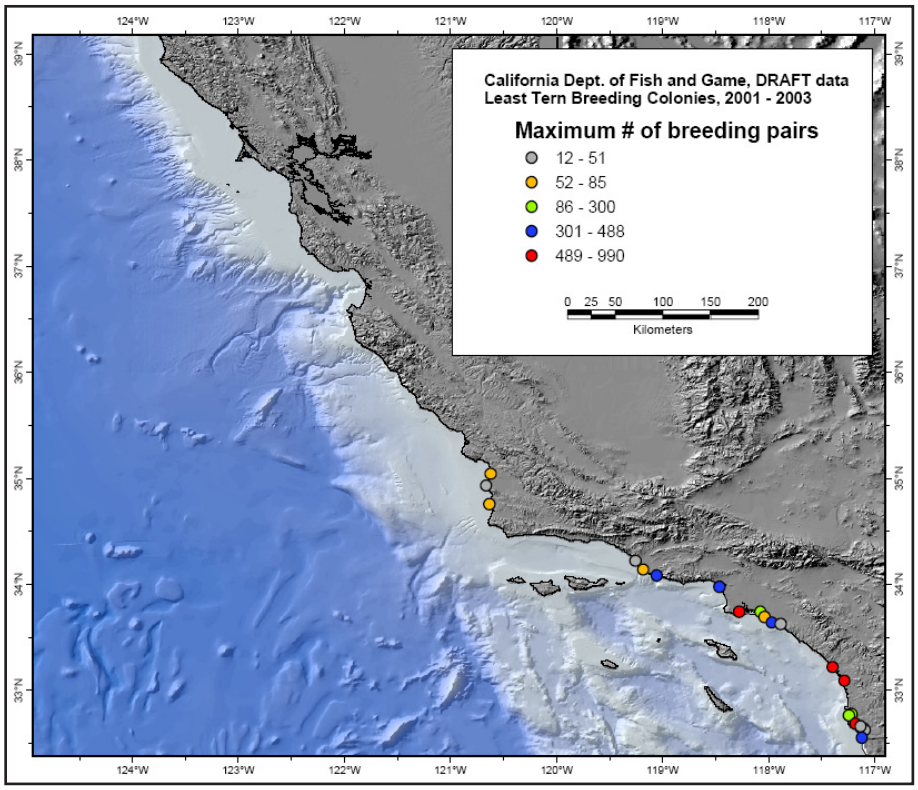


**Figure 5.1.13.** California least tern. Maximum number of breeding pairs 2001-2003 (Source: CDFG, draft data).

**California least tern**
(*Sterna antillarum browni*)
Five subspecies of least tern (Family Sternidae) are found in North America, with the California least tern nesting on beaches and sand dunes from the San Francisco Bay area south to Baja California, Mexico (Carter *et al*., 1992). CINMS is in the southern half of their core breeding distribution. A comprehensive survey of least terns in 1999 (Keane, 2001) estimated a California breeding population of 3,451 to 3,674 pairs at 36 colonies. The ten largest colonies (Mission Bay Mariner's Point, Santa Margarita River North Beach, NAB Ocean, NAS Alameda, Huntington Beach, Delta Beach North, L.A. Harbor Pier, NAWS Point Mugu, Batiquitos Lagoon and Tiuana River) represented 76.6% of the statewide breeding pairs. Numbers are declining in several areas in California (R. Jurek, pers. comm.). California least tern is listed as both a California and Federal endangered species.

**Table 5.1.10.** California least tern. Maximum number of breeding pairs observed at each nesting site surveyed from 2001-2003 for each boundary concept (CDFG, draft data).

| Concept | Maximum Breeding Pairs | Area ($km^2$) |
|---|---|---|
| NAC | 0 | 3745 |
| 5 | 0 | 4536 |
| 4 | 0 | 7981 |
| 3 | 0 | 9044 |
| 2 | **79** | 13736 |
| 1a | **676** | 22591 |
| 1 | **676** | 22613 |
| *SA* | *676* | *17093* |

There were no recorded breeding colonies of California least tern within the NAC or Concepts 3-5 between 2001-2003 (Figure 5.1.13; CDFG, draft data). Concept 2 encompasses one colony at Vandenberg AFB with a maximum of 79 breeding pairs (Table 5.1.10). Concepts 1 and 1a and the study area encompass an additional 4 colonies with a maximum of 676 breeding pairs. Because no colonies exist within the NAC, it is not possible to calculate the OAI for least tern colonies.

**Pigeon guillemot** (*Cepphus columba*)
Pigeon guillemot range throughout the North Pacific coasts with the southern end of their breeding range and feeding distribution in North America occurring at Santa Barbara Island. They nest mainly in rock crevices on mainland and island cliffs. The 1989-1991 breeding colony survey resulted in an estimate of 15,470 breeding birds in California, with 21% of the breeding population occurring in the northern Channel Islands (Carter *et al*., 1992). The survey showed little change in the abundance of pigeon guillemot overall in California since earlier (1975-1980) surveys (Carter *et al*., 1995a). However, greater abundance was observed at colonies on San Miguel, Santa Cruz, Anacapa, and Santa Barbara Islands, likely due to greater survey effort and different survey techniques. Population trends are not known for Southern California. Pigeon guillemot is not an endangered or threatened species.

At-sea sightings indicate that within Central and Southern California, areas of high pigeon guillemot density are found in nearshore waters near Monterey Bay (off Santa Cruz and Carmel), near Point Reyes and the Farallon Islands, off Point Arguello, and, most notably, around the northern Channel Islands (San Miguel, Santa Rosa, and Santa Cruz Islands). Analysis of the observed patterns of pigeon guillemot sightings (Figure 5.1.14) and density relative to the proposed boundary concepts indicate that Concept 2 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.11). Density (relative metric), however, was highest for

pigeon guillemot within the NAC and consequently the density-based OAI is negative for all of the concepts. Much of the increase in density for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to the inclusion of two or three additional high density grid cells near Point Arguello.

Breeding colonies of pigeon guillemot (Figure 5.1.15) exist on San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands, with major colonies (top quintile, 130-953 individuals) found on San Miguel, Santa Rosa, and Santa Cruz Islands. Southern California mainland colonies exist from Point Conception north to Lopez Point.

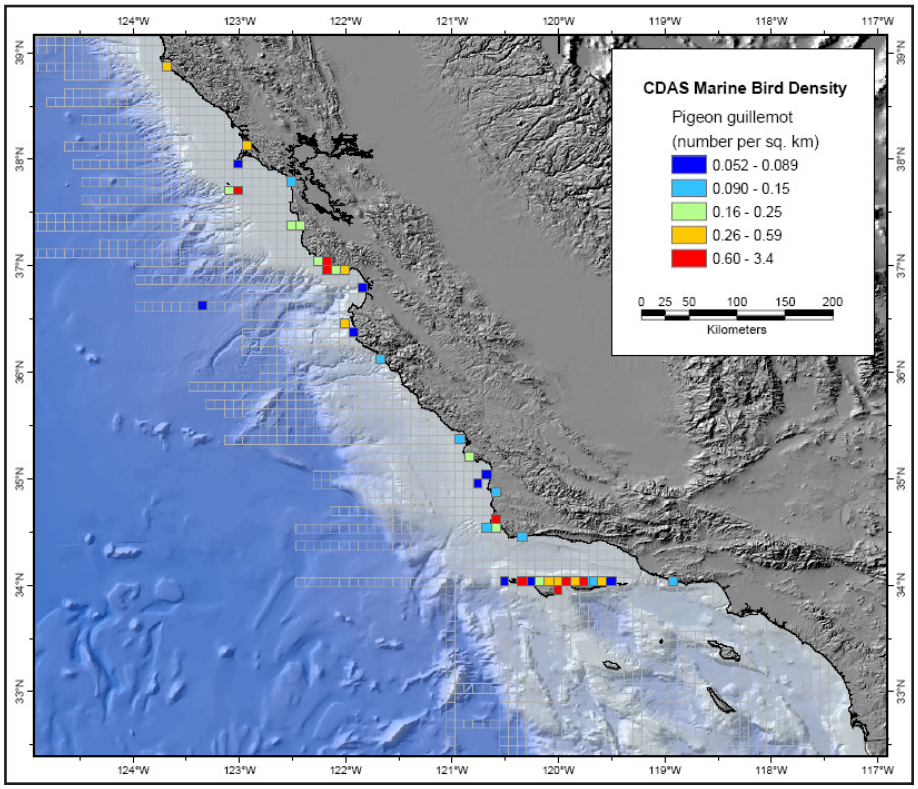


**Figure 5.1.14.** Pigeon guillemot. At-sea densities (individuals/km$^2$) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

Analysis of the distribution of pigeon guillemot breeding colonies within the proposed boundary concepts suggests that Concept 2 provides the greatest increase in breeding individuals for its relative size compared to the NAC (Table 5.1.12). The increase in breeding individuals for Concept 2 relative to the smaller concepts (3, 4, 5, and the NAC) is due to the inclusion of 11 additional colonies on and around Points Conception, Arguello, Purisima, and Sal. Concepts 1 and 1a also encompass these colonies and one additional colony of 5 individuals, but their larger areas result in lower values for the OAI.

**Table 5.1.11.** Pigeon guillemot. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km$^2$) | Density (Individuals per km$^2$) | Area (km$^2$) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 61 | 448.2 | 0.136 | 3745 | - | - | - | - | - |
| 5 | 61 | 492.3 | 0.124 | 4536 | 0.00 | -8.96 | 21.12 | 0.00 | -0.42 |
| 4 | 61 | 748.3 | 0.082 | 7981 | 0.00 | -40.10 | 113.11 | 0.00 | -0.35 |
| 3 | **67** | 984.6 | 0.068 | 9044 | 9.84 | -50.00 | 141.50 | 0.07 | -0.35 |
| 2 | **76** | 1589.1 | 0.048 | 13736 | 24.59 | -64.86 | 266.78 | 0.09 | -0.24 |
| 1a | **79** | 2460.3 | 0.032 | 22591 | 29.51 | -76.41 | 503.23 | 0.06 | -0.15 |
| 1 | **79** | 2460.3 | 0.032 | 22613 | 29.51 | -76.41 | 503.82 | 0.06 | -0.15 |
| *SA* | *79* | *2115.2* | *0.037* | *17093* | *29.51* | *-72.56* | *356.42* | *0.08* | *-0.20* |

**Xantus's murrelet** (*Synthliboramphus hypoleucus*)

Xantus's murrelet is a small alcid (Family Alcidae) that nests only in southern California and northwestern Baja California, Mexico. CINMS is at the northern edge of Xantus's murrelet breeding range, but not their feeding distribution. They nest in crevices and under bushes on offshore islands and rocks. The 1989-1991 breeding colony survey resulted in an estimate of 1719-1727 breeding birds in California. All of this breeding population occurs in the northern Channel Islands, with the vast majority nesting at Santa Barbara Island, and smaller numbers at San Miguel and Santa Cruz Islands (Carter *et al*., 1992). This survey estimate was substantially lower than that

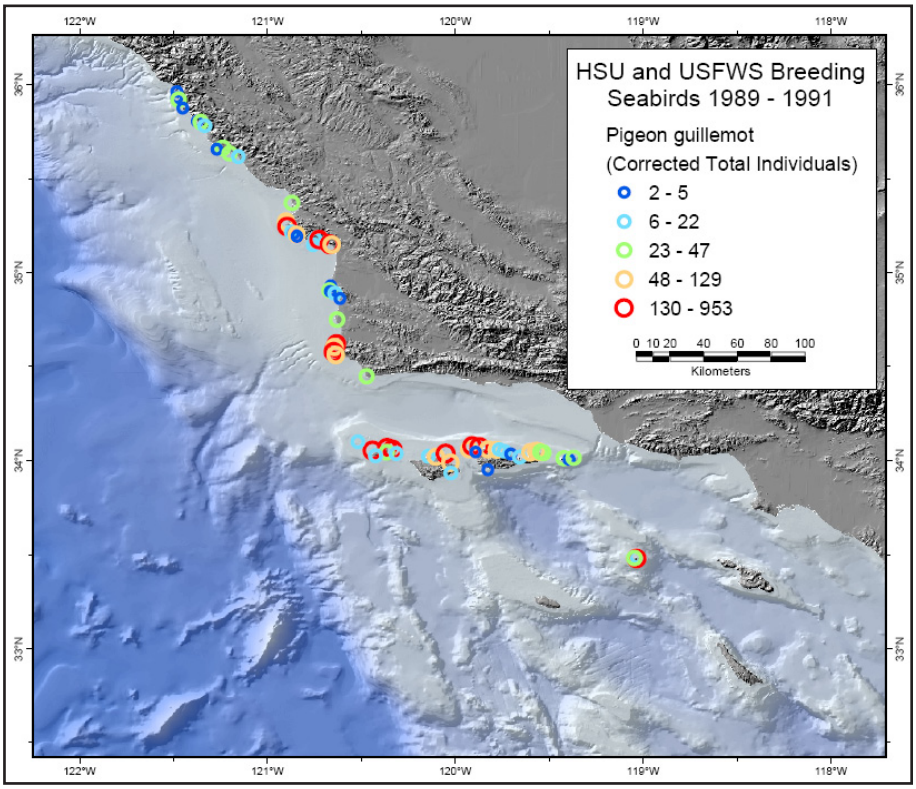


**Figure 5.1.15.** Pigeon guillemot. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al.*, 1992).

**Table 5.1.12.** Pigeon guillemot. Colony counts (total individuals) and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Area ($km^2$) | Δ Individuals (%) | Δ Area (%) | OAI Individuals (absolute metric) |
|---|---|---|---|---|---|
| NAC | 3218 | 3745 | - | - | - |
| 5 | 3218 | 4536 | 0.00 | 21.12 | 0.000 |
| 4 | 3218 | 7981 | 0.00 | 113.11 | 0.000 |
| 3 | **3247** | 9044 | 0.90 | 141.50 | 0.006 |
| 2 | **4777** | 13736 | 48.45 | 266.78 | 0.182 |
| 1a | **4782** | 22591 | 48.60 | 503.23 | 0.097 |
| 1 | **4782** | 22613 | 48.60 | 503.82 | 0.096 |
| *SA* | *4782* | *17093* | *48.60* | *356.42* | *0.136* |

from earlier (1975-1977) surveys due to an apparent decline at Santa Barbara Island, but differences in survey technique make it difficult to infer trends. More recent surveys (H. Carter, unpubl. data) have found new nesting areas at Anacapa, Santa Cruz and Santa Catalina Islands. More recent monitoring indicates that this species has continued to decline at Santa Barbara Island (Whitworth *et al*., 2003; Burkett *et al*., 2003; P. Martin, pers. comm.). Xantus's murrelet was recently recommended for listing as "Threatened" by the California Department of Fish and Game (California Regulatory Notice Register, March 5, 2004).

The at-sea pattern of Xantus's murrelet, as observed in the CDAS dataset, differs from that observed in the telemetry study. Both sources of information should be considered in order to fully understand the biogeography of this species in Southern California.

Although scattered observations of Xantus's murrelets occur in shelf waters off Central California in the fall and in the Santa Barbara Channel throughout the year, two cores of their distribution appear to occur in Southern California: (a) near the northern Channel Islands, and (b) near San Diego. The northern core reflects birds foraging

from colonies in the northern Channel Islands, while the southern core reflects foraging from the large colony at Islas Los Coronados.

Analysis of the observed patterns of Xantus's murrelet sightings (Figure 5.1.16) and density relative to the proposed boundary concepts indicates that Concept 3 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.13). The density-based OAI favors Concept 4, which includes some of the sightings in the Santa Barbara Channel. None of the concepts encompass the apparent core of the distribution in the southern Channel Islands.

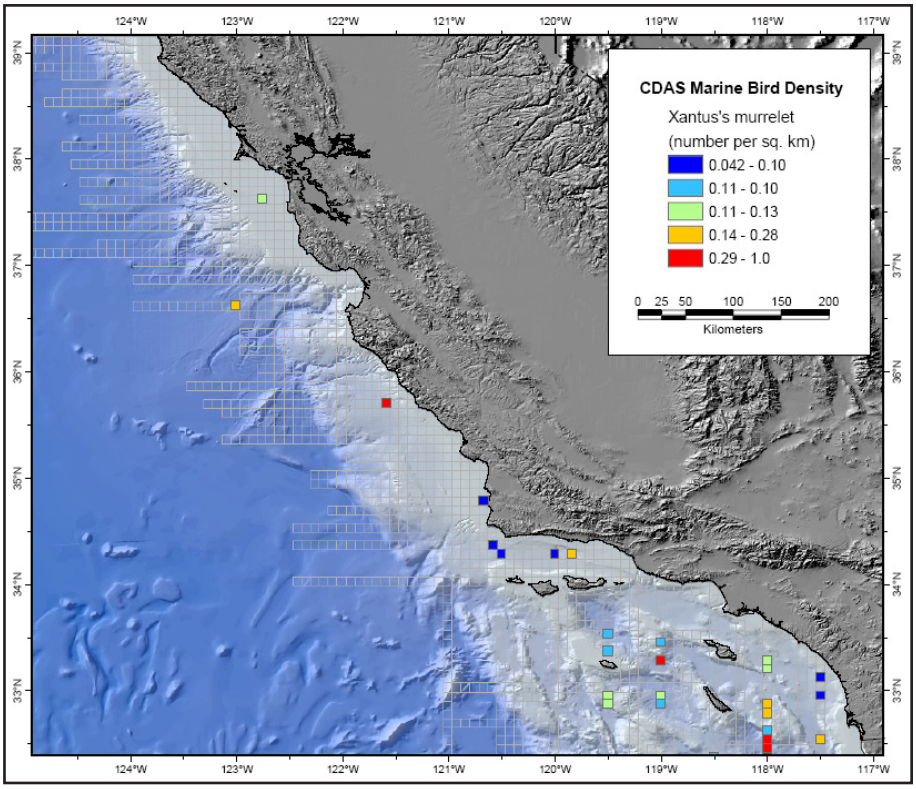


**Figure 5.1.16.** Xantus's murrelet. At-sea densities (individuals/km$^2$) calculated for five minute of latitude by five minute of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

Breeding colonies of Xantus's murrelet (Figure 5.1.17) observed during the 1989-1991 survey on San Miguel (Prince Island), Santa Cruz, and Santa Barbara Islands, with the largest colony (1402 individuals) on Santa Barbara Island. More recent surveys of Xantus's murrelet (H. Carter, unpubl. data) also found colonies on Anacapa (East, Middle, and West, Figure 5.1.18), San Clemente (Figure 5.1.19), San Miguel (Mainland) (Figure 5.1.20), Santa Barbara (Figure 5.1.21), Santa Catalina (Figure 5.1.22), and Santa Cruz (Figure 5.1.23) Islands, with the largest colonies (two shoreline segments had 150-400 pairs each) found on Santa Barbara Island. No colonies were found on Santa Rosa or San Nicolas Islands.

**Table 5.1.13.** Xantus's murrelet. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km$^2$) | Density (Individuals per km$^2$) | Area (km$^2$) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 1 | 448.2 | 0.0022 | 3745 | - | - | - | - | - |
| 5 | 1 | 492.3 | 0.0020 | 4536 | 0 | -8.96 | 21.12 | 0.00 | -0.42 |
| 4 | **5** | 748.3 | **0.0067** | 7981 | 400 | 199.48 | 113.11 | 3.54 | 1.76 |
| 3 | **7** | 984.6 | **0.0071** | 9044 | 600 | 218.65 | 141.50 | 4.24 | 1.55 |
| 2 | **8** | 1589.1 | **0.0050** | 13736 | 700 | 125.64 | 266.78 | 2.62 | 0.47 |
| 1a | **8** | 2460.3 | **0.0033** | 22591 | 700 | 45.74 | 503.23 | 1.39 | 0.09 |
| 1 | **8** | 2460.3 | **0.0033** | 22613 | 700 | 45.74 | 503.82 | 1.39 | 0.09 |
| *SA* | *8* | *2115.2* | *0.0038* | *17093* | *700* | *69.52* | *356.42* | *1.96* | *0.20* |

No analysis of boundary concepts was conducted for Xantus's murrelet breeding colonies since none of the concepts encompass colonies not already contained within the NAC.

Relocation of radiomarked Xantus's murrelets from Santa Barbara Island occurs throughout the western Southern California Bight, with scattered observations occurring as far north as Monterey Bay (Whitworth *et al*., 2000; Figure 5.1.24). During the breeding season (April to June) the density of relocations were highest around the northern Channel Islands from west of San Miguel Island to Point Mugu, around Santa Barbara Island, and to the south of San Nicolas

Island. Modest densities of relocations was found west of the Santa Barbara Channel, between San Miguel Island and Point Sal, but these observations were from birds dispersing northward to central California in late summer (Whitworth *et al*., 2000).

Analysis of observed patterns of radio-marked Xantus's murrelet relocations relative to the proposed boundary concepts indicates that Concept 5 provides the greatest increase in sightings (absolute metric) for its relative size compared to the NAC (Table 5.1.14). As expected, however, more sightings are included in the larger concepts. Each successively larger concept appears to encompass new clusters of relocations, with the exception of Concept 1, which does not encompass any more relocations than Concept 1a.

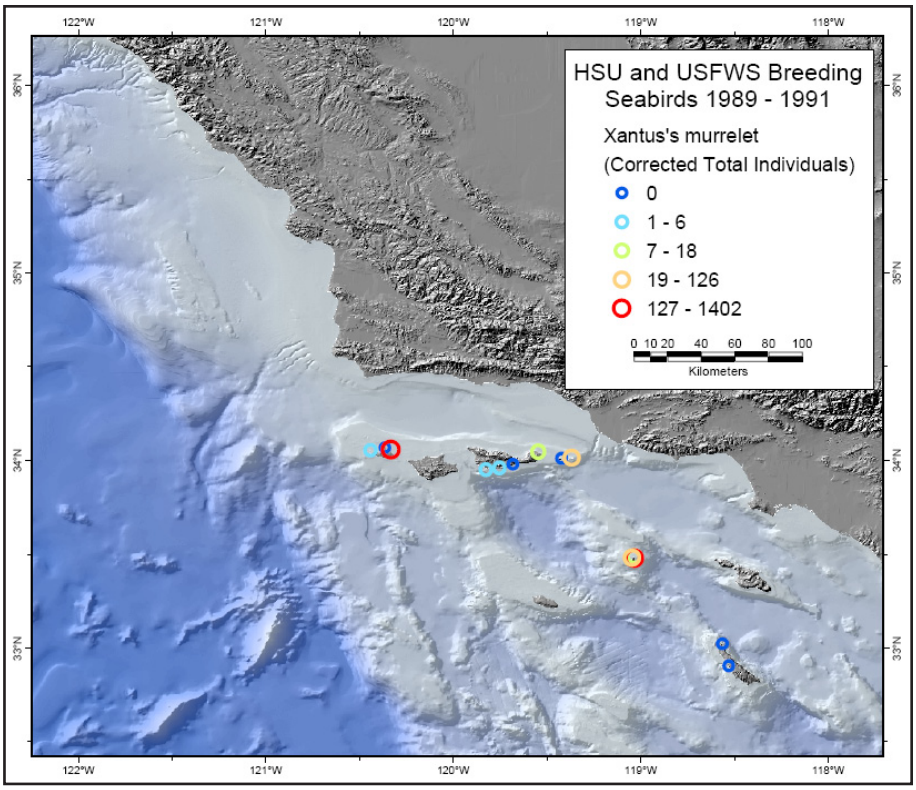


**Figure 5.1.17.** Xantus's murrelet. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al*., 1992).

**Table 5.1.14.** Xantus's murrelet. Telemetry relocations and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Relocations | Area ($km^2$) | Δ Relocations (%) | Δ Area (%) | OAI Relocations (absolute metric) |
|---|---|---|---|---|---|
| NAC | 127 | 3745 | - | - | - |
| 5 | **223** | 4536 | 75.59 | 21.12 | 3.579 |
| 4 | **308** | 7981 | 142.52 | 113.11 | 1.260 |
| 3 | **313** | 9044 | 146.46 | 141.50 | 1.035 |
| 2 | **371** | 13736 | 192.13 | 266.78 | 0.720 |
| 1a | **412** | 22591 | 224.41 | 503.23 | 0.448 |
| 1 | **412** | 22613 | 224.41 | 503.82 | 0.445 |
| *SA* | *411* | *17093* | *223.62* | *356.42* | *0.627* |

**Cassin's auklet**
(*Ptychoramphus aleuticus*)

Cassin's auklet is a small alcid (Family Alcidae) that ranges from the Aleutian Islands to central western Baja California, Mexico. CINMS is south of their core breeding distribution. They nest in burrows and crevices on offshore islands. The 1989-1991 breeding colony survey resulted in an estimate of 56,572 breeding birds in California, with 22% of this population occurring in the northern Channel Islands (Carter *et al*., 1992). Although the survey showed an overall decline in abundance of Cassin's auklet since 1975-1980 surveys (Carter *et al*., 1995a), numbers of breeding birds at Santa Cruz Island were found to be greater than in the 1975-1977 surveys, but a trend could not be determined. Continued decline since 1991 is suspected (H. Carter, unpubl. data). Cassin's auklet is not an endangered or threatened species.

At-sea sightings indicate that Cassin's auklet densities appear to be greater to the north of the CINMS study area with the highest densities occurring north of Point Año Nuevo near the large Farallon Islands colony. Nevertheless, there are many sightings of Cassin's auklet within the study area and within the current CINMS boundaries. Areas of relatively high density exist within the western Santa Barbara Channel especially to the north of San Miguel and Santa Rosa Islands, adjacent to the large Prince Island colony.

Analysis of the observed patterns of Cassin's auklet sightings and density (Figure 5.1.25) relative to the proposed boundary concepts indicates that Concept 2 provides the greatest increase in both sightings (absolute metric) and density (relative metric) for its relative size compared to the NAC (Table 5.1.15). Concepts 1 and 1a also displayed high

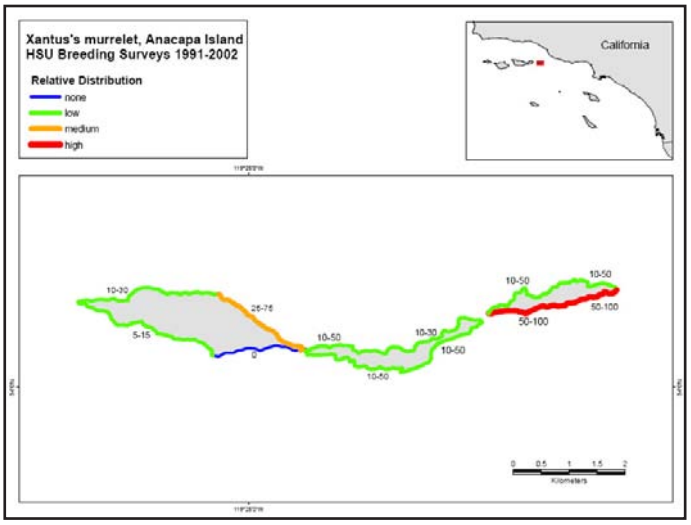


**Figure 5.1.18.** Xantus's murrelet. Anacapa Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

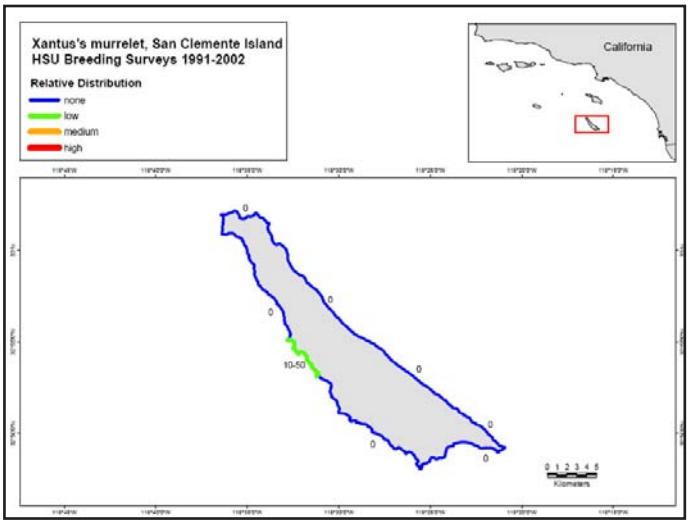


**Figure 5.1.19.** Xantus's murrelet. San Clemente Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

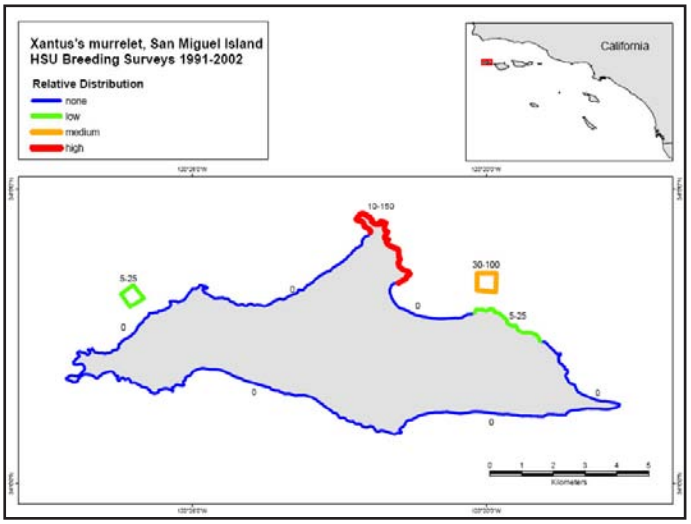


**Figure 5.1.20.** Xantus's murrelet. San Miguel Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

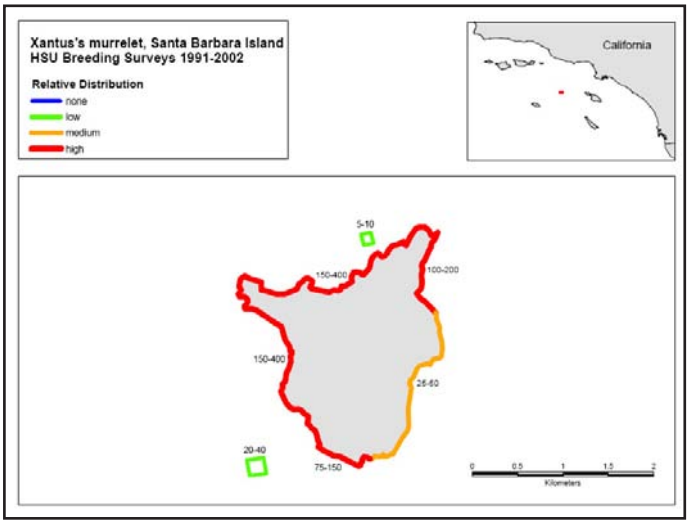


**Figure 5.1.21.** Xantus's murrelet. Santa Barbara Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

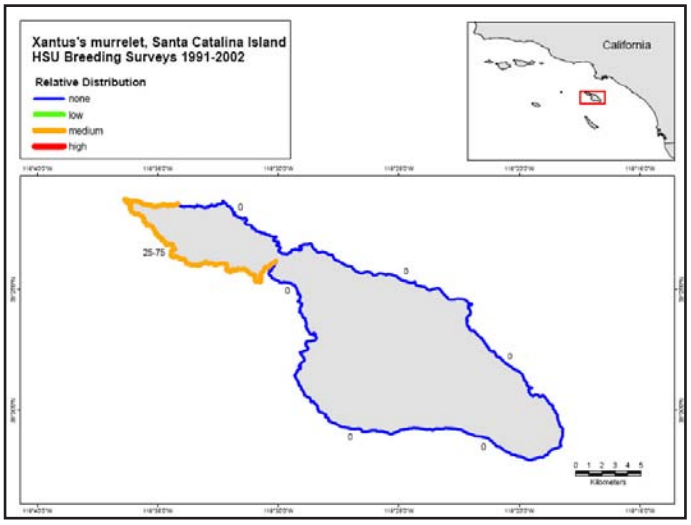


**Figure 5.1.22.** Xantus's murrelet. Santa Catalina Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

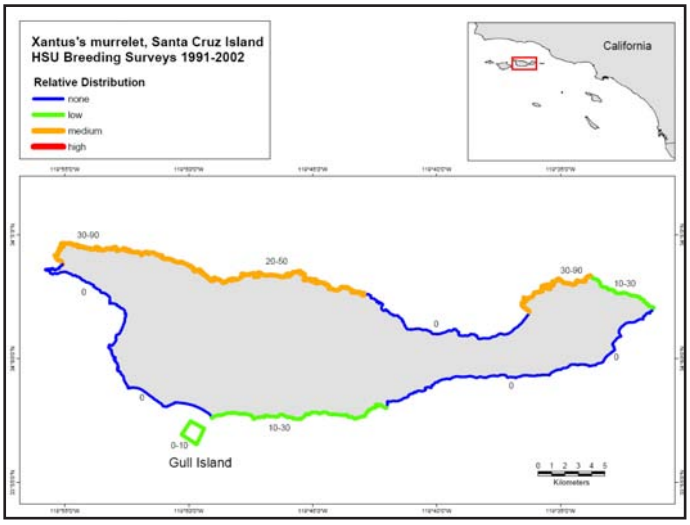


**Figure 5.1.23.** Xantus's murrelet. Santa Cruz Island colony counts (estimated total individuals per shoreline segment) 1991-2002 (Source: H. Carter, unpublished data).

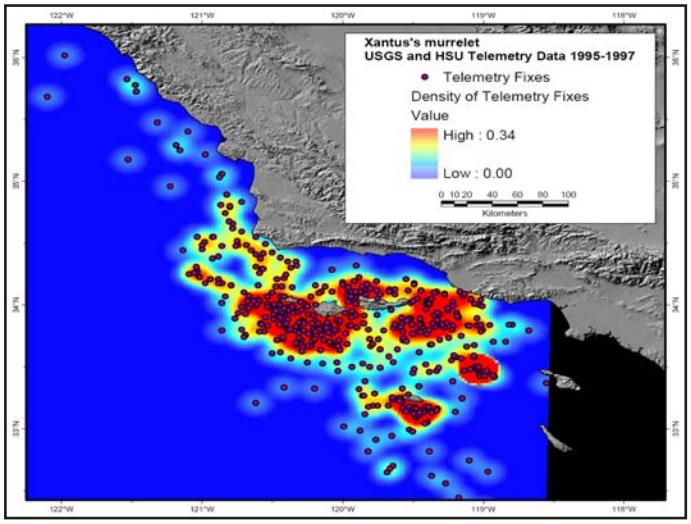


**Figure 5.1.24.** Xantus's murrelet. Telemetry relocations during 1995–1997 and kernel density surface based on the relocation points (cell size=2 km, radius=15 km). Black shading indicates no data available. (Source: USGS ands HSU; Whitworth *et al*., 2000; Carter *et al*. 2000).

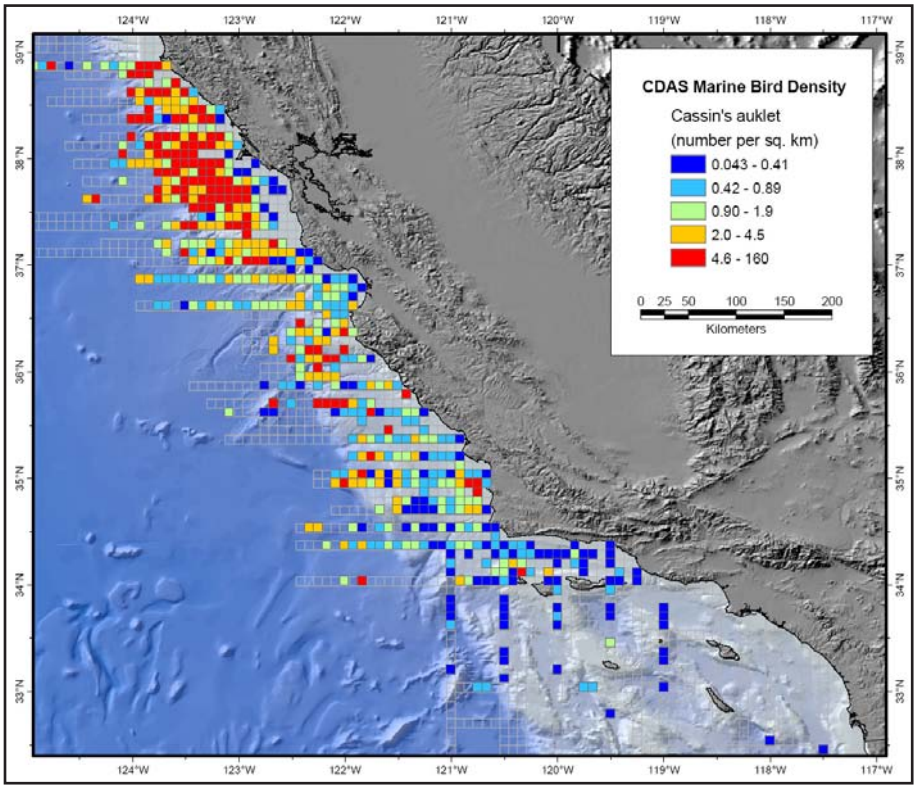


**Figure 5.1.25.** Cassin's auklet. At-sea densities (individuals/km$^2$) calculated for five minutes of latitude by five minutes of longitude grid cells from aerial and shipboard survey data collected from 1975-1997 and summarized in the Computer Database Analysis System v2.1 (MMS, 2001).

values for both OAI's, while the smaller concepts (3-5) showed only modest increases in sightings and lower densities compared to the NAC. Much of the improvement in sightings and densities observed for the larger concepts (1, 1a, and 2) is due to the inclusion of an area of high density off Point Sal.

Breeding colonies of Cassin's auklet (Figure 5.1.26) exist on San Miguel, Santa Cruz, and Santa Barbara Islands, with the two largest colonies (547 and 8922 individuals) in Southern California found on San Miguel Island (Prince Island and Castle Rock).

No analysis of boundary concepts was conducted for Cassin's auklet breeding colonies since none of the concepts encompass any colonies not contained within the NAC.

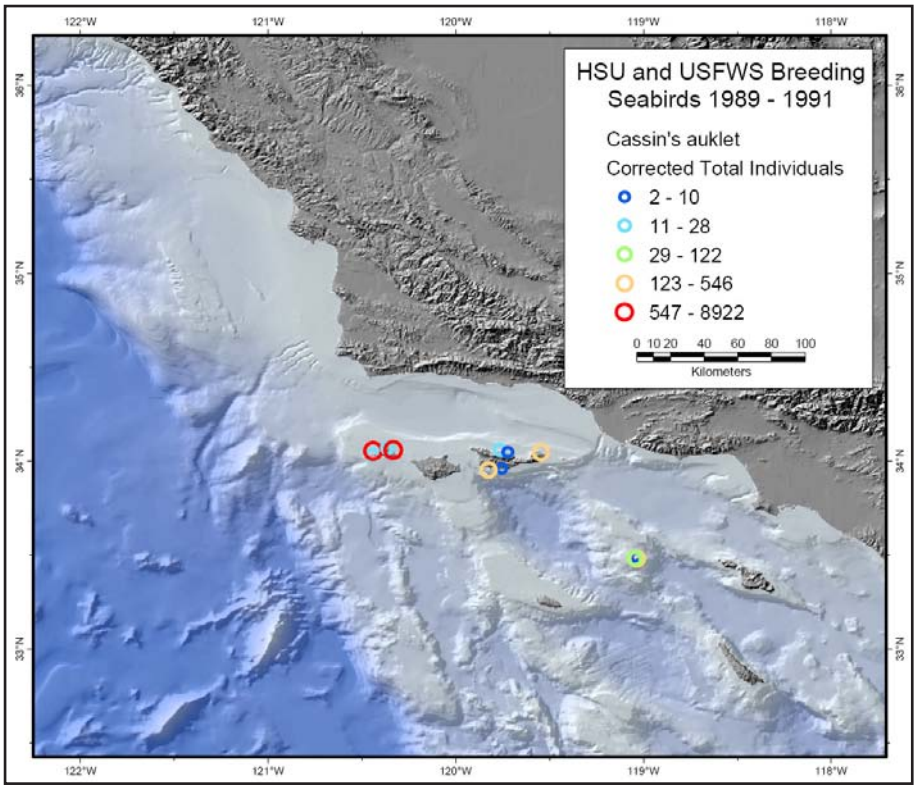


**Figure 5.1.26.** Cassin's auklet. Colony counts (corrected total individuals) 1989-1991 (Source: Carter *et al.*, 1992).

### Other Marine Birds

In addition to the requested species, several other species of marine birds occur in the CINMS or possible concept areas in relatively large numbers at certain times of year or in certain years. Additional seabirds and shorebirds found in the study area may include the Pacific loon, western grebe, sooty shearwater, pink-footed shearwater, black-vented shearwater, Brant, surf scoter, red-necked phalarope, red phalarope, Heermann's gull, Bonaparte's gull, California gull, ring-billed gull, common murre, rhinoceros auklet, and the tufted puffin. While no quantitative analysis was conducted for these species, it is important to recognize that they may be impacted by changes to the boundaries of the CINMS and further investigation into these species may be warranted.

**Table 5.1.15.** Cassin's auklet. At-sea sightings, effort, density, and Optimal Area Index (OAI) for each boundary concept. Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Total Individuals | Total Effort (Area swept km²) | Density (Individuals per km²) | Area (km²) | Δ Individuals (%) | Δ Density (%) | Δ Area (%) | OAI Individuals (absolute metric) | OAI Density (relative metric) |
|---|---|---|---|---|---|---|---|---|---|
| NAC | 149 | 448.2 | 0.332 | 3745 | - | - | - | - | - |
| 5 | **156** | 492.3 | 0.317 | 4536 | 4.70 | -4.68 | 21.12 | 0.22 | -0.22 |
| 4 | **229** | 748.3 | 0.306 | 7981 | 53.69 | -7.95 | 113.11 | 0.47 | -0.07 |
| 3 | **288** | 984.6 | 0.293 | 9044 | 93.29 | -12.01 | 141.50 | 0.66 | -0.08 |
| 2 | **1115** | 1589.1 | **0.702** | 13736 | 648.32 | 111.06 | 266.78 | 2.43 | 0.42 |
| 1a | **1819** | 2460.3 | **0.739** | 22591 | 1120.81 | 122.40 | 503.23 | 2.23 | 0.24 |
| 1 | **1819** | 2460.3 | **0.739** | 22613 | 1120.81 | 122.40 | 503.82 | 2.22 | 0.24 |
| *SA* | *1481* | *2115.2* | *0.700* | *17093* | *893.96* | *110.61* | *356.42* | *2.51* | *0.31* |

### Summary

• Of the five boundary concepts being considered in addition to the NAC, the concept with the highest OAI value varies considerably depending on the particular species being considered.

• For many species, the NAC and the smaller Concepts 4 and 5 showed lower OAI values than the larger Concepts, 1, 2, and 3.

## CHAPTER 5.2 MARINE BIRD DIVERSITY

### Data and Methods

The marine bird diversity data presented in this section are derived from six at-sea surveys (including both marine and aerial platforms) of marine birds from the period 1975-1997. The results of these surveys are compiled in the Computer Database Analysis System (CDAS) v2.1 (MMS, 2001). The surveys used in this analysis are summarized in Table 5.2.1. Although CDAS contains survey data along the west coast of Washington, Oregon, and California, this analysis focused on those sightings south of Point Arena. The location of bird sightings and the distribution of survey effort are shown in Figure 5.2.1. A total of 95 bird species were observed in the combined surveys. Although some shorebirds are included in the list, these at-sea surveys were not designed to sample shorebirds or nesting colonies.

**Table 5.2.1.** Summary of the six surveys that were used in the analysis of marine bird diversity. The information in this table reflects the data used in this analysis, which in some cases may be a temporal and geographic subset of the entire survey.

| Survey | Dates | Platform | Months | Total sightings | Total individuals |
|---|---|---|---|---|---|
| Minerals Management Service Aerial Surveys | 1980-1983 | airplane (low altitude) | Year-round | 28525 | 91298 |
| California Department of Fish and Game, Office of Spill Prevention and Response | 1994-1997 | airplane (low altitude) | Year-round | 7751 | 71151 |
| Southern California Bight Low Aerial Survey | 1975-1978 | airplane (low altitude) | Year-round | 4250 | 17741 |
| Seabird Ecology Study | 1985 | ship and airplane | March and May | 2212 | 8641 |
| Southern California Bight Ship Survey | 1975-1978 | ship | Year-round | 17693 | 58719 |
| Southern California Bight, Minerals Management Service Survey | 1995-1997 | airplane (low altitude) | Year-round | 9780 | 46199 |

The Shannon index of diversity (Shannon and Weaver, 1949) was chosen for this analysis because it is one of the most commonly used diversity metrics in community ecology and has relatively small statistical bias when sample sizes are large (as is the case with this source data) (Magurran, 1988). The Shannon index attempts to balance species richness (*i.e.*, the total number of unique species) with species evenness (i.e. the distribution of individuals among the species). For a given number of individuals and species, the Shannon index is highest when there is an equal number of individuals of each species.

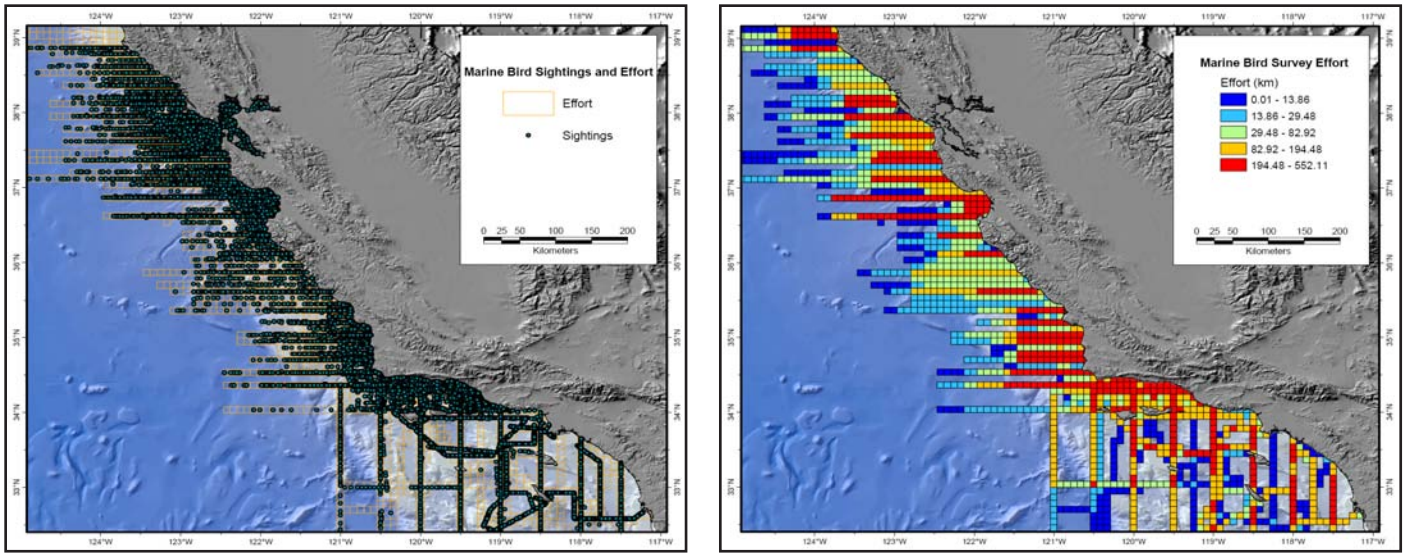


**Figure 5.2.1.** The distribution of CDAS marine bird survey effort and sightings (left) and the total amount of effort within 5 minutes of latitude by 5 minutes of longitude grid cells (right) within the region from Point Arena to the U.S.-Mexico border.

Since the CDAS data includes summaries for 5 minutes of latitude by five minutes of longitude grid cells, we calculated total observed diversity for each 5 minute cell. The Shannon index (H') was calculated using the formula:

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

where $n_i$ is the number of individuals belonging to the $i^{th}$ species (S) in the sample (five minute grid), and N is the total number of individuals in the sample (Magurran, 1988).

To aid in the analysis and visual interpretation of the diversity map, the estimated diversity was then interpolated using kriging to provide a statistically smoothed one km raster surface. To accomplish this, the calculated diversity for each five minute cell was first assigned to a point at the center of the cell (i.e. the cell centroid). These point data were subsequently tested for significant spatial autocorrelation using the Moran's I and Geary's C statistics. A finding of significant autocorrelation indicates that points that are nearer to one another tend to have more similar values of diversity than points that are far away (Legendre, 1993), and is a prerequisite to accurate interpolation. Next, the spatial autocorrelation was described using a variogram, which summarizes the decrease in relatedness between pairs of points as the distance between them increases. The parameters of the variogram were used in a geostatistical interpolation technique known as kriging, which provides a surface of predicted values as well as a standard error surface indicating the regions in which we have higher or lower confidence in the accuracy of estimated diversity. To avoid displaying estimates of diversity in areas where we have little confidence in the prediction, the standard error map was used to clip the diversity surface. The resulting map (Figure 5.2.2) displays interpolated bird diversity for those regions where the standard error was in the lowest 25 percent.

The estimated patterns of bird diversity should be interpreted with care, as they represent a compilation of six surveys with different methods occurring over a period of nearly 25 years. The distribution and abundance of some species are known to have changed since 1975 (the earliest data used in this analysis). A drawback common to nearly all diversity metrics is the strong positive and non-linear (He *et al*., 1994) correlation between diversity and sampling effort. As sampling effort increases in a given region, the calculated diversity within that region increases as well. Consequently, when sampling effort varies over a given area (as it does within the project study area) some of the observed patterns in diversity may be related to patterns in the distribution of sampling effort. For this reason, we have included a map of sampling effort (Figure 5.2.1) to be considered alongside the map of diversity (Figure 5.2.2).

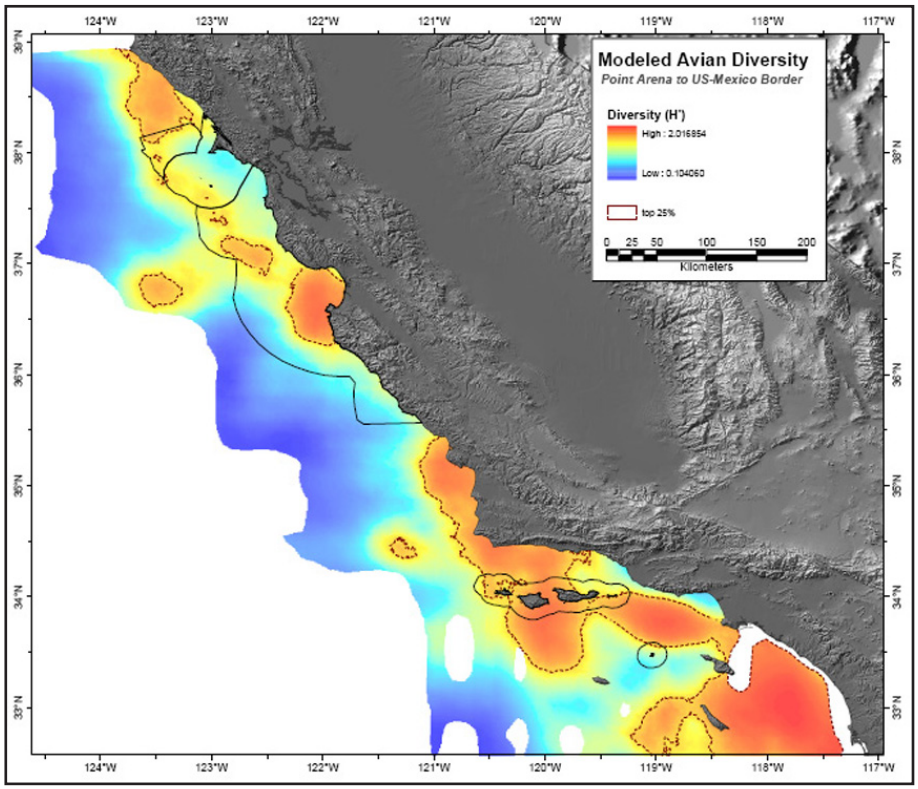


**Figure 5.2.2.** Estimated bird diversity from Point Arena, Calfiornia to the U.S.-Mexico border. Stippled areas delineate zones representing the 75th percentile of the estimate.

## Broad-scale Patterns

The marine bird diversity model resulted in several meso-scale patches (tens to hundreds of kilometers in size) from Point Arena in the north to the U.S.-Mexico border in the south. Regions of high estimated diversity (warm tones) appear along the entire stretch, with a large patch extending from the shelf waters north of Cordell Bank National

Marine Sanctuary through the Gulf of the Farallones and Monterey Bay national marine sanctuaries along the shelf break terminating in the region of Monterey Bay and Point Sur (Figure 5.2.2). A second conspicuous area of high estimated diversity appears approximately 140 km west of Monterey Bay in the open waters over the Guide Seamount. Farther to the south another much smaller patch of high diversity appears in the vicinity of the Santa Lucia Bank. This small patch appears to be a seaward extension of the most prominent extent of high diversity, which ranges along the shelf from Morro Bay in the north down to Point Conception. This significant feature then spreads throughout the entire Southern California Bight, with concentrations around the Channel Islands, the Santa Barbara Channel, and southern shelf areas.

In general, model results indicate that the current arrangement of sanctuaries along the California coastline captures substantial areas of high estimated diversity. In this analysis (ranging from 39° to 32°N latitude), the total area represented by the top 25% of the diversity estimate (Figure 5.2.2, stippled area) was 33,881 $km^2$. Roughly 5,770 $km^2$ (17%) of this overall area is contained within the four California sanctuaries, with 6% falling inside the boundaries of the Channel Islands National Marine Sanctuary. A total of 61% of the area contained within current CINMS boundaries was classified as having high marine bird diversity. This is the largest proportion of any California sanctuary.

More than 195 species of birds occupy coastal and/or offshore aquatic habitats in the SCB (McGinnis, 2000). Although many of these species are widely distributed along the west coast, the area of upwelling off Point Arguello/Conception has long been discussed as a key attraction for many of the region's seabird species (Briggs *et al*., 1987). The convergence of two distinct water masses, coupled with elevated productivity associated with upwelling, attracts birds typical of both cool temperate and warm subtropical waters, and contributes to the diversity of the bird community (Baird, 1993).

Linkages between oceanographic character, marine biological productivity, and bird populations have been a topic of considerable study (Briggs *et al*., 1987; Ainley and Boekelheide, 1990; Ainley *et al*., 1995; Roemmich and McGowan, 1995; Sydeman *et al*., 1997; Schoenherr *et al*., 1999). Upwelling in the SCB has been correlated to relatively high concentrations of krill and secondary consumers off the northern Channel Islands. In turn, these pelagic invertebrates and forage fishes attract seabirds to the open ocean over the continental shelf around the Channel Islands. Sooty shearwaters (*Puffinis griseus*), which are among the most numerous seabirds in the region, forage on fish, squid, and euphausiids (Chu, 1984). Shortbelly rockfish, anchovy, and sardine are among the primary foods of common murres (*Uria aalge*), Brandt's cormorants (*Phalacrocorax penicillatus*), and rhinoceros auklet chicks (*Cerorhinca monocerata*). Murres and some other seabirds feed principally on euphausiids in the spring, before juvenile fish and anchovies are available (Ainley and Boekelheide, 1990; Ainley *et al*., 1995). California brown pelicans (*Pelecanus occidentalis californicus*) feed primarily on northern anchovy, Pacific sardine, and Pacific mackerel. Cassin's auklets (*Ptychoramphus aleuticus*) depend on euphausiids and mysids as their primary food supply (Sydeman *et al*., 1997). Rhinoceros auklets frequent waters of the continental slope, where they feed on euphausiids, oceanic squid, and fishes, including lanternfishes and Pacific saury. Adult rhinoceros auklets are also known to consume sablefish and juvenile lingcod found in deep waters far offshore (Airamé *et al*., 2003). The diet of the ashy storm-petrel is poorly known, but includes euphausids.

While these trophic linkages do not explain all of the diversity model results, they do corroborate many of the emerging patterns. Each of the high diversity areas identified in the results section occurs near well known upwelling centers (Breaker and Gilliland, 1981; Kelly, 1985; Breaker and Mooers, 1986; Huyer and Kosro, 1987; Tracy, 1990; Brink and Cowles, 1991; Schwing *et al*., 1991; Breaker and Broenkow, 1994; Rosenfeld *et al*., 1994), including the area near Point Arena, the area near Point Año Nuevo, the nearshore waters directly adjacent to Point Sur, and, as described above, the area of upwelling near Point Arguello/Conception.

Another likely contributing factor in the expression of patterns of bird diversity is proximity to nesting sites. The Farallon Islands are the highest density area for nesting seabirds along the California coast and offshore islands/rocks (Airamé *et al*., 2003). Over 300,000 adult birds nest on the islands in May, which represents the height of the breeding season, although two species (common murre and Cassin's auklet) comprise over half of all birds. Twelve species of marine birds, including common murre, Cassin's and rhinoceros auklets, pigeon guillemot, tufted puffin, western gull, cormorants (double-crested, Brandt's, and pelagic), ashy and Leach's storm-petrels, and black oystercatcher, breed on the Farallon Islands (Ainley and Boekelheide, 1990; Schoenherr *et al*., 1999). This concentration of individuals and species likely influences the broad band of relatively high diversity south and seaward of the Farallones. Most of the remainder of California breeding seabird populations nest on the

northern Channel Islands, including: Leach's, ashy and black storm-petrels; California brown pelican; double-crested, Brandt's, and pelagic cormorants; western gull; pigeon guillemot; Xantus's murrelet; Cassin's and rhinoceros auklets; and tufted puffin. Over 200,000 adult birds nest on the islands in April-May, which represents the height of the breeding season. Although not condensed into such a small area as the Farallon Islands, the Channel Islands populations of breeding seabirds are of similar magnitude and diversity as the Farallon Islands. Additionally, the Channel Islands contain the entire U.S. populations of black storm-petrel, California brown pelican, and Xantus's murrelets, plus over 33% of the world populations of ashy storm-petrels and Xantus's murrelets. While the Farallon Islands also hosts over 33% of the world population of ashy storm-petrels, its populations of other species do not reach significant portions of world populations. Thus, in several ways, Channel Islands populations are more important than the Farralon Islands populations on a world scale. Breeding populations in the Channel Islands clearly influence diversity estimates in this area.

**Analysis of Boundary Concepts**

The preceding discussion identified a large region of high bird diversity centered on the Channel Islands, ranging along the shelf from Morro Bay in the north down to Point Conception, where it then spreads throughout the entire Southern California Bight. This region corresponds roughly with the general region of range termini between 36° and 26°N and the southern part of the California Current Upwelling System. A total of 61% of the area contained within current CINMS boundaries was classified as having high (top 25%) marine bird diversity – the largest proportion of any California Sanctuary. As such, it is important to note that the current sanctuary boundary captures areas of high marine bird diversity; however, a review of the remaining concepts clearly suggests that an expansion could provide further conservation benefit in terms of preserving areas of high bird diversity. In this section we will use the current boundary (NAC) as a reference point against which the remaining concepts and analyses will be compared.

Mean estimated diversity for the NAC was calculated to be 1.49 with a coefficient of variation (CV) of 8.8%. Mean diversity and CV values for the remaining concepts, ranging from smallest in size to largest, are as follows: Concept 5-1.49, 8.7%; Concept 4-1.52, 9.9%; Concept 3-1.53, 9.8%; Concept 2-1.50, 10%; Concept 1a-1.37, 20.3%; and Concept 1-1.38, 20.4%. Mean diversity for the Study Area boundary is estimated to be 1.49 with a CV of 9.9% (Figure 5.2.3, also see Table 5.2.2.) As discussed in Chapter 1.4 which describes absolute versus relative metrics, results shown here are generally predictable, with a trend of larger areas exhibiting lower mean diversity values than smaller ones. This trend is graphically represented in Figure 5.2.4 as a linear regression function between area ($km^2$) and mean diversity ($r^2$=0.60, P=0.02). It should be noted, however, that the trend shown in this figure is largely driven by concepts 1 and 1a, and that while the trend is predictable, concepts 2, 3, and 4 are higher than expected. This indicates that the boundary configuration for these concepts disproportionately captures areas of high bird diversity, and that any of these concepts would be a suitable choice for expansion. Clearly, concepts 1 and 1a would be a less suitable choice based on mean diversity alone. The relationship between the absolute areas of high diversity (Figure 5.2.2, stippled area) is even more predictable than mean diversity, with larger concepts containing ever larger areas of high diversity (Table 5.2.2). Figure 5.2.5 shows the linear regression function between the total area ($km^2$) and the area of high diversity contained within each concept ($r^2$=0.91, $P < 0.01$).

A more balanced metric to use in assessing the relative conservation value for bird diversity is the Optimal Area Index (OAI) (Table 5.2.2). While this metric decouples the predictable relationships between concept area and conservation value to some extent, results of the OAI are still dependent upon the input data – absolute vs. relative measures. As such, we've provided results of the OAI for both mean and absolute bird diversity. Again, the OAI takes into account the proportional (%) change in diversity as you step from the NAC to each of the concepts under consideration. It also incorporates the proportional change (%) in area from the NAC.

In both cases, the OAI indicate that concepts 3 and 4 provide the largest conservation value per area gained (Table 5.2.2). Because the mean OAI incorporated a negative value in the numerator for concepts 1 and 1a (decreased mean diversity), the calculated value is necessarily negative. Likewise, because the absolute count of high diversity area always increases with each concept, the OAI values are positive.

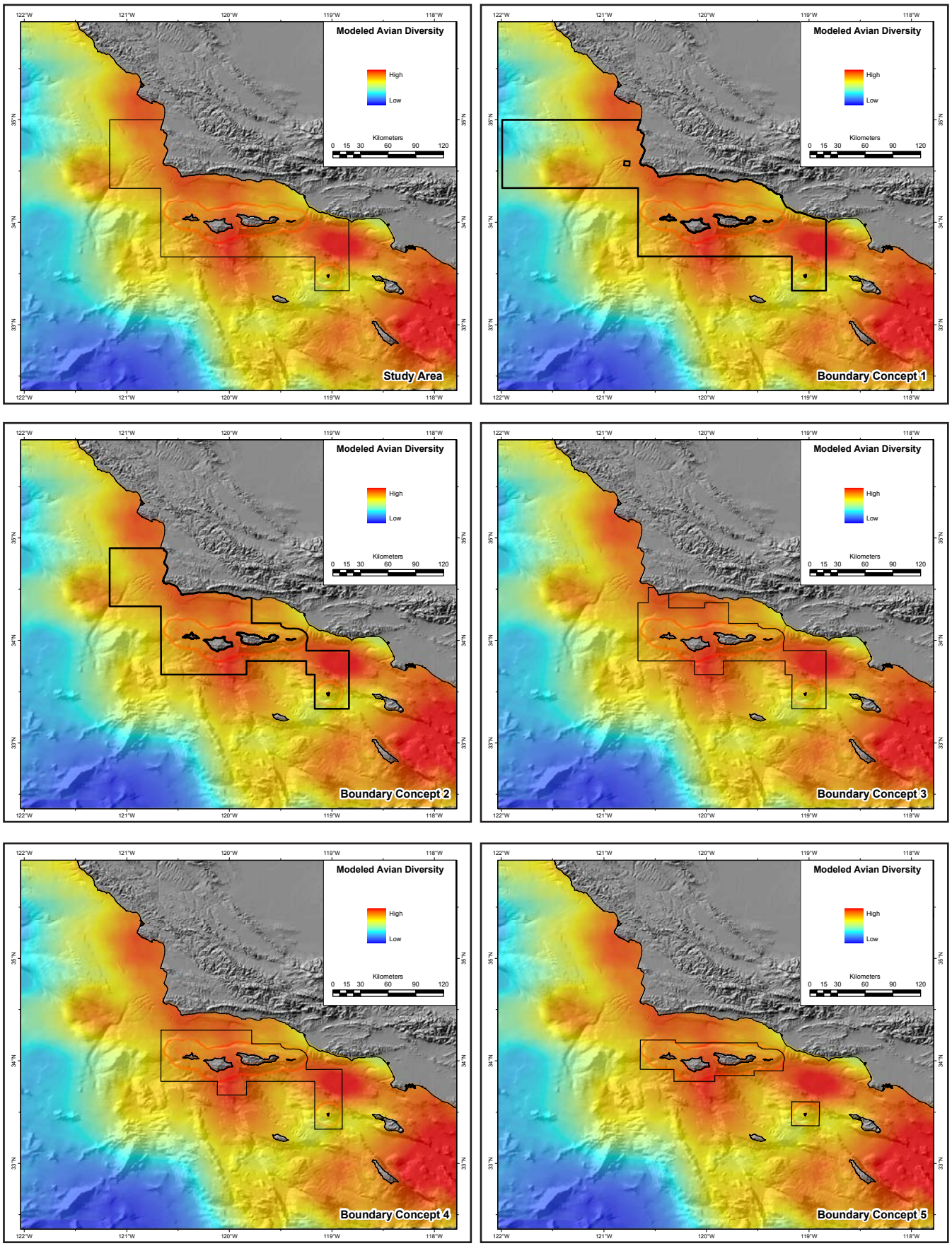


**Figure 5.2.3.** Overlay of estimated marine bird diversity and CINMS boundary concepts. The Study Area (upper left) is not a concept currently under consideration, but is analyzed to provide a point of comparison to the McGinnis report. Concept 1 is shown with the "cutout" and is to be used as a representative map for both Concepts 1 and 1a.

**Table 5.2.2.** Analysis of bird diversity within boundary concepts. Numbers in bold indicate an increase in the estimate when compared to the No Action Concept (NAC). Values in bold indicate an increase in the estimate when compared to the NAC. Shaded OAI estimates reflect the concept with the greatest positive value.

| Concept | Area ($km^2$) | Mean Bird Diversity | High Diversity Area ($km^2$) | Δ Area (%) | Δ Mean Diversity (%) | Δ High Diversity Area (%) | Mean Bird Diversity OAI (relative) | High Diversity Area OAI (absolute) |
|---|---|---|---|---|---|---|---|---|
| NAC | 3745 | 1.485 | 2284 | - | - | - | - | - |
| 5 | 4536 | **1.487** | **2812** | 21 | 0.13 | 23.12 | 0.00638 | 1.094 |
| 4 | 7981 | **1.523** | **5507** | 113 | 2.56 | 141.11 | 0.02262 | 1.248 |
| 3 | 9044 | **1.53** | **6421** | 141 | 3.03 | 181.13 | 0.02141 | 1.28 |
| 2 | 13736 | **1.502** | **8791** | 267 | 1.14 | 284.89 | 0.00428 | 1.068 |
| 1a | 22591 | 1.372 | **10391** | 503 | -7.61 | 354.95 | -0.01512 | 0.705 |
| 1 | 22613 | 1.375 | **10401** | 504 | -7.41 | 355.39 | -0.0147 | 0.705 |
| *SA* | *17093* | *1.489* | *9914* | *356* | *0.27* | *334.06* | *0.00076* | *0.937* |

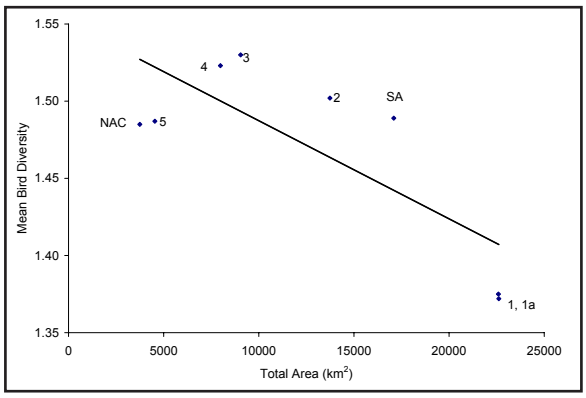


**Figure 5.2.4.** Regression of mean bird diversity and concept area. Numbers indicate concepts, and NAC=No Action Concept; SA=Study Area.

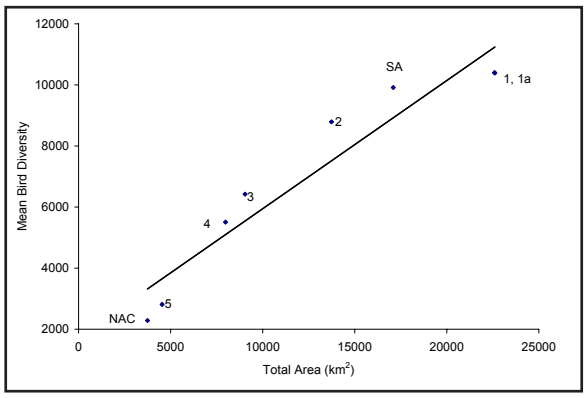


**Figure 5.2.5.** Regression of the area of highest mean bird diversity and concept area. Numbers indicate concepts, and NAC=No Action Concept; SA=Study Area.

## Summary

• Patterns of marine bird diversity appear to reflect the distribution of known upwelling regions and areas of high productivity, as well as breeding areas.

• The current boundaries of the CINMS encompass a region of high bird diversity and a significant concentration of seabird breeding areas.

• Of the six boundary concepts being considered, Concepts 3 and 4 provide relatively large increases in mean bird diversity relative to the NAC; only a few small new breeding areas would be added in any concept being considered.

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