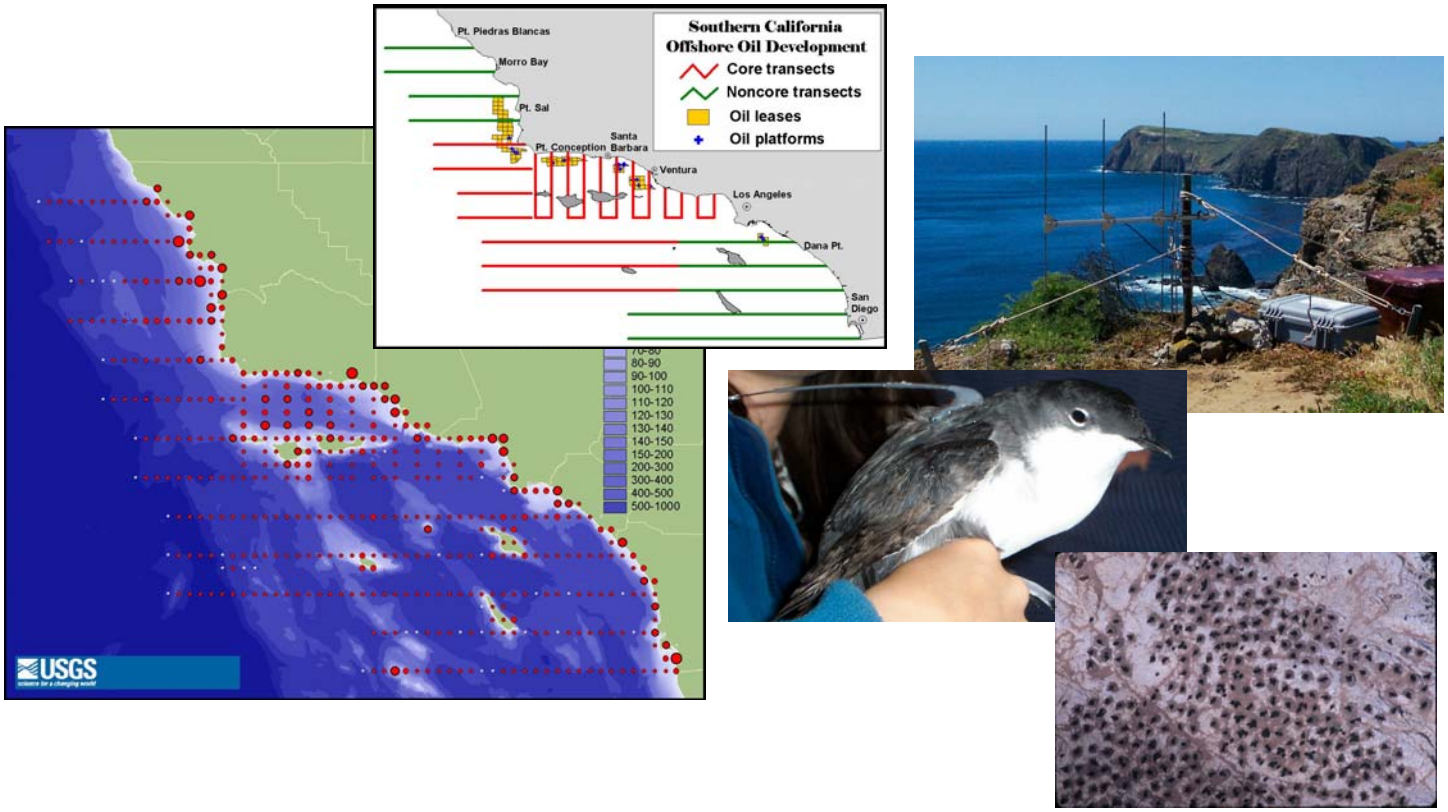
At-Sea Distribution and Abundance of Seabirds and Marine Mammals in the Southern California Bight: 1999–2003

Summary Report



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Summary Report

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EXECUTIVE SUMMARY

OBJECTIVES

- ✓ In 1999-2003, the U.S. Geological Survey and Humboldt State University conducted a research project to study the at-sea distribution and abundance of seabirds and marine mammals off the coast of Southern California. Partnerships with other agencies and universities allowed expansion of our original goals and greater data collection.
- ✓ To address the management needs of the Minerals Management Service and other natural resource agencies, our primary objectives were to:
  - I. describe the spatial and temporal patterns of the at-sea distribution of seabirds and marine mammals within the Southern California Bight.
  - II. provide current biological data for examining potential anthropogenic impacts, including oil pollution.
  - III. compare current seabird population densities at-sea to historical population densities at-sea to identify differences from past studies and possible population trends, especially for locally breeding species.

METHODS

- ✓ We conducted three main research projects to complete our primary objectives:
  - I. at-sea aerial surveys of seabirds and marine mammals (May 1999 to January 2002).
  - II. radio telemetry studies of Cassin’s Auklets to determine at-sea foraging ranges (March-August 1999–2001).
  - III. radio telemetry studies of Xantus’s Murrelets to determine at-sea foraging ranges (April-July 2002–2003).

RESULTS

Chapter 1

- ✓ We used aerial at-sea and coastline transects to survey seabirds from Cambria, California to the United States and Mexico border during January, May, and September during 1999 to 2002.
- ✓ On transect we identified 54 species of seabirds, comprising 12 families, and counted 127,578 birds.
- ✓ Seabird densities were higher along island and mainland coastlines than on at-sea transects and were generally highest during January surveys.
- ✓ On at-sea transects seabird densities were highest near the northern Channel Islands in January and north of Point Conception in May. Sooty Shearwaters and Western Gulls were the most abundant species at sea during May and September surveys, whereas, California Gulls, Western Grebes, Cassin’s Auklets, and Western Gulls were the most abundant species at sea in January.
- ✓ On coastal transects seabird densities were highest along the central and southern portions of the mainland coastlines from Point Arguello to Mexico and lowest around the Channel Islands in the southwestern portion of the study area. California Gulls, Western Grebes, Western Gulls, and Surf Scoters were the most abundant species on coastline transects in January; Western Grebes, Western Gulls, Surf Scoters, and Brown Pelicans were the most abundant species in May; and Sooty Shearwaters, Western Gulls, Western

Grebes, Brown Pelicans, and Heermann's Gull were the most abundant species in September.

- ✓ Comparing 1975–1983 (Briggs et al. 1987) with 1999–2002, we found a 14%, 57%, and 42% decrease in total seabird abundance during January, May, and September, respectively. Most notably, Common Murre abundance decreased in each season by 75–87%, Sooty Shearwater abundance decreased by 55% during May and 27% during September, and Bonaparte's Gull abundance decreased in each season by 95–100%. Some species increased in abundance, including a 167% increase in Brown Pelican, a 125% increase in Xantus's Murrelet, a 100% increase in Cassin's Auklet, and a 55% increase in Western Gull abundance during May. While aerial surveys were conducted with the same methods between time periods, differences in seabird abundance reflected changes in the abundance and distribution of seabirds, as well as changes in survey coverage and frequency, and must be interpreted with caution.
- ✓ We estimated that 981,400 seabirds used the Southern California Bight region during January, 862,100 in May, and 762,000 in September.

Chapter 2

- ✓ Simultaneously with the seabird surveys, we used aerial at-sea transects to survey marine mammals during January, May, and September from 1999 to 2002.
- ✓ On transect we identified 20 species of marine mammals, including 4 pinnipeds, 1 carnivore, and 15 cetaceans, and counted 68,309 marine mammals.
- ✓ The two most common marine mammal species in the study area were Common Dolphins and California Sea Lions. Collectively, these two species account for 86% of all marine mammals recorded.
- ✓ Marine mammal abundance was highest in the Santa Barbara Channel, near the northern Channel Islands, and from the Santa Rosa/Cortes Ridge to the vicinity of San Nicolas Island.
- ✓ Marine mammal sightings were widespread in January and most restricted in distribution during September when they were concentrated near the Santa Barbara Channel.
- ✓ The combined at-sea density of the four most common species (Common Dolphins, California Sea Lions, Bottlenose Dolphins, and Harbor Seals) was 1.57 km^{-2}, with seasonal densities ranging from 1.06 to 1.96 km^{-2}. Densities were highest in September when Common Dolphins were abundant, intermediate in January when California Sea Lions were abundant at sea, and lowest in May.
- ✓ We estimated the population size of Common Dolphins in the Southern California Bight area to be 28,500 in January, 8,500 in May, and 93,100 in September. Similarly, we estimated the population size of California Sea Lions to be 88,500, 54,700, and 47,000 during the same months.

Chapter 3

- ✓ We examined the at-sea distribution, foraging range, and areas used by Cassin's Auklets breeding on the northern California Channel Islands from 1999–2001.
- ✓ We radio-marked 99 Cassin's Auklets nesting at Prince Island and Scorpion Rock.
- ✓ Locations of auklets from Prince Island were aggregated north to northeast of the colony near the insular shelf break and in the western Santa Barbara Channel. Locations from

Scorpion Rock were aggregated in the Anacapa Passage and over the southeastern Santa Barbara Channel.

- ✓ Auklets generally foraged <40 km from their colonies. At Prince Island, distance from colony was greater among females than males, whereas the opposite trend was observed at Scorpion Rock.
- ✓ Home ranges were 750 ± 944 km^2 and did not differ by year, colony, or sex. Colony foraging areas overlapped during 2000, but not during 2001.
- ✓ The Prince Island colony's foraging area (1216 ± 654 km^2) was twice as large as the foraging area of auklets nesting at Scorpion Rock (598 ± 204 km^2). Greater wind speeds near Prince Island compared with Scorpion Rock reduced foraging distances and affected distribution.
- ✓ Dispersal coincided with decreased upwelling off Point Conception and sea-surface warming throughout the Santa Barbara Channel.

Chapter 4

- ✓ We examined the diets of Cassin's Auklet chicks in relation to yearly foraging areas and reproductive success during 1999–2001 at Prince Island.
- ✓ Chick diets varied within seasons and among years.
- ✓ Seven items comprised 87% of the food delivered by number and mass. In all years, parents provisioned chicks with euphausiids, larval fishes, and minor amounts of cephalopods.
- ✓ *Thysanoëssa spinifera* (Euphausacea) juveniles and adults were the most important items during 1999 and 2001, followed by *Euphausia pacifica* (Euphausacea), whereas *E. pacifica* replaced *T. spinifera* in 2000 after an anomalous eastward inflection of the California Current occurred off Point Conception during March – April.
- ✓ Despite this variation in chick diet, parents foraged in a similar area within 40 km of their colony each year, indicating that dietary composition was influenced by fluctuations in upwelling and regional circulation rather than foraging location.
- ✓ Moreover, the variation in chick diet did not influence fledging success or chick growth rates, but double-clutching was especially prevalent in 1999 (63%) and 2000 (75%) compared to 2001 (7%).

Chapter 5

- ✓ We studied the at-sea distribution, foraging habitat, and dive durations of Xantus's Murrelets during 2002–2003.
- ✓ In 2002, we radio-marked 68 Xantus's Murrelets captured near Anacapa Island and Santa Barbara Island, and in 2003 we radio-marked 44 Xantus's Murrelets at Anacapa Island.
- ✓ Xantus's Murrelets were located farther from Anacapa Island in 2002 compared to 2003.
- ✓ Similarly, home range sizes were larger in 2002 compared to 2003.
- ✓ Distance to land, sea surface temperature, and water depth at Xantus's Murrelet locations were greater in 2003 compared to 2002.
- ✓ The (feeding) dive durations of Xantus's Murrelets were short in duration throughout the 2003 breeding-season (19, 29, and 30 sec), indicating that they were foraging near the water's surface.

Chapter 6

- ✓ We examined whether radio transmitters adversely affected the reproductive performance of Cassin's Auklets breeding on Anacapa Island and Scorpion Rock during 1999–2001.
- ✓ We attached external radio transmitters to one partner in 108 Cassin's Auklet pairs and to both partners in 7 pairs after nest initiation, and used 131 unmarked, but handled, pairs as controls.
- ✓ Compared to alpha chicks raised by radio-marked pairs, alpha chicks raised by unmarked pairs had faster mass growth rates (1.95 ± 0.30 g d^{-1} vs. 3.37 ± 0.53 g d^{-1}, respectively), faster wing growth rates (2.46 ± 0.10 mm d^{-1} vs. 2.85 ± 0.05 mm d^{-1}), greater peak fledging masses (118.9 ± 3.5 g vs. 148.3 ± 2.4 g), and higher fledging success (61% vs. 90%).
- ✓ Fledging success was reduced more when we radio-marked the male (50% fledged) than the female partner (77% fledged).
- ✓ Furthermore, after fledging an alpha chick, unmarked pairs were significantly more likely to initiate a second clutch (radio-marked: 7%, unmarked: 39%) and tended to hatch a second egg (radio-marked: 4%, unmarked: 25%) and fledge a second (beta) chick (radio-marked: 4%, unmarked: 18%) more often than radio-marked pairs.
- ✓ However, radio-marked Cassin's Auklets foraged in similar areas compared to unmarked Cassin's Auklets that were surveyed concurrently by aircraft.
- ✓ Our results indicate that although radio telemetry influences the reproductive performance of Cassin's Auklets, it is still a valuable technique to assess their at-sea movements and foraging ranges.

Appendix 1

- ✓ See Appendix 1 for a full list of products including publications, reports, and scientific presentations.

FUTURE RESEARCH

- ✓ The first phase of this research has been successfully completed on schedule; however, much additional work is needed to better understand seabird and marine mammal distributions in the Southern California Bight and to make research findings available to agency and other users.
- ✓ To maximize the value of our expansive data set for management agencies and to build on this new biological knowledge, the U.S. Geological Survey (Western Ecological Research Center), with several past partners, is continuing research on seabirds and marine mammals in the Southern California Bight.
- ✓ Additional funding is needed to:
    - I. publish this research in scientific literature.
    - II. synthesize large databases into a relational database for distribution to government client agencies (CDROM) and a web-page for public use.
    - III. integrate existing data bases with environmental datasets to relate distribution and abundance patterns to habitat variables and oil platform structures.
    - IV. develop integrated mechanistic models to relate seabirds to their marine habitats and prey resources.

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CHAPTER 1:

AT-SEA AERIAL SURVEYS OF SEABIRDS IN THE SOUTHERN CALIFORNIA BIGHT: 1999–2002

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Abstract: We conducted aerial at-sea and coastal surveys to examine distribution and abundance of seabirds off Southern California, from Cambria, California to the Mexican border. From May 1999 to January 2002, we flew aerial surveys on 102 days, covered >54,640 km of transect lines, and completed nine surveys of the entire Southern California Bight (SCB) during January, May, and September. We identified 54 species of seabirds, comprising 12 families, and counted 135,545 birds. Seabird densities were greater along island and mainland coastlines than at sea and were usually greatest during January surveys. Seabird densities at sea were greatest near the northern Channel Islands during January and north of Point Conception during May and lowest

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at sea in the southwestern portion of the study area in all survey months. On coastal transects, seabird densities were greatest along central and southern portions of the mainland coastline from Point Arguello to Mexico. We estimated that 981,000 ± 144,000 (mean ± SE) seabirds occurred in the region during January, 862,000 ± 95,000 during May, and 762,000 ± 172,000 during September. On at-sea transects, California Gulls (*Larus californicus*), Western Grebes (*Aechmophorus occidentalis*), and Casssin's Auklets (*Ptychoramphus aleuticus*) were most abundant during January surveys, whereas Sooty Shearwaters (*Puffinus griseus*), phalaropes, and Western Gulls (*Larus occidentalis*) were most abundant during May and September surveys. On coastal transects, California Gulls, Western Grebes, Western Gulls, and Surf Scoters (*Melanitta perspicillata*) were most abundant during January, Western Grebes, Western Gulls, Surf Scoters, and Brown Pelicans (*Pelecanus occidentalis*) were most abundant during May, and Sooty Shearwaters, Western Gulls, Western Grebes, Brown Pelicans, and Heermann's Gulls (*Larus heermanni*) were most abundant during September. We also compared current seabird densities (1999–2002) to historical seabird densities collected in the same area two decades ago (1975–1978 and 1980–1983). Estimated seabird abundance for all species from 1999–2002 compared with 1975–1978 and 1980–1983 was reduced by 14%, 57%, and 42% during January, May, and September, respectively. Notable species with reduced densities from 1999–2002 compared with 1975–1978 and 1980–1983 were Common Murres (*Uria aalge*; ≥75% in each season), Sooty Shearwaters (55% during May and 27% during September), and Bonaparte's Gulls (*Larus philadelphia*; ≥95% in each season). Conversely, species with increased densities were Brown Pelicans (167%), Xantus's Murrelets (125%), Cassin's Auklets (100%), Ashy Storm-Petrels (450%) and Western Gulls (55%) during May, and Brandt's Cormorants (450%) during September. We present detailed accounts for 30 seabird species that were abundant or of special interest in the SCB.

INTRODUCTION

The Southern California Bight (SCB) comprises critical habitat for numerous seabird species (Briggs et al. 1981a, 1983a, 1987; Carter et al. 1992, Veit et al. 1996, 1997; Pierson et al. 2000). More than 20 species of seabirds breed in the SCB, primarily on the California Channel Islands (hereafter Channel Islands), including four threatened or endangered seabird species (U.S. Fish and Wildlife Service 2002). The SCB is the only region in California supporting breeding Brown Pelicans (*Pelecanus occidentalis*), Black Storm-Petrels (*Oceanodroma melania*), Elegant Terns (*Sterna elegans*), and Xantus's Murrelets (*Synthliboramphus hypoleucus*; Carter et al. 1992, Burness et al. 1999). The region also contains almost half of the world population of Ashy Storm-Petrels (*Oceanodroma homochroa*; Carter et al. 1992). In addition, numerous seabirds migrate through or winter in the SCB region (Briggs et al. 1987).

The SCB is used extensively by humans and is of economic significance, contributing approximately nine billion dollars annually to local economies via offshore oil production, oil transportation by tankers, commercial shipping, commercial fishing, military activities (e.g., weapons testing and exercises), and public recreation (Anderson et al. 1993, Carter et al. 2000). From 1970 to 2000, the human population bordering the SCB increased by 64% with concomitant increases in coastal development, sewage discharge, recreational use, and commercial activities (U.S. Census Bureau 2003). Censuses conducted in 2002 estimated >16 million people in counties rimming the SCB (U.S. Census Bureau 2003). As a consequence, great concern exists regarding potential effects of human activities on seabird and marine mammal populations in this area and federal and state agencies have established several marine reserves to protect wildlife (Airamé et al. 2003).

During the past 20 years, the SCB also has undergone changes in oceanography and biology. An increase in sea surface temperature (SST) coincident with the Pacific Decadal Oscillation (PDO) began in 1977 and extended to 1999. This period was characterized by reduced phytoplankton and zooplankton abundances and altered prey fish distributions (Mantua et al. 1997, Minobe 1997, Peterson and Schwing 2003). Several studies in the 1980s and 1990s reported declines in abundance or changes in community composition of plankton and seabirds in the California Current System (CCS; Veit et al. 1996, 1997; McGowan et al. 1998, Oedekoven et al. 2001, Hyrenbach and Veit 2003). The CCS extends up to 1000 km from shore from Oregon to Baja California, Mexico, and consists of a southward surface current, a poleward undercurrent, and several surface countercurrents. A temperature increase of 0.8°C in the top 500 m of the CCS occurred between 1950 and 1992 with most of the increase occurring since 1975 (Roemmich 1992). Reproductive success of seabirds generally declines as ocean temperatures increase off California (Ainley et al. 1994, 1996), but it is unknown whether this general warming has caused a long-term decrease in seabird populations in the SCB. In addition, the effects of DDE (dichlorodiphenyldichloroethylene) contamination in the SCB have abated leading to increased reproductive success of several seabird species including Brown Pelicans and cormorants (Gress et al. 1995). Based on seabird surveys conducted in 1991, Carter et al. (1992) reported increased populations of several species compared with the 1970s, including Brown Pelicans, cormorants, and Western Gulls (*Larus occidentalis*) but decreased populations of Cassin's Auklets (*Ptychoramphus aleuticus*) and Xantus's Murrelets.

Collectively, these changes in oceanography and human demography prompted a need for updated information regarding at-sea populations of seabirds in the SCB using techniques that would allow comparison with previous seabird surveys conducted by Briggs et al. (1987). From 1975–1978 and 1980–1983 (hereafter 1975–1983), Briggs et al. (1987) conducted the first replicated, quantitative assessment of the distribution, abundance, and diversity of seabirds off California using aerial survey techniques. They conducted surveys in the SCB from 1975–1978 and off central and northern California from 1980–1983. More than two decades later, we have used similar aerial survey techniques in the SCB and adjacent waters to provide updated information and examine differences in seabird distribution, abundance, and diversity.

STUDY AREA

The SCB extends from Point Conception to just south of the Mexican border and comprises a unique oceanographic environment. Off Point Conception and to the north, shelf currents and water properties respond to strong, persistent upwelling-favorable winds, whereas offshore and in the SCB, flows consist of eddies, jets, and fronts which show no relation to local winds (Harms and Winant 1998). These unique conditions result in a transition zone between warmer sub-tropical waters to the south and colder nutrient rich waters to the north (Hunt et al. 1980). As a result, the SCB hosts a diverse avifauna that includes species typical of both northern and southern climates. Several seabird species have their northern or southern distribution limit in this region.

The study area encompassed continental shelf and slope waters from 35°35′N (off the city of Cambria, San Luis Obispo County, CA) south to the Mexican border, and from the mainland shoreline west to 122°W at the northern boundary, and to 119°30′W at the southern boundary (Figure 1.1). In this area, most of the coastline and seafloor is oriented north to south.

Like most parts of the California coast, the continental shelf gradually slopes westward before dropping precipitously to depths in excess of 3,000 m. At Point Conception, the coastline and bottom topography abruptly turn eastward to southeastward but have a more southward orientation between Los Angeles and San Diego.

The SCB contains a variety of bathymetric and land features that combine to form a highly complex oceanographic region. Eight major islands, 11 deep-water basins, three major banks and seamounts, and at least 13 major submarine canyons bisect the U.S. portion of the SCB (Dailey et al. 1993, Hickey 1993). These features strongly affect local circulation patterns of the California Current, which turns from its more typical equatorward flow to poleward flow in the central-southern SCB, with a predominant counterclockwise eddy south of the northern Channel Islands (Hickey 1993). The strong coastal upwelling off the northern and central California coasts is much reduced in the SCB, resulting in warmer and less productive waters.

Human uses of the SCB and adjacent waters also are complex. The southern California coastal region is one of the most densely populated coastal areas in the United States and this has led to highly modified coastal habitats. Various pollutants, including oil, sewage, agricultural runoff, pesticides, and other chemicals have affected coastal waters (Schiff 2000). Several offshore oil leases for commercial oil development are located off Point Conception, Santa Barbara Channel, and the San Pedro Channel and several other lease sales remain undeveloped (Figure 1.2). Many commercial ships, including oil tankers, traverse the area en route to and from SCB ports. Within the SCB, there are four active offshore oil platforms off Point Conception and Point Arguello, 15 in the Santa Barbara Channel, and five in San Pedro Channel. Three major oil tanker and commercial ship transport lanes pass through the SCB to enter Los Angeles and Long Beach harbors, and significant tanker traffic and oil volume pass through the San Diego and Estero Bay–Avila Beach areas. Relatively small oil spills along the California and Washington coast have resulted in significant losses to local seabird populations (Page et al. 1990, Piatt et al. 1990, Carter and Kuletz 1995). Seabird mortality also has been documented for spills from offshore platforms, pipelines, on-shore oil facilities, tankers, and military and commercial shipping (Anderson et al. 1993, Carter and Kuletz 1995). The region also is used extensively by the military. In particular, the Naval Air Systems Command's sea test range covers a large portion of the southern California offshore zone (Figure 1.3). Additionally, several military bases are located along the mainland coast of the SCB and on San Nicolas and San Clemente Islands. Although there is little documented mortality of seabirds from military operations in the SCB (i.e., missile and target-drone testing, low-level aircraft flights, and naval fleet maneuvers), seabirds may be disturbed or killed during such activities.

METHODS

Aerial Surveys

We conducted aerial surveys for seabirds during January, May, and September from May 1999 to January 2002 (Table 1.1). Fixed transect lines were located both at sea and along all mainland and island coastlines in the SCB (Figure 1.4). Coastal transects included the mainland shoreline from Cambria, CA (35° 35′N, 121° 07′W) to the Mexican border (32° 32′ N, 117° 07′W) and the shorelines of the eight Channel Islands. We surveyed in January, May, and September because these months coincide with over-wintering, breeding, and post-breeding dispersal, respectively, for many species of seabirds in the SCB (Briggs et al. 1981a, Carter et al. 1992).

We conducted surveys from a high-winged, twin-engine Partenavia PN 68 Observer aircraft following methods developed for seabirds by Briggs et al. (1987). We flew surveys at 60 m (200 ft) above sea level at 160 km/hr (90 knots) ground speed and flew coastline (mainland and island) transects 300 m from shore. In ecologically sensitive areas (e.g., seabird nesting and roosting sites and marine mammal rookery and haul-out sites), we flew 400 m from shore. Observers sat on both sides of the aircraft and scanned the sea surface through bubble windows. Each of two observers counted and identified seabirds occurring within a 50 m strip on their side of the aircraft for a total strip width of 100 m when both observers were surveying simultaneously. At least one observer surveyed at all times, but individual effort was discontinued when glare obscured >25% of an observer's field of view. To ensure that we maintained a strip width of 50 m, we estimated sighting angles from the aircraft to the water using clinometers. Observers rechecked sighting angles with a clinometer several times during each survey.

We recorded seabird observations on audiotape using hand-held tape recorders (VSC–2002, Model No. 14-1158, Tandy Corporation, Fort Worth, TX, USA). We identified animals to species or nearest taxon and made exact counts for solitary seabirds or small groups and estimated numbers for groups >10 birds. For each observation, we recorded time to the nearest second, species, number of birds, behavior (e.g., flying or sitting on water), and flight direction.

Each observer transcribed data from audiotape onto standardized data forms and entered data into the computer program SIGHT (Micro Computer Solutions, Portland, OR, USA). We used SIGHT because it had preset data entry protocols that helped to ensure entry accuracy. Two people checked data entry for accuracy by printing SIGHT data for comparison with transcribed forms.

We determined the location of each observation and tracked survey lines using a Garmin® 12 Plus Global Positioning System (GPS; Garmin Ltd., Olathe, KS, USA) connected to a laptop computer that was operated by a third observer. The computer program dLog (R.G. Ford Consulting, Portland, OR, USA) recorded aircraft position (waypoint) from the GPS unit every 5 seconds into a log file. We chose an interval of 5 seconds to allow adequate spatial coverage of the trackline (225 m is traversed every 5 seconds at our survey speed of 160 km/hr) and to limit the size of the resulting data files. We synchronized observer watches with the computer clock twice each survey day.

Following each survey, we plotted trackline log files in ArcView (ESRI, Redlands, CA, USA) and checked for GPS errors or missing trackline data. For transects with missing trackline data (e.g., from occasional computer errors or momentary loss of satellite coverage), we re-created transect lines based on known waypoints and constant airspeed using interpolation programs written in SAS (SAS Institute, 1999) statistics program. After correcting trackline files, we calculated the position of each sighting based on observation time with the program INTERPD (R.G. Ford Consulting, Portland, OR, USA).

Previous studies indicated greatest densities of seabirds in the SCB occurred near the northern Channel Islands (Briggs et al. 1981a, 1987). This also was the area of greatest aggregation of breeding seabirds and commercial oil development in the study area. Therefore, we concentrated our survey effort in this core area (Figure 1.4). Transect lines were arranged systematically and were designed to concentrate survey effort in areas near the northern Channel Islands and to include the wide range of habitats and bathymetry throughout the SCB. At-sea transects near the northern Channel Islands were oriented predominantly north-to-south (perpendicular to bathymetric contours) and were spaced at intervals of 10′ of longitude (~15 km). In other parts of the study area, at-sea transects were oriented east-to-west and were spaced at intervals of 15′ of latitude (~27 km) to cover a larger sampling area. Whereas all at-sea and coastal transect lines within the core area were replicated each survey month, transects in the non-core area were surveyed only once per survey month. We conducted the replicate survey of the core area 5–10 days after the initial survey. Weather conditions (e.g., fog or strong winds) and aircraft availability determined whether the non-core area was surveyed during the first or second survey period for each month.

We surveyed north of the SCB because the area contained current and potential oil and natural gas operations. Currently, there are four oil and gas platforms north of Point Conception (Figure 1.2) and oil and gas operations will continue on these platforms for more than a decade and other leases might be developed in the future.

At-sea Subareas

We divided the at-sea study area into five subareas to facilitate a more spatially refined comparison of our data with historic data (Figure 1.5; Briggs et al. 1987). We created subareas based on biological and oceanographic features and also attempted to equalize total transect length within each subarea. Subarea boundaries were located such that they bisected the distance between contiguous parallel transect lines (i.e., subarea boundaries were equidistant from adjacent parallel transect lines). Briggs et al. (1987) surveyed farther offshore than we did; thus, we restricted our comparisons to their data that were collected within our study area. We chose five subareas based on distinct oceanographic and biological regions in the SCB: three subareas within the SCB, one north of Point Conception to Cambria, and one west of the Santa Barbara Channel.

(A) Subarea 1 (S1) extended from Point Piedras Blancas to north of Point Conception and seaward 108 km (60 NM; Figure 1.5). The southern boundary was along the edge of the transition zone between colder, upwelled waters of central California and the more variable waters of the SCB (Chelton 1984, Lynn and Simpson 1987). This area represented the southern portion of the area surveyed by Briggs et al. (1987) from 1980–1983.

(B) Subarea 2 (S2) extended south from 34º 30′N to 33º 40′N and from 120º 30′W seaward to the western edge of the study area 117 km (65 NM) west of San Miguel Island (Figure 1.5). This area represented the offshore zone west of the northern Channel Islands. It was downstream and slightly offshore from the central California upwelling zone and was largely outside the foraging areas for most Channel Islands seabirds during the breeding season.

(C) Subarea 3 (S3) comprised the northern Channel Islands from Point Conception east to Point Mugu (Figure 1.5). Main ecological features of this area included the Santa Barbara Channel and the northern Channel Islands seabird-breeding habitat. Significant upwelling (Point Conception upwelling plume) from S1 becomes entrained in the western half of S3 (Denner et al. 1988, Harms and Winant 1998).

(D) Subarea 4 (S4) comprised the eastern SCB and was less influenced by coastal upwelling and had fewer breeding seabirds relative to S3 (Figure 1.5; Carter et al. 1992). Subarea four contained breeding and roosting habitat provided by Santa Barbara, Santa Catalina, and San Clemente Islands and complex bathymetry with several deep basins and the Santa Rosa Ridge.

(E) Subarea 5 (S5) represented the offshore portion of the southwestern SCB and contained large expanses of open, deep ocean as well as ocean ridges and banks (Figure 1.5). The northern section of S5 was influenced by the Point Conception upwelling plume, but compared with S1, S2, and S3, waters were generally warmer, more saline, and less nutrient enriched. San Nicolas Island provided breeding and roosting habitat in S5.

Coastal Subareas

The coastlines of the mainland and Channel Islands also were divided into five subareas: three mainland subareas and two island coastline subareas (Figure 1.5). We created coastline subareas to represent biologically distinct areas and to make total transect length within subareas approximately equal. Coastal subareas were not intended to match at-sea subareas because we assumed avifauna in these subareas were not similar.

(A) Northern Mainland Coast (NMC) included the northern portion of the mainland coastline extending from Cambria to Point Arguello (Figure 1.5). The NMC was oceanographically similar to the central California coast and characterized by strong, upwelling-favorable winds.

(B) Central Mainland Coast (CMC) included the central portion of the mainland coastline from Point Arguello to just east of Point Dume including Point Conception, the northern Santa Barbara Channel coastline, and Mugu Lagoon (Figure 1.5).

(C) Southern Mainland Coast (SMC) included the southern portion of the mainland coastline just east of Point Dume to the Mexican border and included Santa Monica Bay, Palos Verdes, Dana Point, and Point Loma (Figure 1.5).

(D) Northern Island Coast (NIC) included the northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands; Figure 1.5).

(E) Southern Island Coast (SIC) included the southern Channel Islands (Santa Barbara, San Nicolas, Santa Catalina, and San Clemente Islands; Figure 1.5).

Spatial Analysis Methods

We originally collected data in geographic coordinates (NAD 27) and later reprojected data into the California Teale Albers projection to ensure accuracy of distance and area calculations. Track log GPS data collected during aerial surveys were reformatted using SAS to create formatted text files. We processed text files with an ArcInfo (ESRI, Redlands, CA, USA) arc macro language program to create point and line coverages.

Track line coverages were buffered to form strips parallel to the transect line depending on number of observers. We created strips 50 m wide for one observer and strips 100 m wide for two observers. We separated strip data into coastal and at-sea groups and intersected both groups with 1′ x 1′ and 5′ x 5′ latitude and longitude grid cells, thereby creating unique grid identifiers for buffered transects. We used these data for analysis and mapping.

Species observations were linked to track log data, output as a dbase file, imported into Arcview (Version 3.3, ESRI, INC.), and converted to shape files. We intersected shape files with buffered strips to transfer grid identifiers to points. These data were exported as dBASE files (dBASE Inc., Vestal, NY) and entered into SAS to calculate densities.

Statistical Analyses

We examined seabird distribution hierarchically at three taxonomic levels: individual species, families, and all seabirds grouped together. Occasionally seabirds could be identified only to family or, very infrequently, just as seabirds. Unidentified seabirds were excluded from species-specific analyses, but were used in the broader taxon groupings.

We analyzed at-sea and coastal transect data separately and included both flying and non-flying birds in analyses. Unlike shipboard surveys, densities of flying birds were not corrected for the effect of flight direction (Spear and Ainley 1997). Because of the greater relative speed of the survey aircraft compared with flying seabirds, error in density calculations of flying birds was assumed to be negligible. We assessed differences among seasons (January, May, and September) and subareas. We compared our at-sea transect data with similar aerial survey data collected from 1975–1978 throughout the SCB and from 1980–1983 off central and northern California (Briggs et al 1987). We were unable to compare coastal transect data with previous data because Briggs et al. (1987) did not collect coastal transect data.

We used generalized linear mixed models (GLMM) using SAS software to model species counts within grids (Poisson distribution) with means that are proportional to the area of buffered transect (offset variable; McCullagh and Nelder 1989) and that vary according to subarea, season, year, and replicate. We assessed effects of subarea and season on densities and controlled for variation between replicates and years by including replicate and year as random effect variables in models.

We restricted the GLMM to test for differences in densities only for those subareas and seasons in which species were observed. For subareas or seasons where a species was not observed, density and standard error were zero. In this case, one of two possibilities occurred: 1) the entire season or subarea contained no individuals of a particular species causing season or subarea to be significantly different from any other season or subarea where the species was observed at least once, 2) the species was present but too rare to be observed by the survey. Because, there were not enough data for the GLMM to distinguish between these two alternatives, we evaluated differences in subareas and seasons by identifying those with and without observations.

For similar reasons, we occasionally restricted the GLMM to exclude the replicate random effect when no observations occurred for one of the replicates. Conversely, for species with sufficiently large densities, we tested for presence of subarea and season interactions. We considered differences in average densities with an alpha level of 0.05 to be statistically significant.

Comparisons to Past Density Estimates

We obtained data for Briggs et al. (1987) from the Computer Database Analysis System compact disc (Bonnell and Ford 2001). Aerial survey data were collected in the SCB from 1975–1978 that corresponded to our areas S2–S5. Aerial survey data were collected off central and northern California from 1980–1983 that corresponded to our area S1. We assigned observations from Briggs et al. (1987) to subareas based on latitude and longitude associated with each observation. Briggs et al. (1987) did not conduct aerial coastline surveys so we compared only our at-sea transect data to data collected in the same subarea from 1975–1983. To compare at-sea densities of seabirds between the two studies, we used Briggs et al. (1987) data that bracketed the months of our survey (i.e., Jan 2000–2002 vs. average of Dec, Jan, and Feb 1975–1983; May 1999–2001 vs. Apr, May, and Jun 1975–1983; and Sep 1999–2001 vs. Aug, Sep, and Oct 1975–1983). We did this to reduce the possibility of missing species density peaks occurring from 1975–1983 and to ensure that, if Briggs et al. (1987) did not survey during January, May or September in a particular year, that we could obtain data from a similar time of year with which to compare.

Preliminary analyses revealed replicate and year as insignificant sources of variability in seabird density; thus, we removed replicate and year for further analyses. We used generalized linear mixed models (GLMM) to test differences in density between the current survey and the historical survey. We created a classification variable for the historical and current survey periods. This variable was included in the GLMM and tested the effects of period on density. We conducted this analysis separately for the five at-sea subareas and all at-sea subareas combined. We included season in the model after preliminary results revealed density varied by season. We used contrasts to express the difference in densities between the two periods and extrapolated seabird abundance in the entire study area for both periods.

Estimated Abundance

We calculated estimates of seabird abundance in the study area during January, May, and September based on densities from at-sea transects. We assumed constant densities throughout subareas from which transects originated, extrapolated numbers based on size of subarea, added the five subarea totals for the total estimate, and averaged total estimates by month. We also used coastal transect data to calculate estimates of seabird abundance within 1 km of shore for species with >100 observations and for which >70% of observations occurred on coastal transects. We calculated abundance estimates for the study area during January, May, and September by multiplying the number of birds observed by 10 for areas in which two people were observing (i.e., 100m strip width) and by 20 for areas in which one person (i.e., 50 m strip width) was observing. We assumed constant densities from shore out to 1 km and only used data from the replicate from each survey month that covered the entire study area (not just the core area). We note that these calculations provide only a cursory estimate of population abundance and should be used and interpreted with caution.

Species Diversity

We calculated the number of species and the Shannon-Weiner Diversity Index (SWDI; Krebs 1989) for data collected from 1999–2002 for subareas, survey months, and survey types (at-sea and coastal). The SWDI is defined as:

$$H' = -\sum_{i=1}^{s} \rho_i \ln \rho_i$$

where s is the number of species and ρ_i is the proportion of total density contributed by species i. To standardize calculations, we used the replicate from each survey month that covered the entire study area (not just the core area) to calculate diversity indices.

Distribution and Abundance Maps

We created maps in ArcView of species and family distribution for the study area. For the 1999–2002 data, we averaged seabird densities for 5′ latitude and longitude grids across years and replicates for each survey month. This resulted in three maps for each species and family representing January, May, and September. To facilitate visual comparisons among maps for individual species or families, map legends were standardized for each species or family based on percentages of maximum densities observed for that species or family. The five categories were: (1) 0 (none observed), (2) >0–50% of densities, (3) >50–75% of densities, (4) >75–90% of densities, and (5) >90% of densities to the maximum density observed. Standardized density legends highlight areas of greatest importance to individual species.

RESULTS

From May 1999 to January 2002, we completed nine surveys (102 flight days). For all surveys combined, we flew >54,600 km (30,350 NM) of transects with >20,100 km (11,150 NM) in the core area and >14,400 km (8,000 NM) along coastlines. We identified 54 species of seabirds representing 12 families and counted a total of 135,545 seabirds on transect (Table 1.2).

Seabirds occurred in the study area in all subareas in all seasons (Figure 1.6). Seabird densities (all species) averaged >33.7 birds/km^2 (for at-sea and coastal transects combined) and ranged from 0–12,244 birds/km^2. Densities for both at-sea and coastal transects were greatest during January (Tables 1.3–1.6), primarily due to large numbers of California Gulls (*Larus californicus*), Western Grebes (*Aechmophorus occidentalis*), Surf Scoters (*Melanitta perspicillata*) and, to a lesser extent, Black-legged Kittiwakes (*Rissa tridactyla*), Cassin's Auklets, loons, and phalaropes. Average densities were lowest during May and September. Western Grebes, Sooty Shearwaters (*Puffinus griseus*), phalaropes, and Western Gulls were the most abundant species in the SCB in May. Sooty Shearwaters were the most abundant seabird in the SCB in September followed by Western Grebes, Western Gulls, and Brown Pelicans. Maximum seabird densities for a single 5' by 5' grid occurred during September due to large flocks of Sooty Shearwaters.

Densities for all seabirds combined differed among at-sea subareas ($F_{4,4932} = 22.1$, $P < 0.001$) and coastal subareas ($F_{4,1781} = 5.5$, $P < 0.001$). Greatest densities of seabirds occurred in S3 (Table 1.3), CMC, and SMC (Table 1.5) and lowest densities occurred in S5 (Table 1.3). Densities along coastal transects differed among seasons ($F_{4,1781} = 13.5$, $P < 0.001$) with greatest densities during January and lowest densities during May (Tables 1.4–1.6). Densities along at-sea transects did not differ among seasons ($F_{2,4932} = 0.8$, $P < 0.451$) but greatest seasonal densities for at-sea transects occurred in S3 during January and in S1 during May (Table 1.3). We estimated an average of 981,000 ± 144,000 seabirds throughout the study area during January using at-sea transect data (Table 1.7).

At-sea densities for all seabirds combined were greater from 1975–1983 than from 1999–2002 for the entire study area ($\chi^2_1 = 155.8$, $P < 0.001$), S2 ($\chi^2_1 = 5.1$, $P < 0.024$), S4 ($\chi^2_1 = 76.3$, $P < 0.001$), and S5 ($\chi^2_1 = 162.0$, $P < 0.001$) but did not differ in S1 ($\chi^2_1 = 1.8$, $P < 0.182$) and S3 ($\chi^2_1 < 0.1$, $P < 0.942$). From 1975–1983 to 1999–2002, we observed a decline in abundance of 14% in January, 57% in May, and 42% in September (Table 1.8).

SWDI for at-sea and coastal subareas combined was greatest during May (2.10) and lowest during January (1.80) and September (1.86; Table 1.9). At-sea transects had a greater species diversity (2.56) than did coastal transects (1.95). At-sea, S5 had the greatest species diversity (2.30) and S4 had the lowest (1.79). With island transects removed from at-sea subareas, species diversity decreased in S3 (1.92) but increased in S4 (2.4) and S5 (2.35; Table 1.9). Among coastal subareas, the northern Channel Islands had the greatest species diversity (1.75), whereas the southern Channel Islands had the lowest species diversity (1.17). The number of species was greater in January (46) than in May (40) or September (40; Table 1.9).

Species Accounts

Brown Pelican *Pelecanus occidentalis*

The Brown Pelican subspecies, *P. o. californicus,* breeds from California to the Pacific coast of southern Mexico and the Gulf of California (Carter et al. 1992). Greatest pelican abundance in the SCB occurs in late summer and early fall coincident with dispersal of birds from breeding colonies in Mexico; abundance is lowest after breeding Brown Pelicans return to breeding colonies in Mexico in early winter (Anderson and Anderson 1976, Briggs et al. 1981b, 1983b; Jaques 1994, Jaques et al. 1996). During the late 1960s and early 1970s, Brown Pelicans experienced extremely poor breeding success due to eggshell thinning caused by DDE contamination (Keith et al. 1971, Risebrough 1972, Jehl 1973, Anderson et al. 1975, Anderson and Gress 1983, Gress and Anderson 1983). Reproductive success did not rebound until the late 1970s (Gress et al. 1995). From 1969 to 1978, <800 nests were estimated on West Anacapa Island (Carter et al. 1992). In 1991, 10,680 breeding Brown Pelicans were estimated on West Anacapa Island and 1,236 were estimated on Santa Barbara Island (Gress 1992, T. Ingram, unpublished data as cited in Carter et al. 1992).

Briggs et al. (1987) reported reduced densities of Brown Pelicans in California from December through March and increased densities during September and October with most <20 km from shore. Similarly, from 1999–2002, we observed greatest densities during September and 83% of Brown Pelicans were <10 km from shore (at-sea transects only).

From 1999–2002, Brown Pelicans were distributed along coastlines throughout the study area and occurred in all at-sea subareas except S2 (Figure 1.7). Pelicans generally were more abundant along mainland than island coastlines (Tables 1.4–1.6). Densities were greatest along the CMC during May and NMC and SMC during September (Table 1.5). Brown Pelicans occurred consistently near Point Loma, Palos Verdes, Point Sal, and along the mainland coast of the Santa Barbara Channel and the southern coast of Santa Rosa Island (Figure 1.7).

At-sea densities of Brown Pelicans differed among seasons ($F_{2,4940} = 9.4$, $P < 0.001$) and subareas ($F_{4,4940} = 6.2$, $P < 0.001$). Densities were greatest during September corresponding with the return of breeding birds to the SCB from Mexico. During each month, Brown Pelican densities were greatest in S3, probably due to numerous available roost sites on the northern Channel Islands and on the central mainland coast (Point Conception to Point Dume). We observed only 12 Brown Pelicans in S2. Along coastlines, Brown Pelican densities also differed among seasons ($F_{2,1781} = 12.3$, $P < 0.001$) with greatest densities, again, during September but did not differ among subareas ($F_{4,1781} = 2.01$, $P < 0.091$).

At-sea densities of Brown Pelicans were greater from 1999–2002 than from 1975–1983 throughout the entire study area ($\chi^2_1 = 19.5$, $P = 0.01$) but lower in S4 ($\chi^2_1 = 4.3$, $P < 0.039$) and S5 ($\chi^2_1 = 169.5$, $P < 0.001$). Densities did not differ in S1 ($\chi^2_1 = 1.0$, $P < 0.330$) and S3 ($\chi^2_1 = 3.6$, $P < 0.059$). We estimated an average maximum abundance of 63,900 ± 47,700 Brown Pelicans from 1999–2002 using at-sea transect data and 1,325 ± 100 using coastal data (Tables 1.7 and 1.10).

Phalacrocoracidae

Because Brandt's and Double-crested Cormorants (*Phalacrocorax penicillatus* and *P. auritus*) were difficult to distinguish from the air, 45% of cormorants were unidentified (Figure

1.9). Pelagic Cormorants (*P. pelagicus*) also were difficult to distinguish, except during May surveys, when their white flank patch was conspicuous. Therefore, proportionately more Pelagic Cormorants were identified during May than in other months. At-sea densities of cormorants did not differ among seasons ($F_{3,4481} = 0.9$, $P < 0.409$) but did differ among subareas ($F_{3,4481} = 7.0$, $P < 0.001$) with greatest densities occurring in S3 (Table 1.3). Cormorants occurred in every season and subarea but only two cormorants (Brandt's Cormorants) occurred in S2 (Figure 1.8). Coastal densities of cormorants did not differ among seasons ($F_{2,1781} = 0.6$, $P < 0.549$) but did differ among subareas ($F_{4,1781} = 10.1$, $P < 0.001$) with greatest densities along the NMC in all months (Tables 1.4–1.6). At-sea densities were greater in 1999–2002 than 1975–1983 throughout the entire study area ($\chi^2_1 = 17.1$, $P < 0.001$), S1 ($\chi^2_1 = 12.5$, $P < 0.001$), and S5 ($\chi^2_1 = 16.5$, $P < 0.001$) and lower in S3 ($\chi^2_1 = 121.3$, $P < 0.001$) and S4 ($\chi^2_1 = 22.4$, $P < 0.001$). We estimated an average maximum abundance of 14,625 ± 3,900 cormorants during January from 1999–2002 using at-sea transect data (Table 1.7).

Double-crested Cormorant *Phalacrocorax auritus*

Double-crested Cormorants are the most numerous and widely distributed of the six North American cormorants and are rarely observed far from land (Hatch and Weseloh 1999). Along the Pacific coast, the subspecies *P. a. albociliatus* breeds from southern British Columbia, Canada to Sinaloa, Mexico (west coast of central Mexico mainland) in marine and estuarine habitats (Harrison 1983, Carter et al. 1995). Double-crested Cormorants experienced reduced breeding success in the mid-twentieth century due to DDE (Gress et al. 1973, Gress and Lewis 1988). In 1969, severe eggshell thinning from DDE contamination was discovered in Double-crested Cormorants breeding on West Anacapa Island and South Los Coronados Island, Mexico (Gress et al. 1973, Jehl 1973). Reduced breeding success continued until the early 1970s at the West Anacapa Island colony, but thereafter, breeding success improved (Anderson and Gress 1983, Gress et al. 1995). In 1991, the estimated 10,040 birds in the SCB represented greater than a fourfold increase in numbers compared with 1975–1978 estimates (Carter et al. 1992). In the SCB, breeding colonies were located on Prince (<1 km north of San Miguel Island), West Anacapa, Santa Barbara, and Sutil Islands (<1 km east of Santa Barbara Island; Carter et al. 1992). Briggs et al. (1987) rarely observed Double-crested Cormorants during at-sea surveys, and did not conduct surveys along coastlines. Only a few Double-crested Cormorants were observed at sea from 1975–1983 and these were <3 km from breeding colonies (Briggs et al. 1987). We consistently observed Double-crested Cormorants near Point Loma and Palos Verdes, south of Point Buchon, north of Morro Bay, along the mainland coast of the Santa Barbara Channel, and near the four northern Channel Islands and San Nicolas Island (Figure 1.11). We observed 86% of Double-crested Cormorants <1 km from shore, however, during May and September, individuals were occasionally observed 20–30 km northwest of Santa Barbara Island.

From 1999–2002, at-sea densities of Double-crested Cormorants differed among seasons ($F_{2,4487} = 4.5$, $P < 0.012$) and subareas ($F_{3,4487} = 7.3$, $P < 0.001$). Double-crested Cormorants were present in all at-sea subareas except S2 and at-sea densities were generally greatest during January and in S1 (Table 1.3). During May and September, densities were greatest in S3 near breeding colonies (Table 1.3). Densities on coastal transects did not differ among seasons ($F_{2,1781} < 0.1$, $P < 0.953$) but did differ among subareas ($F_{4,1781} = 25.3$, $P < 0.001$) and greatest densities occurred along the central portion of the mainland coast during each survey month

(Tables 1.5 and 1.6). Double-crested Cormorants occurred in all coastal subareas and coastal densities were up to fortyfold greater than at-sea densities.

Statistical comparisons between 1975–1983 and 1999–2002 were possible only for all subareas combined, S3, and S4 because of limited observations from 1975–1983 throughout the other subareas. At-sea densities of Double-crested Cormorants were greater from 1999–2002 than 1975–1978 for all subareas combined ($\chi^2_1 = 267.7$, $P < 0.001$) and S3 ($\chi^2_1 = 35.3$, $P < 0.001$) but lower in S4 ($\chi^2_1 = 9.8$, $P < 0.002$). We estimated an average maximum abundance of 3,850 ± 3,080 Double-crested Cormorants during January from 1999–2002 using at-sea transect data and 430 ± 50 in January using coastal data (Tables 1.7 and 1.10). The high variability of the at-sea estimate is due to one observation of 40 Double-crested Cormorants 1 km from shore north of Point Conception.

Brandt's Cormorant *Phalacrocorax penicillatus*

Brandt's Cormorants nest along the Pacific coast from southern Vancouver Island, British Columbia, Canada to southern Baja California, Mexico, including the Gulf of California (Wallace and Wallace 1998). They are one of the most widely distributed and abundant breeding seabirds in the SCB and breed in dense colonies on all eight of the Channel Islands except Santa Catalina Island (Carter et al. 1992). The population size of Brandt's Cormorants decreased in the 1950s and 1960s due to breeding failures caused by DDE contamination (Jehl 1973, Anderson and Gress 1983, Gress and Anderson 1983, Hunt et al. 1979). At Santa Barbara and San Nicolas Islands, abundance of cormorants decreased by 50–90% from the 1950s to 1977 (Hunt et al. 1979). In 1991, however, 29,400 breeding birds were estimated at 31 active breeding colonies in the SCB (13 of the colonies were newly discovered). This represents an almost four-fold increase in the numbers of Brandt's Cormorants since 1975–1978 (7,600 birds; Carter et al. 1992). From 1975–1983, Brandt's Cormorants occurred primarily in shallow waters <10 km from shore and <25 km from island or mainland roosts or colonies (Briggs et al. 1987). Along mainland coasts, birds consistently occurred in large roosts near Point Loma, Palos Verdes, Point Sal, and Point Buchon (Fig 1.11). Brandt's Cormorants were present at Santa Catalina Island during January and San Clemente Island during January and September. During May, however, reduced densities occurred in the southeastern SCB and increased densities occurred in the northern SCB where breeding colonies were located.

In 1999–2002, at-sea densities of Brandt's Cormorants did not differ among seasons ($F_{2,4481} = 0.3$, $P < 0.734$) but did differ among subareas ($F_{3,4481} = 5.5$, $P < 0.001$). We observed greatest densities in S3 and S5 (Table 1.3). In all seasons, Brandt's Cormorants were concentrated near the northern Channel Islands (S3) and near San Nicolas Island (S5; Figure 1.10). This distribution corresponds with the presence of large breeding colonies and roost sites on these Channel Islands. Coastal densities of Brandt's Cormorants did not differ among seasons ($F_{2,1781} = 2.2$, $P < 0.107$) but did differ among subareas ($F_{4,1781} = 23.7$, $P < 0.001$) with greatest densities occurring along Channel Island coastlines, especially along the NIC (Table 1.6).

We observed greater densities of Brandt's Cormorants at sea from 1999–2002 than from 1975–1983 throughout the entire study area ($\chi^2_1 = 169.8$, $P < 0.001$), S1 ($\chi^2_1 = 19.6$, $P < 0.001$), S3 ($\chi^2_1 = 36.7$, $P < 0.001$), S4 ($\chi^2_1 = 17.13.95$, $P < 0.047$), and S5 ($\chi^2_1 = 35.6$, $P < 0.001$). During May 1999–2002, we estimated 8,500 ± 1,500 Brandt's Cormorants in the study area (at-sea transects; Table 1.7). This represents more than a fourfold increase in numbers compared with 1975–1983 during the breeding season (Table 1.8). Similarly, pre-breeding (January) populations have increased more than twofold compared with 1975–1983 (Table 1.8). We estimated 1,530 ± 100 Brandt's Cormorants during May using coastal transect data (Table 1.10).

Pelagic Cormorant *Phalacrocorax pelagicus*

Pelagic Cormorants are the least pelagic of the cormorants occurring in the SCB and are rarely observed more than a few kilometers from shore (Sowls et al. 1980, Ainley et al. 1990). Pelagic Cormorants breed along the Pacific coast from northern Alaska to Los Coronados Islands in northern Baja California, Mexico (Wilbur 1987, Howell and Webb 1995) and occur south to central Baja California, Mexico (Hobson 1997). They breed on all Channel Islands except San Nicolas, San Clemente, and Santa Catalina Islands. In 1991, Carter et al. (1992) estimated 2,700 birds in the SCB, a threefold increase compared with estimates during 1975–1978. Briggs et al. (1987) observed few Pelagic Cormorants; most were observed north of Point Conception <10 km from shore. Similarly, we observed most birds <10 km from shore, but unlike the previous study >80% of the birds occurred south of Point Conception near San Miguel, Santa Rosa, and Santa Cruz Islands. Along the mainland coastline during May and September, we consistently observed birds near Point Buchon and Morro Bay during May and September (Figure 1.12). Although Pelagic Cormorants bred on Santa Barbara Island in 1991 (Carter et al. 1992), we did not observe birds near the island during May from 1999–2002. The few birds we observed during September surveys however, occurred <10 km from Santa Barbara Island.

We observed only nine Pelagic Cormorants on at-sea transects and did not compare at-sea densities among season, subarea, or to previous data. Most Pelagic Cormorants occurred in the Santa Barbara Channel, but two birds occurred near Morro Bay. Along coastlines, densities of Pelagic Cormorants differed among seasons ($F_{2,1789} = 14.6$, $P < 0.001$) and subareas ($F_{4,1789} = 14.9$, $P < 0.001$). Greatest densities of birds occurred along the CMC and along the NIC (Tables 1.5 and 1.6). Densities were similar during January and May, and few birds were observed during September surveys (Tables 1.5 and 1.6). Briggs et al. (1987) recorded few Pelagic Cormorants and did not estimate total numbers at sea. From 1999–2002, we estimated an average maximum of 130 ± 15 birds during January using coastal data (Table 1.10).

Pelagic Cormorants were more easily identified to species during May, due to the presence of their conspicuous white flank patches. During January and September surveys, without the aid of the white flank patch, we probably included some Pelagic Cormorants as unidentified cormorants and therefore our population estimates and distribution maps may be an underestimate in these months.

Alcidae

Five alcid species commonly occur in the SCB (Table 1.2). As a group, alcids were recorded throughout the study area in all seasons (Figure 1.13). At-sea densities differed among seasons ($F_{2,4941} = 25.3$, $P < 0.001$) and subareas ($F_{4,4941} = 11.1$, $P < 0.001$) with greatest densities during January in S1 and during May in S3 (Table 1.3). On coastal transects, densities differed among seasons ($F_{2,1436} = 12.3$, $P < 0.001$) and subareas ($F_{3,1436} = 10.0$, $P < 0.001$) with greatest densities along the NIC, except in May when greatest densities occurred along the NMC (Tables 1.5 and 1.6). At-sea densities of alcids were greater during 1975–1983 than during 1999–2002 throughout the entire study area ($\chi^2_1 = 125.7$, $P < 0.001$), S1 ($\chi^2_1 = 3.9$, $P < 0.001$), S2 ($\chi^2_1 = 9.7$,

$P < 0.002$), S4 ($\chi^2_1 = 17.1$, $P < 0.001$), and S5 ($\chi^2_1 = 26.3$, $P < 0.001$). At-sea densities did not differ in S3 ($\chi^2_1 = 1.8$, $P < 0.187$). We estimated an average at-sea abundance of 183,000 ± 16,900 alcids during January (Table 1.7).

Cassin's Auklet *Ptychoramphus aleuticus*

Cassin's Auklets are one of the most widely distributed alcids of the Pacific Ocean and breed from the western tip of the Aleutian Archipelago, Alaska to central Baja California, Mexico (Manuwal and Thoresen 1993). Cassin's Auklets are the third most abundant species breeding in the SCB (Carter et al. 1992). From 1975–1983, Briggs et al. (1987) observed Cassin's Auklets year-round throughout California waters from the mid-continental shelf out to 150 km from shore, but in late spring and summer, auklets were concentrated near breeding colonies. From August through October, birds were distributed throughout the SCB west of San Clemente Island, and over the continental shelf and slope from San Miguel Island to Point Buchon (Briggs et al. 1987). In contrast, from 1999–2002, Cassin's Auklet distribution varied markedly with survey month, but birds generally were observed >10 km from shore in all survey months (Figure 1.14). During May, birds were concentrated in the northwest portion of the Santa Barbara Channel and at sea north of Point Conception. During September, most auklets were observed north of Point Conception and were widely distributed across the SCB during January primarily west of San Nicolas Island. Similarly to Briggs et al. (1987), during September we observed Cassin's Auklets primarily in deeper water seaward of the continental slope.

In 1991, the population in the SCB was estimated at 12,500 birds (Carter et al. 1992). In the SCB, >90% of breeding birds occurred off San Miguel Island, especially Prince Island (1 km north of San Miguel Island) and Castle Rock (1 km northwest San Miguel Island); fewer breeding birds occur off Santa Cruz, Anacapa, and Santa Barbara Islands (Carter et al. 1992, McChesney et al. 2000). Numbers at Prince Island, the largest Cassin's Auklet colony in the SCB, possibly declined between 1975–1978 and 1991, but differences in survey protocols and effort between the two periods prevented assessment of population trends (Carter et al. 1992).

From 1999–2002, at-sea densities differed among seasons ($F_{2,4940} = 13.3$, $P < 0.001$) and subareas ($F_{4,4940} = 10.7$, $P < 0.001$). Whereas greatest densities occurred during January, few birds were observed during September (Table 1.3). Densities were greatest during May in S3 near northern Channel Island breeding colonies. During January, densities were greatest in S2 (west of San Miguel Island) in an average water depth of 1450 m (Table 1.3). On coastline surveys, Cassin's Auklets only occurred near the northern Channel Islands and in January and May. Densities were greatest during January ($F_{1,310} = 4.9$, $P < 0.027$; Table 1.6).

At-sea densities of Cassin's Auklets during 1975–1983 were greater than during 1999–2002 throughout the entire study area ($\chi^2_1 = 24.9$, $P < 0.001$) and S1 ($\chi^2_1 = 8.9$, $P < 0.003$) but lower in S3 ($\chi^2_1 = 9.1$, $P < 0.003$), S4 ($\chi^2_1 = 8.9$, $P < 0.003$), and S5 ($\chi^2_1 = 64.6$, $P < 0.001$) possibly indicating a shift in distribution. At-sea densities did not differ in S2 ($\chi^2_1 = 3.5$, $P < 0.062$). Maximum estimates from 1975–1978 off southern California ranged from 50,000 to 100,000 individuals during January (Briggs et al. 1987). In 1999–2002, we estimated an annual average maximum of 115,000 ± 15,000 Cassin's Auklets during January (Table 1.7).

Rhinoceros Auklet *Cerorhinca monocerata*

Rhinoceros Auklets breed from the Aleutian Islands, Alaska and the Gulf of Alaska to San Miguel Island off southern California. Birds winter from southeast Alaska to southern Baja California, Mexico (Gaston and Dechesne 1996). From 1975–1978, densities in the SCB were lowest in the summer and greatest during January, February, and March (Briggs et al. 1987). During the spring, birds occurred along the western margin of the SCB, in the passages between the northern Channel Islands, and along the shelfbreak from Point Arguello to Oregon (Briggs et al. 1987). From 1999–2002 during January, we observed birds throughout the SCB from 0.3–95 km from shore (Figure 1.15). Of the few birds observed during May and September, most occurred near the northern Channel Islands or north of Point Conception (Figure 1.15). In the SCB, Rhinoceros Auklets have only been observed to breed at three locations around San Miguel Island (19 birds; Carter et al. 1992). North of the SCB within the study area in 1991, six small breeding colonies were observed (41 birds; Carter et al. 1992). The California breeding population was estimated to be 1,769 individuals representing almost a fivefold increase over estimates from 1979–1980 (Carter et al. 1992).

At-sea densities differed among seasons ($F_{2,4940} = 73.6$, $P < 0.001$) and subareas ($F_{4,4940} = 22.7$, $P < 0.001$). Rhinoceros Auklets densities were greatest during January and much lower during May and September (Table 1.3). In all months, at-sea densities were greatest in S1 and lowest in S2 with lower but similar densities in S3, S4, and S5 (Table 1.3). We observed only five Rhinoceros Auklets on coastal transects from 1999–2002, all near the northern Channel Islands.

At-sea densities of Rhinoceros Auklets from 1975–1983 were greater than densities from 1999–2002 in all subareas combined ($\chi^2_1 = 9.8$, $P < 0.002$), S2 ($\chi^2_1 = 43.6$, $P < 0.001$), and S3 ($\chi^2_1 = 114.8$, $P < 0.001$) but lower in S1 ($\chi^2_1 = 7.9$, $P = 0.006$). At-sea densities did not differ in S4 ($\chi^2_1 = 0.2$, $P = 0.653$) or S5 ($\chi^2_1 = 1.1$, $P = 0.290$). Briggs et al. (1987) estimated 100,000 to 300,000 birds during March in the SCB. During January 1999–2002, we estimated an average maximum of 46,200 ± 4,620 birds (Table 1.7).

Common Murre *Uria aalge*

Common Murres are the most abundant breeding seabird in California (Carter et al. 1992). Along the eastern Pacific coast, murres breed on islands from western Alaska to Hurricane Point, Monterey County in central California (Ainley et al. 2002). Common Murres generally winter from the southern limit of sea ice in the Bering Sea to southern California but have been observed as far south as San Quintin, Baja California, Mexico, in times of cooler sea surface temperatures (Ainley et al. 2002). Historically, Common Murres bred in the SCB on Prince Island, (<1 km north of San Miguel Island), but as a result of egg gathering for private collections, the colony was extirpated in 1912 (Wright and Snyder 1913, Howell 1917, Ainley et al. 2002).

In central California (Point Conception to 38º 50'N latitude), Common Murre breeding populations declined by 53% from 1980 to 1986 (Takekawa et al. 1990) and continued to decline through 1989 (Carter et al. 1992). The central California breeding population was estimated to be 194,000–224,000 Common Murres in 1980–1982 and 90,200 breeding birds by 1989 (Carter et al. 2001). Declines in the breeding population were attributed to several factors including reduced reproductive success associated with the severe 1982–1983 El Niño, mortality from oil spills and gill net fisheries, and human disturbance at breeding colonies (Stenzel et al. 1988, Ainley and Boekelheide 1990, Takekawa et al. 1990, Carter et al. 2001).

During the nesting season (April through July), Briggs et al. (1987) observed Common Murres in waters <150 m deep, and 75% occurred <40 km of breeding colonies. From 1980–1983, Common Murres occurred south of Point Sur only outside the nesting season. Even in the winter, murres still were most abundant <50 km of breeding colonies (Briggs et al. 1987). From 1975–1983, large numbers (20,000–30,000) occurred within the Santa Barbara Channel and from Morro Bay to Point Arguello (30,000) during the fall and winter, but not during the spring and summer (Briggs et al. 1987). From 1999–2002, we observed only 232 Common Murres (Table 1.2) and >85% were north of Point Conception (Figure 1.16). More than 90% of murres occurred <20 km from shore in waters <150 m deep.

Densities on at-sea transects from 1999–2002 differed among seasons ($F_{2,3270} = 8.0$, $P < 0.001$) and subareas ($F_{2,3270} = 27.8$, $P < 0.001$). At-sea densities were greatest during January and lowest during May (Table 1.3). At-sea densities were greatest in S1 (Table 1.3). We observed only eight murres in S2 and nine murres in S5 and did not make comparisons in these subareas. We observed birds along coastal transects only during January (Tables 1.5 and 1.6). Most coastal sightings occurred near Morro Bay and Point Conception, but we observed one bird near Santa Barbara Island (Figure 1.16).

At-sea densities of Common Murres were much lower during 1999–2002 than from 1975–1983 for the entire study area ($\chi^2_1 = 308.3$, $P < 0.001$), S1 ($\chi^2_1 = 5.2$, $P < 0.023$), S3 ($\chi^2_1 = 214.3$, $P < 0.001$), and S4 ($\chi^2_1 = 111.0$, $P < 0.001$). For both studies, population densities were greatest during January. We estimated 10,700 ± 3,900 Common Murres in January in the study area, representing an 87% decrease in abundance compared with 1975–1983 (Tables 1.7 and 1.8).

Xantus's Murrelet (*Synthliboramphus hypoleucus*)

Xantus's Murrelets are one of the most southerly distributed alcids with a limited breeding range extending from the SCB to central Baja California, Mexico (Drost and Lewis 1995). There are two subspecies of Xantus's Murrelets: *S. h. scrippsi* nests primarily in California and *S. h. hypoleuca* nests primarily in Baja California, Mexico (Jehl and Bond 1975, Hunt et al. 1979). Both subspecies were recently listed as threatened by the California Department of Fish and Game and have been petitioned for Federal listing under the Endangered Species Act. Xantus's Murrelets breed on all Channel Islands except Santa Rosa and San Nicolas Islands (Drost and Lewis 1995). In 1991, Carter et al. (1992) estimated 1,400 breeding birds (81% of the California population) on Santa Barbara Island and considered this colony to be stable or declining slightly. Xantus's Murrelets typically occur near breeding colonies in December and January (Murray et al. 1983, Gaston and Jones 1998). Briggs et al. (1987) noted birds concentrated around Santa Barbara Island during the breeding months (March to May) and distributed north of Point Conception from August through October 20–100 km from shore (Briggs et al. 1987). During May in 1999–2001, greatest densities were near Santa Barbara and Anacapa Islands and north of Point Conception along the coast; 88% of murrelets occurred <40 km from shore and correspondingly 87% occurred in depths <1,400 m (Figure 1.17).

At-sea densities of Xantus's Murrelets did not differ among subareas ($F_{4,4940} = 0.6$, $P < 0.699$) but did differ among seasons ($F_{2,4940} = 15.4$, $P < 0.001$). We only observed 10 Xantus's Murrelets in S2. Greatest densities occurred during May with few birds observed during January or September (Table 1.3). Xantus's Murrelets were not observed on coastal transects in any month.

During 1999–2002, at-sea densities were greater than during 1975–1983 throughout the entire study area ($\chi^2_1 = 6.18$, $P = 0.01$) and S1 ($\chi^2_1 = 174.7$, $P < 0.001$) and S5 ($\chi^2_1 = 19.84$, $P < 0.001$). Densities did not differ in S3 ($\chi^2_1 = 0.0$, $P < 0.993$) or S4 ($\chi^2_1 = 1.0$, $P < 0.316$). Briggs et al. (1987) estimated 3,000 birds from Point Año Nuevo to San Miguel Island, and few birds southeast of this area. From 1999–2002, we estimated 13,800 ± 3,000 individuals during May in the study area (Table 1.7). Our estimate may be elevated given that the world population of Xantus's Murrelets is estimated at between 5,000 and 11,500 breeding birds with between 2,500 and 2,800 birds nesting in California (Drost and Lewis 1995, Carter et al. 2000). However, estimates between studies are difficult to compare due to differing survey and estimation techniques.

Pigeon Guillemot *Cepphus columba*

Pigeon Guillemots breed on rocky shorelines near shallow water foraging areas from north of the Bering Strait to Santa Barbara Island in the SCB and range from northern Alaska to northern Mexico (Ewins 1993). In 1991, Carter et al. (1992) estimated 3,218 breeding birds at 34 active colonies (12 new breeding colonies compared with surveys in 1975–1978) in the SCB, 97% more birds than estimates from 1975–1978 (Carter et al. 1992). Briggs et al. (1987) observed guillemots in June and July <2 km from shore and distributed from Santa Barbara Island to the Oregon border. We observed birds near Santa Barbara Island, between Santa Rosa and Santa Cruz Island, and along the mainland coast near Point Sal and Point Buchon. More than 92% occurred <2 km from shore (Figure 1.18).

From 1999–2002, we recorded only seven Pigeon Guillemots on at-sea transects, all observed during May. Densities on coastal transects differed among seasons ($F_{2,927} = 20.5$, $P < 0.001$) and subareas ($F_{2,927} = 6.1$, $P < 0.002$). More than 89% of observed Pigeon Guillemots occurred during May. We observed most birds along the NMC and the NIC (Tables 1.5 and 1.6).

With so few at-sea observations from 1999–2002, we were unable to compare at-sea transect data with data from 1975–1983. We estimated 280 ± 55 Pigeon Guillemots during May using coastal transect data (Table 1.10).

Tufted Puffin *Fratercula cirrhata*

Tufted Puffins breed from California to Japan and as far north as Wrangel Island, Russia (Gaston and Jones 1998). Tufted Puffins have not bred in the SCB for more than a century. At the Farallon Islands off San Francisco, California, puffins have experienced population declines from 1000s of birds in the late 1800s to an estimated 100 breeders in 1982 (Gaston and Jones 1998). Although their winter distribution is not well known, Tufted Puffins generally spend the winter well offshore and Briggs et al. (1987) stated that puffins were most abundant during January, April, and May. During periods of annual maximum abundance in the winter and spring from 1975–1978, an estimated 1,000 to 5,000 birds were in the SCB (Briggs et al. 1987).

We did not observe Tufted Puffins during our study. In the winter, we may have misidentified Tufted Puffins as Rhinoceros Auklets, but we only observed 366 Rhinoceros

Auklets. Even if we misidentified a great proportion of Tufted Puffins as Rhinoceros Auklets, our population estimates still would be much lower than estimates from Briggs et al. (1987).

Gaviidae

Common and Pacific Loons (*Gavia immer* and *G. pacificus*) commonly occurred in the SCB and both were observed primarily along mainland and island coastlines (Figure 1.19). Because it was difficult to distinguish between Common and Pacific Loons, 52% of loons counted were recorded as unidentified (Figure 1.20). At-sea densities differed among seasons ($F_{2,4487} = 6.2$, $P < 0.002$) and subareas ($F_{3,4487} = 4.5$, $P < 0.004$). Greatest densities occurred in S3 during January and in S1 during May (Table 1.3). Coastal densities differed among seasons ($F_{2,1789} = 57.6$, $P < 0.001$) and subareas ($F_{4,1789} = 8.5$, $P < 0.001$). Greatest densities occurred during January along mainland coasts (Tables 1.5 and 1.6). At-sea densities of loons were greater during 1975–1983 than during 1999–2002 throughout the entire study area ($\chi^2_1 = 25.0$, $P < 0.001$), S2 ($\chi^2_1 = 113.3$, $P < 0.001$), S4 ($\chi^2_1 = 138.3$, $P < 0.001$), and S5 ($\chi^2_1 = 193.1$, $P < 0.001$). At sea densities did not differ in S1 ($\chi^2_1 = 0.2$, $P < 0.690$).

Pacific Loon *Gavia pacifica*

Pacific Loons probably are the most abundant loons in North America and are strictly marine except when breeding in the arctic and sub-arctic (Russell 2002). In North America, Pacific Loons winter along the Pacific Coast from Alaska to Mazatlan, Mexico (Russell 2002). Briggs et al. (1987) recorded greatest abundances off southern California in mid-December, especially within the eastern Santa Barbara Channel, northeast of Anacapa Island. Pacific Loons were most common <40 km from the mainland off southern California (Briggs et al. 1987). From 1999–2002, we observed loons during January and May near the northern Channel Islands (except near Anacapa), from Point Conception to Point Buchon, between Santa Barbara and Point Dume, and on the west side of Santa Catalina Island (Figure 1.21). On at-sea transects, 87% of observed Pacific Loons were <5 km from shore.

From 1999–2002, at-sea densities of Pacific Loons did not differ among seasons ($F_{1,3038} = 3.7$, $P < 0.055$) or subareas ($F_{3,3038} = 1.7$, $P < 0.160$). At-sea densities were greatest during January with only one Pacific Loon observed in the study area during September (Table 1.3). Greatest at-sea densities occurred in S3 during January and in S1 during May (Table 1.3). On coastal transects, densities differed among seasons ($F_{1,1208} = 10.0$, $P < 0.002$) and subareas ($F_{4,1208} = 7.3$, $P < 0.001$). Coastal densities were greatest in January and along the northern mainland coast and along the northern Channel Island coastlines (Tables 1.4–1.6).

At-sea densities of Pacific Loons were greater during 1975–1983 than during 1999–2002 throughout the entire study area ($\chi^2_1 = 76.7$, $P < 0.001$), S3 ($\chi^2_1 = 76.7$, $P < 0.001$), S4 ($\chi^2_1 = 8.2$, $P < 0.005$), and S5 ($\chi^2_1 = 205.6$, $P < 0.001$). At sea densities did not differ in S1 ($\chi^2_1 = 2.6$, $P < 0.110$). From 1975–1978, Briggs et al. (1987) estimated 40,000 to 60,000 birds in April and 5,000 birds in the winter off southern California. During January from 1999–2002, we estimated an average maximum abundance of 24,600 ± 8,500 Pacific Loons using at-sea transect data and 1,700 ± 300 using coastal data (Tables 1.7 and 1.10).

Common Loon *Gavia immer*

Common Loons winter inshore along the Pacific coast from the western Aleutian Islands, Alaska to southern Baja California, Mexico, throughout the Gulf of California, and along the west coast of Mexico to Colima (McIntyre and Barr 1997). From 1975–1983, Common Loons occurred in California waters from late March to late May and from late October to December (Briggs et al. 1987). During January and May from 1999–2002, we observed loons along the coast near Morro Bay, from Point Arguello to Point Dume, near San Diego, and near San Miguel and Santa Rosa Islands (Figure 1.22).

At-sea densities of Common Loons did not differ among seasons ($F_{1,1335} = 3.1$, $P < 0.077$) or subareas ($F_{1,1335} = 0.0$, $P < 0.950$). Densities were greatest during January and in S1 and S3 (Table 1.3). Most (82%) Common Loons were observed on coastal transects. Coastal densities differed among seasons ($F_{2,1789} = 9.9$, $P < 0.001$) and among subareas ($F_{4,1789} = 3.8$, $P < 0.005$) and were greatest during January and along the northern portion of the mainland coast (Tables 1.5 and 1.6).

There only were enough at-sea data to compare densities for the entire study area and S3. At-sea densities of Common Loons from 1975–1983 were greater than from 1999–2002 throughout the entire study area ($\chi^2_1 = 131.6$, $P < 0.001$) and S3 ($\chi^2_1 = 81.0$, $P < 0.001$). Briggs et al. (1987) estimated between 5,000 and 10,000 birds at sea during April off California with 1,000 occurring <0.5 km from shore. Most of the large loon concentrations from 1975 ± 1983 were recorded north of our study area (Briggs et al. 1987). During January, we estimated an average maximum abundance of 1,540 ± 770 Common Loons using at-sea transect data and 130 ± 40 using coastal data (Tables 1.7 and 1.10). Many of the Common Loons observed on coastal transects occurred during the second survey of just the core area and were not included in the coastal estimate.

Laridae

We observed 22 species of larids (Table 1.2) throughout the study area (Figure 1.23). At-sea densities differed among seasons ($F_{2,4932} = 5.9$, $P < 0.003$) and subareas ($F_{4,4932} = 13.9$, $P < 0.001$). Greatest densities occurred during January and in S3 (Table 1.3). Coastal densities of larids did not differ among subareas ($F_{4,1781} = 1.3$, $P < 0.281$) but did differ among seasons ($F_{2,1781} = 23.2$, $P < 0.001$) with greatest densities during January primarily due to California Gulls (Tables 1.5 and 1.6). At-sea densities of larids were greater during 1975–1983 than during 1999–2002 throughout the entire study area ($\chi^2_1 = 111.9$, $P < 0.001$), S1 ($\chi^2_1 = 16.6$, $P < 0.001$), S2 ($\chi^2_1 = 4.1$, $P < 0.044$), S3 ($\chi^2_1 = 12.0$, $P < 0.001$), S4 ($\chi^2_1 = 23.0$, $P < 0.001$), and S5 ($\chi^2_1 = 225.7$, $P < 0.001$). We estimated an average abundance during January of 404,000 ± 60,000 larids (Table 1.7).

Western Gull *Larus occidentalis*

Western Gulls breed on offshore islands and rocks from central Baja California, Mexico, to Washington (Speich and Wahl 1989, Penniman et al. 1990) and winter in nearshore waters from the southern tip of Baja California, Mexico to Vancouver Island, Canada (Campbell et al. 1990, Howell and Webb 1995). The North American population was estimated at 40,000 pairs (Pierotti and Annett 1995). Western Gulls are the most widely distributed and the second most abundant breeding seabird in the SCB. Large breeding colonies occur at San Miguel, Santa Barbara, Anacapa, and San Nicolas Islands (Carter et al. 1992). In 1991, 28,000 breeding birds were estimated to be in the SCB, a 144% increase in numbers compared with surveys conducted in the late 1970s (Carter et al. 1992). Briggs et al. (1987) observed Western Gulls along California coastlines during all months and seldom observed birds farther than 25 km seaward of the shelf break. Western Gulls were more restricted to areas near breeding colonies from April to August, and from November through February, were distributed more evenly throughout the SCB (Briggs et al. 1987). In contrast, we observed Western Gulls throughout the SCB during 1999–2002 in all seasons, on all at-sea and coastal transect lines, and along all mainland and island coastlines (Figure 1.24). More than 96% of observed Western Gulls occurred <20 km from shore.

From 1999–2002, at-sea densities of Western Gulls did not differ among seasons ($F_{,4932} = 0.3$, $P < 0.968$) but did differ among subareas ($F_{4,4932} = 21.9$, $P < 0.001$). We observed greatest densities in S3 during each month (Table 1.3). Along coastlines, densities did not differ among subareas ($F_{4,1781} = 1.6$, $P < 0.163$) but did differ among seasons ($F_{2,1781} = 4.1$, $P < 0.017$). Mainland coastal densities were greatest in September and island coastal densities were greatest in January (Tables 1.5 and 1.6).

At-sea densities from 1999–2002 were greater than from 1975–1983 throughout the entire study area ($\chi^2_1 = 11.6$, $P < 0.001$) and S3 ($\chi^2_1 = 4.1$, $P < 0.043$) but lower in S2 ($\chi^2_1 = 7.9$, $P < 0.005$), S4 ($\chi^2_1 = 6.0$, $P < 0.015$), and S5 ($\chi^2_1 = 9.3$, $P < 0.024$). At-sea densities did not differ in S1 ($\chi^2_1 = 0.5$, $P < 0.486$). In 1976, Briggs et al. (1987) estimated 25,000–50,000 Western Gulls in the SCB during January–February. From 1999–2002 during January, we estimated an average annual maximum of 163,000 ± 56,200 Western Gulls using at-sea transect data and 17,000 ± 3,000 using coastal data (Tables 1.7 and 1.10).

California Gull *Larus californicus*

California Gulls are one of the most common larids in California's offshore waters (Stallcup 1990). They breed at numerous sites on inland lakes from Mono Lake to San Francisco Bay, California, and from southern Colorado to Manitoba, Canada (Winkler 1996). Beginning in late summer, California Gulls winter on the eastern Pacific coast from southern British Columbia, Canada, to southern Baja California, Mexico, and the Gulf of California (Winkler 1996). They undergo a northward migration during early fall to southern British Columbia coastal waters and move south during late fall reaching maximum abundances off central and southern California during January and February (Winkler 1996). Breeding adults begin returning to inland colonies in February (Winkler 1996). Briggs et al. (1987) found that they were the most abundant gulls in nearshore waters in the fall and winter. From 1975–1978, California Gulls arrived in the SCB during late September or October. Surveys conducted from mainland and island coasts indicated maximum abundances in the SCB were from January through March (Briggs et al. 1987). From 1999–2002, we observed California Gulls near mainland and island coastlines in all survey months and throughout the SCB during January (Figure 1.25). California Gulls were observed on 86% of transects and 84% occurred <1 km from shore.

From 1999–2002, densities of California Gulls on at-sea transects differed among seasons ($F_{2,4940} = 22.1$, $P < 0.001$) and subareas ($F_{4,4940} = 6.2$, $P < 0.001$). Densities were greatest during January and lowest during September (Table 1.3). At-sea densities were greatest in S3 during

January and September, and in S1 and S4 during May (Table 1.3). On coastal transects, densities did not differ among subareas ($F_{4,1781} = 0.4$, $P < 0.840$) but did differ among seasons ($F_{2,1781} = 12.2$, $P < 0.001$) and were greatest during January (Tables 1.5 and 1.6).

At-sea densities were greater from 1975–1983 than from 1999–2002 throughout the entire study area ($\chi^2_1 = 65.9$, $P = 0.015$), S2 ($\chi^2_1 = 35.9$, $P < 0.001$), and S5 ($\chi^2_1 = 18.9$, $P < 0.001$). At-sea densities did not differ in S1 ($\chi^2_1 = 1.8$, $P < 0.182$), S3 ($\chi^2_1 = 3.6$, $P < 0.057$), and S4 ($\chi^2_1 = 0.4$, $P < 0.546$). Briggs et al. (1987) estimated 150,000 California Gulls during December and January off southern California. From 1999–2002 during January, we estimated an average abundance of 231,000 ± 58,000 California Gulls in the study area using at sea transect data and 39,900 ± 5,500 using coastal data (Tables 1.7 and 1.10).

Heermann's Gull *Larus heermanni*

Heermann's Gulls nest in dense colonies in desert habitats on only a few islands adjacent to productive ocean areas (Velarde 1999). In 1981, the world breeding population was estimated at 260,000 individuals, 95% of which bred on Isla Rasa in the Gulf of California, Mexico (Velarde 1999). Small numbers also have bred on two islands on the Pacific coast of Baja California, Mexico (Everett and Anderson 1991). Briggs et al. (1987) reported post-breeding arrival of Heermann's Gulls off southern California from late April to June and departure to breeding areas in Mexico in early fall. From 1975–1978, they occurred consistently from Morro Bay to the Santa Barbara Channel and near San Diego (Briggs et al. 1987). In all survey months from 1999–2002, we observed Heermann's Gulls near Palos Verdes. During January and September, we consistently observed birds along the mainland coast from Point Sal to Gaviota and near Huntington Beach, San Diego, and Santa Rosa, Santa Cruz, Anacapa, and San Clemente Islands (Figure 1.26). More than 86% of observed Heermann's Gulls occurred <1 km from shore.

From 1999–2002, densities on at-sea transects did not differ among seasons ($F_{1,2950} = 0.13$, $P < 0.721$) but did differ among subareas ($F_{3,2950} = 6.5$, $P < 0.001$). At-sea densities were greatest in S3 and Heermann's Gulls were not observed in S2 (Table 1.3). Coastal densities also did not differ among seasons ($F_{4,1781} = 0.2$, $P < 0.922$) but did differ among subareas ($F_{2,1781} = 16.0$, $P < 0.001$). Coastal densities were greatest along the NMC during September and along the SCI during January (Tables 1.5 and 1.6).

At-sea densities from 1975–1983 were greater than densities from 1999–2002 throughout the entire study area ($\chi^2_1 = 5016.5$, $P < 0.001$), S1 ($\chi^2_1 = 43.0$, $P < 0.001$), S4 ($\chi^2_1 = 107.3$, $P < 0.001$), and S5 ($\chi^2_1 = 73.8$, $P < 0.001$) but lower in S3 ($\chi^2_1 = 14.3$, $P < 0.001$). Based on beach surveys, Briggs et al. (1987) estimated approximately 9,000 Heermann's Gulls in July in the SCB. During September from 1999–2001, we estimated an average maximum abundance of 19,250 ± 6,200 Heermann's Gulls using at-sea transect data and 5,100 ± 960 Heermann's Gulls using coastal data (Tables 1.7 and 1.10).

Sabine's Gull *Xema sabini*

Sabine's Gulls winter at sea along coastal upwelling zones from northern Mexico to Peru (Day et al. 2001). During migrations between their Alaskan nesting grounds and wintering areas off northern South America, Briggs et al. (1987) recorded Sabine's Gulls statewide from the shoreline to at least 200 km offshore. Off southern California, gulls occurred seaward of the

Santa Rosa-Cortes Ridge (Briggs et al. 1987). From 1999–2002 during September, we observed gulls near Tanner and Cortez Banks (Figure 1.27). During May and September, gulls were observed north of Point Conception and west of San Miguel Island (Figure 1.27).

At-sea densities did not differ among seasons ($F_{1,3262} = 1.3$, $P < 0.259$) but did differ among subareas ($F_{4,3262} = 17.3$, $P < 0.001$). We observed greatest at-sea densities in S1 and lowest densities in S4 (Table 1.3). We did not observe Sabine's Gulls on coastal transects.

At-sea densities were greater from 1999–2002 than from 1975–1978 throughout the entire study area ($\chi^2_1 = 219.3$, $P < 0.001$), S1 ($\chi^2_1 = 276.9$, $P < 0.001$), S2 ($\chi^2_1 = 14.55$, $P < 0.001$), S4 ($\chi^2_1 = 10.1$, $P < 0.002$), and S5 ($\chi^2_1 = 27.0$, $P < 0.001$). We did not compare at-sea densities in S3 because of a lack of data. Briggs et al. (1987) estimated 5,000 to 10,000 Sabine's Gulls off southern California during fall compared with our estimate of 9,200 ± 1,500 gulls from 1999–2002 during May and 8,460 ± 2,300 gulls during September (Table 1.7).

Bonaparte's Gull *Larus philadelphia*

Bonaparte's Gulls winter on the Pacific Coast, from southern British Columbia, Canada to southern Baja California and Nayarit, Mexico (Burger and Gochfeld 2002). Off California, gulls arrived during September to October, reaching maximum numbers in late October to November (Briggs et al. 1987). Numbers declined through the winter and increased again during March to May. Although dispersed widely throughout shelf and slope waters, greatest numbers of birds occurred <40 km from shore (Briggs et al. 1987). From 1999–2002, birds occurred only during January and May with >99% of observed Bonaparte Gulls south of Point Conception and >90% of birds <40 km from shore (Figure 1.28).

At-sea densities differed among seasons ($F_{1,3362} = 7.8$, $P < 0.006$) and subareas ($F_{4,3362} = 3.6$, $P < 0.007$). Greatest densities occurred during January and in S4 and S5 (Table 1.3). Coastal densities did not differ among seasons ($F_{1,589} = 0.2$, $P < 0.664$) or among subareas ($F_{1,589} = 2.0$, $P < 0.161$). We counted 166 Bonaparte's Gulls on coastal transects and all but two birds were observed along the CMC.

At-sea densities from 1975–1983 were greater than from 1999–2002 throughout the entire study area ($\chi^2_1 = 409.2$, $P < 0.001$), S1 ($\chi^2_1 = 58.1$, $P < 0.001$), S2 ($\chi^2_1 = 23.3$, $P < 0.001$), S3 ($\chi^2_1 = 11.8$, $P < 0.001$), S4 ($\chi^2_1 = 714.4$, $P < 0.001$), and S5 ($\chi^2_1 = 256.7$, $P < 0.001$). Briggs et al. (1987) reported that the spring migration of Bonaparte's Gulls occurred during a short period beginning in March and ending in May and estimated maximum instantaneous populations in April and May to be 300,000 gulls. During January from 1999–2002, we estimated an average maximum number of 7,700 ± 3,100 Bonaparte's Gulls (Table 1.7) suggesting that we probably did not survey during periods of peak abundance.

Black-legged Kittiwake *Rissa tridactyla*

In the eastern Pacific, Black-legged Kittiwakes winter offshore from the ice edge in Alaska to central Baja California, Mexico (Baird 1994). Kittiwakes migrate south from their breeding colonies in the arctic during September and return in March (Baird and Gould 1983). Kittiwakes arrived in California waters in November with greatest densities occurring from January through March and departed California waters in April and May (Briggs et al. 1987). Kittiwakes occurred from the coastline to 200 km from shore and density did not decrease significantly with increasing distance from shore (Briggs et al. 1987). During January from

2000–2002, kittiwakes occurred throughout the study area, except in the southeastern portion (S4). Birds were concentrated primarily <15 km from the northern Channel Islands and near San Nicolas Island (Figure 1.29).

From 1999–2002, densities on at-sea transects did not differ among subareas ($F_{4,3363}$ = 2.1, $P < 0.082$) but did differ among seasons ($F_{1,3363}$ = 29.8, $P < 0.001$). Densities were greatest during January (Table 1.3); we observed only four birds during May 2000 and none during September. At-sea densities were greatest in S5, S2, and S3 (Table 1.3). We observed only 15 Black-legged Kittiwakes on coastal transects, all during January and all but two occurred near the northern Channel Islands.

At-sea densities of Black-Legged Kittiwakes were greater from 1975–1983 than from 1999–2002 throughout the entire study area ($\chi^2_1 = 63.7$, $P < 0.001$), S1 ($\chi^2_1 = 4.3$, $P < 0.036$), S3 ($\chi^2_1 = 56.8$, $P < 0.001$), and S4 ($\chi^2_1 = 31.9$, $P < 0.001$) but lower in S2 ($\chi^2_1 = 15.5$, $P < 0.001$). At-sea densities did not differ in S5 ($\chi^2_1 = 3.8$, $P < 0.052$). Briggs et al. (1987) estimated 50,000 to 300,000 occurred in the SCB in the winter. During January from 2000–2002, we estimated 34,600 ± 3,900 in the study area.

Caspian Tern *Sterna caspia*

Caspian Terns are the largest terns and occur on every continent except Antarctica (Cuthbert and Wires 1999). Caspian Terns breed in widely dispersed locations on the shores of rivers, lakes, and marshes throughout North America and along the Pacific, Atlantic, and Gulf coasts. Terns winter along the Pacific coast from southern California to Guatemala (Cuthbert and Wires 1999). In southern California, terns breed on salt pond levees in San Diego Bay (Gill and Mewaldt 1983). From 1960 to 1980, the Pacific coast population increased 70% (Gill and Mewaldt 1983). From 1979–1981, 2,684 were estimated in California, whereas 4,350 were estimated in 1997 representing a 62% increase (Cuthbert and Wires 1999). In South San Diego Bay National Wildlife Refuge, an estimated 379 pairs of Caspian Terns bred in 2002 (USFWS 2004). Briggs et al. (1987) reported Caspian Terns rarely occurred >1 km from shore and recorded few terns on surveys because they did not conduct aerial surveys of coastlines. From 1999–2002, we consistently observed Caspian Terns on coastal transects near Point Loma, northern Santa Monica Bay, Santa Cruz Island, and south of Gaviota (Figure 1.30).

We observed only 16 Caspian Terns on at-sea transects. Coastal densities differed among seasons ($F_{2,1789}$ = 32.9, $P < 0.001$) and subareas ($F_{4,1789}$ = 24.0, $P < 0.001$). Whereas greatest densities occurred during September, few birds were observed during January (Tables 1.5 and 1.6). Greatest densities occurred along SMC (Tables 1.5 and 1.6).

Because we observed only 16 Caspian Terns on at-sea transects, we did not statistically compare surveys. Briggs et al. (1987) made no estimate of Caspian Terns for the SCB. We estimated 640 ± 240 Caspian Terns in the SCB based on coastal transect data (Table 1.10).

Procellariidae

We observed ten species of procellariids in the study area (Table 1.2; Figure 1.31). At-sea densities differed among seasons ($F_{2,4932}$ = 5.9, $P < 0.003$) and subareas ($F_{4,4932}$ = 3.7, $P < 0.005$) with greatest densities occurring during January in S1 and during May in S3 (Table 1.3). Coastal densities of procellariids did not differ among seasons ($F_{2,1436}$ = 1.0, $P < 0.380$) or subareas ($F_{3,1436}$ = 1.2, $P < 0.306$). At-sea densities were greater during 1975–1983 than during

1999–2002 throughout the entire study area ($\chi^2_1 = 10.7, P < 0.002$), S2 ($\chi^2_1 = 29.0, P < 0.001$), S4 ($\chi^2_1 = 5.9, P < 0.015$), and S5 ($\chi^2_1 = 8.3, P < 0.004$) but lower in S3 ($\chi^2_1 = 8.2, P < 0.005$). At-sea densities did not differ in S1 ($\chi^2_1 < 0.1, P < 0.886$). We estimated average maximum abundance during May to be 380,000 ± 66,000 procellariids during 1999–2002 (Table 1.7).

Sooty Shearwater *Puffinus griseus* and Short-tailed Shearwater *P. tenuirostris*

Sooty and Short-tailed Shearwaters are difficult to distinguish from the air and so we consider them together here. Sooty Shearwaters are one of the most abundant seabirds of the Pacific Ocean (Spear and Ainley 1999). Shearwaters breed on islands near New Zealand, Chile, and Australia from October to May and migrate to the northern Pacific Ocean from May to September (Everett and Pitman 1993, Warham 1996). In the 1970s, an estimated four million Sooty Shearwaters occurred off California (Briggs and Chu 1986). From 1987 to 1994, Sooty Shearwater numbers decreased by 80–90% coincident with increased sea surface temperatures throughout the CCS (Veit et al. 1997). Maximum numbers off southern California occurred during May in the shelf waters off Point Conception (Briggs et al. 1987). From 1999–2002, Sooty Shearwaters were distributed throughout the study area during May and concentrated near the northern Channel Islands (Figure 1.32).

At-sea densities of Sooty Shearwaters differed among seasons ($F_{2,4940} = 14.3, P < 0.001$) and subareas ($F_{4,4940} = 16.5, P < 0.001$). Densities on at-sea transects were greatest during May when shearwaters occurred on all at-sea transect lines (Figure 1.32). Greatest densities occurred in S3 during May and in S1 during September (Table 1.3). Densities on coastal transects did not differ among seasons ($F_{2,1436} = 1.5, P < 0.222$) or subareas ($F_{3,1436} = 1.5, P < 0.219$; Tables 1.5 and 1.6). A single flock of 6,000 Sooty Shearwaters near Point Sal accounted for >40% of all Sooty Shearwaters observed for the entire study period (at-sea and coastal transects).

At-sea densities of Sooty Shearwaters were greater from 1975–1983 than from 1999–2002 in S2 ($\chi^2_1 = 55.4, P < 0.001$), S4 ($\chi^2_1 = 192.8, P < 0.001$), and S5 ($\chi^2_1 = 24.3, P < 0.001$) but lower in S3 ($\chi^2_1 = 32.9, P < 0.001$). At-sea densities did not differ for the entire study area ($\chi^2_1 = 0.1, P < 0.741$) and S1 ($\chi^2_1 = .34, P < 0.560$). Briggs and Chu (1986) estimated >2,000,000 Sooty Shearwaters off central and southern California in May. We estimated an average maximum abundance of 366,500 ± 66,000 Sooty Shearwaters during May from 1999–2001 (Table 1.7).

Pink-footed Shearwater *Puffinus creatopus*

Pink-footed Shearwaters breed off the coast of Chile from November to May (Guicking et al. 2001) and are listed as a threatened species due to a restricted breeding range and a population presumed to be decreasing. Their main breeding island, Isla Mocha, hosts 20,000 to 25,000 nesting burrows (Guicking et al. 2001). Briggs et al. (1987) observed Pink-footed Shearwaters in the SCB in almost every month. Greatest densities occurred during May or June and decreased until a second maximum in August to September. In the SCB, shearwaters were common in the Santa Barbara Channel near the Santa Rosa-Cortes Ridge, and near the southern coasts of the northern Channel Islands (Briggs et al. 1987). From 1999–2002, we observed Pink-footed Shearwaters throughout the study area during September, primarily south of Point Conception during May, and near Point Conception during January (Figure 1.33).

At-sea densities of Pink-footed Shearwaters differed among seasons ($F_{2,4940} = 24.6$, $P < 0.001$) and subareas ($F_{4,4940} = 5.0$, $P < 0.001$). Densities were greatest during September and lowest during January and in S3 (Table 1.3). Coastal densities did not differ among subareas ($F_{1,433} = 0.6$, $P < 0.451$) but did differ among seasons ($F_{1,433} = 6.2$, $P < 0.014$) and were greatest during September (Tables 1.5 and 1.6). Pink-footed Shearwaters occurred only on the northern portion of the mainland and northern Channel Island coastlines.

At-sea densities of Pink-footed Shearwaters were greater from 1975–1983 than from 1999–2002 in S2 ($\chi^2_1 = 66.6$, $P < 0.001$) and S5 ($\chi^2_1 = 262.6$, $P < 0.001$) but lower in S4 ($\chi^2_1 = 10.2$, $P < 0.002$). At-sea densities did not differ for the entire study area ($\chi^2_1 = 0.15$, $P = 0.703$), S1 ($\chi^2_1 = 1.8$, $P = 0.186$), and S3 ($\chi^2_1 = 1.15$, $P = 0.284$). From 1975–1978, maximum abundances of 60,000 to 400,000 Pink-footed Shearwaters were estimated in the SCB during the summer (Briggs et al. 1987). We estimated an average abundance of 62,400 ± 16,200 birds during September from 1999–2002 (Table 1.7).

Black-vented Shearwater *Puffinus opisthomelas*

Black-vented Shearwaters are the only shearwaters that breed in the California Current, nesting on remote desert islands near productive upwelling zones off the west coast of Baja California, Mexico; greater than 95% of the breeding population occurs on Natividad Island, Baja California Sur, Mexico (Keitt et al. 2000). Black-vented Shearwaters are listed as a Species of Special Concern by the International Union for the Conservation of Nature (Birdlife International 2003). Post-breeding birds disperse northward in July or August and are most abundant off southern California during November, December, and January usually <25 km from shore (Everett 1988, Keitt et al. 2000). Briggs et al. (1987) recorded Black-vented Shearwaters in all months except April with maximum numbers from September to December. Ainley (1976) noted that Black-vented Shearwaters occurred farther northward during years of warm water associated with El Niño events. During September 1977 (El Niño year), Black-vented Shearwaters occurred throughout the SCB east of the Santa Rosa-Cortes Ridge, in the eastern Santa Barbara Channel, and near Oceanside (Briggs et al. 1987). From 1975–1978, shearwaters were recorded in nearshore waters from south of Dana Point to San Diego (Briggs et al. 1987). From 1999–2002, we observed Black-vented Shearwaters in the eastern Santa Barbara Channel. Birds generally were found <10 km from shore (Figure 1.34).

At-sea densities differed among seasons ($F_{2,4487} = 3.0$, $P < 0.047$) and subareas ($F_{3,4487} = 2.9$, $P < 0.032$). From 1999–2002, densities were three times greater during January than during September (Table 1.3). We counted only one bird in the SCB in early May 1999. Seventy-seven percent of Black-vented Shearwaters recorded at sea occurred in S3. On coastal transects, we observed only two birds and these occurred in the passage between Anacapa and Santa Cruz Islands during September 2001.

We were not able to obtain Black-vented Shearwater data for the period 1975–1983 and therefore could not compare studies statistically. Briggs et al. (1987) estimated 20,000 to 30,000 individuals occurred in the fall 1977 in the SCB. We estimated an average maximum abundance of 13,900 ± 9,200 during January in the study area (Table 1.7).

Northern Fulmar *Fulmarus glacialis*

Northern Fulmars breed at several colonies in Alaska, British Columbia, the Arctic, and eastern Canada and are distributed widely across the Pacific Ocean south to Baja California and Sonora, Mexico, during the winter (Hatch and Nettleship 1998). Briggs et al. (1987) observed Northern Fulmars off California in all seasons with maximum abundances occurring off southern California during December to January and then again in March, indicating that birds were passing through on their way to Mexican waters in the winter and then returning through the SCB to northern waters in the spring. Northern Fulmars occurred in greatest densities 5–40 km from shore but also were observed from the mainland shore to the maximum distance surveyed (460 km; Briggs et al. 1987). From 1999–2002, we observed Northern Fulmars in all survey months and throughout the study area during January (Figure 1.35).

From 1999–2002, at-sea densities of Northern Fulmars differed among seasons ($F_{2,4940}$ = 49.1, $P < 0.001$) and subareas ($F_{4,4940}$ = 5.0, $P < 0.001$) with greatest densities during January and in S2 (Table 1.3). Only four Northern Fulmars were observed on coastal transects; one near Point Mugu (CMC) and the others near San Miguel Island.

At sea densities from 1975–1983 were greater than densities from 1999–2002 throughout the entire study area (χ^2_1 = 37.8, $P < 0.001$), S3 (χ^2_1 = 7.9, $P < 0.005$), and S4 (χ^2_1 = 73.9, $P < 0.001$) but lower in S5 (χ^2_1 = 17.6, $P < 0.001$). At-sea densities did not differ in S1 (χ^2_1 = 0.0, $P < 0.976$) and S2 (χ^2_1 = 0.5, $P < 0.489$). Briggs et al. (1987) estimated 35,000 to 95,000 birds in the winter off of all of California. From 2000–2002, we estimated an average maximum abundance of 16,900 ± 2,300 Northern Fulmars in the study area during January (Table 1.7).

Ashy Storm-Petrel (*Oceanodroma homochroa*)

There are an estimated 10,000 Ashy Storm-Petrels off of California and Baja California, Mexico (Ainley 1995). Ashy Storm-Petrels occur year-round in waters of the continental slope and slightly farther to sea and do not migrate or disperse far from breeding locations (Ainley 1995). In the SCB, birds breed on Los Coronados Islands, Baja California, Mexico, and all California Channel Islands except Santa Rosa, San Nicolas, and Santa Catalina (Ainley 1995). The state of California designated Ashy Storm-Petrels a species of special concern (Remsen 1978) and the U.S. Fish and Wildlife Service designated the species as a bird of conservation concern (USFWS 2002). In 1991, Carter et al. (1992) estimated 3,135 birds in the SCB but differences in survey protocols and efforts from past studies made trends in population size difficult to assess. Off southern California, Briggs et al. (1987) observed Ashy Storm-Petrels in greatest abundance near San Miguel Island from April to June. After October, birds occurred near San Clemente and Santa Catalina Islands, over the Santa Rosa-Cortes Ridge, and in the western Santa Barbara Channel to Point Buchon (Briggs et al. 1987). From 1999–2002, we observed Ashy Storm-Petrels throughout the SCB with aggregations between Santa Cruz and San Nicolas Islands, in the western Santa Barbara Channel, and 10–70 km offshore from San Miguel Island to Point Buchon (Figure 1.36).

From 1999–2002, at sea densities differed among seasons ($F_{2,4940}$ = 4.3, $P < 0.014$) and subareas ($F_{4,4940}$ = 5.2, $P < 0.001$). Densities were greater during May and September and we observed birds in all subareas in all months except during January in S2 and S3 (Table 1.3). We did not observe Ashy Storm-Petrels on coastal transects.

At-sea densities of Ashy Storm-Petrels from 1999–2002 were greater than densities from 1975–1983 throughout the entire study area (χ^2_1 = 270.5, $P < 0.001$), S1 (χ^2_1 = 57.5, $P < 0.001$), S2 (χ^2_1 = 17.7, $P < 0.001$), S3 (χ^2_1 = 32.1, $P < 0.001$), and S5 (χ^2_1 = 41.3, $P < 0.001$). At-sea densities did not differ in S4 (χ^2_1 = 32.1, $P < 0.001$). From 1975–1983, Briggs et al. (1987)

estimated 1,400 birds occurred south of Point Buchon. From 1999–2002, we estimated average maximum abundances during September of 8,470 ± 1,540 (Table 1.7).

Black Storm-Petrel (*Oceanodroma melania*)

Black Storm-Petrels breed primarily on the Channel Islands, off the west coast of Baja California, Mexico, and on islands in the Gulf of California, Mexico (Pitman and Speich 1976, Sowls et al. 1980, Everett and Anderson 1991). In the SCB, storm-petrels breed on Santa Barbara, Sutil, and Los Coronados Islands, and possibly on Prince (<1 km north of San Miguel Island) and San Clemente Islands (Carter et al. 1992). Breeding numbers are difficult to estimate because Black Storm-Petrels nest in inaccessible burrows or crevices and are active at breeding colonies only at night. In 1991, 274 breeding birds were estimated at Santa Barbara and Sutil Islands representing >54% increase from 1975–1978 (Carter et al.1992). Briggs et al. (1987) observed Black Storm-Petrels in all months with maximum abundances in August and September. From 1975–1978, birds occurred primarily off California south of Point Conception and <50 km from the mainland, although aggregations of birds also were observed at Forty Mile Bank (30 km southeast of San Clemente Island), near Santa Barbara Island, and along the Santa Rosa-Cortes Ridge (Briggs et al. 1987). From 1999 to 2001 during September and May, Black Storm-Petrels occurred between Cortez Bank and San Diego, <40 km from the northern Channel Islands, and 50–100 km from Point Buchon during September (Figure 1.37).

At-sea densities of Black Storm-Petrels differed among seasons ($F_{2,4940} = 5.5$, $P < 0.004$) and subareas ($F_{4,4940} = 2.5$, $P < 0.041$). Birds were observed in nearly equal abundance during May and September, but were virtually absent during January (Table 1.3). Densities were greatest in S4 and S5 (Table 1.3). Black Storm-Petrels were not observed on any coastal transect.

At-sea densities from 1999–2002 were greater than from 1975–1983 throughout the entire study area ($\chi^2_1 = 82.8$, $P < 0.001$), S3 ($\chi^2_1 = 20.0$, $P < 0.001$), S4 ($\chi^2_1 = 44.9$, $P < 0.001$), and S5 ($\chi^2_1 = 20.3$, $P < 0.001$) but lower in S1 ($\chi^2_1 = 21.3$, $P < 0.001$) and S2 ($\chi^2_1 = 39.1$, $P < 0.001$). Briggs et al. (1987) estimated <5,000 Black Storm-Petrels off southern California in most months. From 1999–2002, we estimated an average maximum abundance of 3,080 ± 770 birds during May in the study area (Table 1.7).

Leach's Storm-Petrel (*Oceanodroma leucorhoa*)

Leach's Storm-Petrels are the most widespread procellariiform breeding in the Northern Hemisphere and, in the eastern Pacific, breed from the Aleutian Islands, Alaska to Guadalupe Island, Baja California, Mexico (Huntington et al. 1996). In the SCB, Leach's Storm-Petrels breed on Prince, Sutil, Santa Barbara, and Los Coronados Islands (Carter et al. 1992). Although difficult to census, an estimate of 314 breeding birds was made in 1991 for the SCB, but the estimate was not comparable to previous estimates due to different sampling protocols and lack of earlier reliable estimates (Carter et al. 1992). Briggs et al. (1987) observed Leach's Storm-Petrels in all months of the year with greatest densities off southern California from June through October and lower densities from December through May. During the spring from 1975–1978, Leach's Storm-Petrels occurred from San Miguel Island to Cortez Bank and eastward to just south of San Clemente Island (Briggs et al. 1987). During late summer, distribution shifted northwestward, seaward of the outermost islands (Briggs et al. 1987). From 1999–2002, we observed similar distributions to Briggs et al. (1987) except we did not observe birds as far east during May and noted a more northward distribution of birds during September (Figure 1.38). For all surveys combined, we observed 64% of birds in the southwest portion of the SCB between 33° and 34° latitude and 120° and 121° longitude and, during January, they occurred only within this area.

At-sea densities of Leach's Storm-Petrels differed among seasons ($F_{2,4940} = 17.0$, $P < 0.001$) and subareas ($F_{4,4940} = 25.4$, $P < 0.001$). Greatest densities occurred during May and September and very few birds occurred during January (Table 1.3). Greatest densities were in S5 and lowest densities in S4. Leach's Storm-Petrels were observed in all subareas in all months except for January when they were observed only in S5. We did not observe Leach's Storm-Petrels on coastal transects.

At-sea densities of Leach's Storm-Petrels from 1975–1983 were greater than densities from 1999–2002 throughout the entire study area ($\chi^2_1 = 100.8$, $P < 0.001$), S1 ($\chi^2_1 = 27.4$, $P < 0.001$), S2 ($\chi^2_1 = 98.3$, $P < 0.001$), S3 ($\chi^2_1 = 116.5$, $P < 0.001$), and S4 ($\chi^2_1 = 127.3$, $P < 0.001$) but lower in S5 ($\chi^2_1 = 20.3$, $P < 0.001$). In late August 1977, Briggs et al. (1987) estimated a maximum of 150,000 Leach's Storm-Petrels in the SCB. From 1999–2002, we estimated an average maximum abundance during September of 5,400 ± 700 birds in the study area (Table 1.7). Given the large difference in estimates, we may not have surveyed during periods of peak abundance.

Laysan Albatross *Phoebastria immutabilis*

Laysan Albatrosses are the most abundant albatross species in the Northern Hemisphere with a population estimated to be 2.5 million individuals in the early 1990s (Whittow 1993a). They breed almost entirely on the Hawaiian Archipelago from Kure Atoll to Kauai, Hawaii. In the 1980s, a small breeding colony was discovered on Guadalupe Island off central Baja California, Mexico, and other incipient colonies on San Benedicto Island and Clarion Island in the Revillagigedos (west of central Mexico) and at Alijos Rocks (west of southern Baja California, Mexico; Whittow 1993a). Laysan Albatrosses occur off California primarily in deeper water and well offshore (Stallcup 1990). From 1975–1978, Briggs et al. (1987) observed only seven birds, most of which were recorded over deep water and seaward of the continental shelf. From 1999–2002, we observed only six birds, four individuals and one pair (Figure 1.39). Sightings occurred during January of all years and May of 2001. Two albatross were recorded together during January 2001 and, during May 2001, a third individual was observed on the same transect line <2 km from the pair's location. Sightings occurred in an average of 1,855 meters of water and 72 km from shore.

Black-footed Albatross *Phoebastria nigripes*

Black-footed Albatrosses are the most abundant albatross off the Pacific coast and occur off California in all months of the year (Briggs et al. 1987). They breed on remote beaches in the Hawaiian Archipelago; population numbers were estimated to be 200,000 individuals in the early 1990s (Whittow 1993b). After breeding concludes in June, adults disperse into the North Pacific Ocean and are most abundant off California from June through August (Stallcup 1990, Whittow 1993b). Briggs et al. (1987) observed maximum numbers of birds off southern California during May or June and <25 km from the axis of the Santa Rosa-Cortes Ridge, especially near San

Miguel Island and Tanner and Cortez Banks. From 1999–2002, we observed only eight Black-footed Albatrosses with most occurring in May of 2000 northwest of the SCB (Figure 1.40). On average, sightings occurred <45 km from land (four sightings <20 km from land) and in 1,260 m of water (Figure 1.40).

Western Grebe *Aechmophorus occidentalis* and Clark's Grebe *A. clarkii*

We were unable to distinguish between Western and Clark's Grebes from the air and so combine both species here and refer to them as Western Grebes. Western Grebes breed on lakes from northwestern Canada to northern Baja California, Mexico and east to Minnesota (Storer and Nuechterlein 1992). Along the Pacific coast, Western Grebes winter from southern British Columbia, Canada to southern Baja California and Sinaloa, Mexico (Storer and Nuechterlein 1992). From 1975–1978 in the SCB, Western Grebes were abundant from October through May in the eastern Santa Barbara Channel and rare near the Channel Islands and offshore (Briggs et al. 1987). From 1999–2002, Western Grebes were distributed along mainland and island coasts throughout the entire study area and we consistently observed aggregations of grebes during all survey months near Morro Bay, Point Sal, and Palos Verdes, and from 75 km north of San Diego to the Mexican border (Figure 1.42).

More than 90% of Western Grebes occurred along mainland coasts on coastal transects and at-sea density comparisons were not statistically significant for season ($F_{2,3266} = 0.8$, $P < 0.431$) or subarea ($F_{2,3266} = 1.1$, $P < 0.322$). From 1999–2002, densities of Western Grebes on coastal transects did not differ among seasons ($F_{2,1781} = 0.1$, $P < 0.897$) but did differ among subareas ($F_{4,1781} = 6.1$, $P < 0.001$). Greatest densities occurred along the NMC during January, the SMC during May, and the CMC during September (Tables 1.5 and 1.6).

Excluding one aggregation of 1,000 Western Grebes observed 4 km offshore, >70% of Western Grebes observed on at-sea transects occurred <2 km from shore and, therefore, we did not compare statistically with data from Briggs et al. (1987). Using "along-coast counts" (i.e., by foot), Briggs et al. (1987) estimated 27,000 Western Grebes in the SCB in winter. We estimated an average maximum abundance of 42,000 ± 3,100 Western Grebes in January (Table 1.10). Although comparing different survey techniques has its limitations, our greater estimate is in contrast to various reports of population declines for Western Grebes along the U.S. west coast (Ivey 2004).

Surf Scoter (*Melanitta perspicillata*) and White-winged Scoter (*M. fusca*)

Surf Scoters breed on the west coast of North America from the western Aleutian Islands, Alaska to British Columbia, Canada and at several inland sites to eastern Canada (Savard et al. 1998). Scoters primarily winter from the eastern Aleutian Islands and southeast Alaska to central Baja California, Mexico and in the northern Gulf of California to central Sonora, Mexico (Savard et al. 1998). From 1975–1978, Surf Scoters arrived in the SCB during November and December with maximum abundances from December through March (Briggs et al. 1987). In the winter from 1975–1978, they most often occurred in nearshore waters in the eastern Santa Barbara Channel, along northern shores of the northern Channel Islands, in Santa Monica Bay, and from south of Dana Point to San Diego (Briggs et al. 1987). From 1999–2002, Surf Scoters were recorded in all survey months and consistently observed near San Diego and Morro Bay and in the eastern Santa Barbara Channel (Figure 1.41).

We only observed Surf Scoters (n = 126) on at sea transects in S1 and S3 during January and found no difference in densities between S1 and S3 ($F_{1,1335} = 2.1$, $P < 0.145$). On coastal transects, densities differed among seasons ($F_{2,1789} = 36.9$, $P < 0.001$) and subareas ($F_{4,1789} = 10.5$, $P < 0.001$). Surf Scoters were most abundant in the SCB during January, least abundant during September, and were equally abundant on the NMC and SMC (Tables 1.5 and 1.6).

Because we observed few Surf Scoters on at-sea transects, we did not compare statistically with data from Briggs et al. (1987). In midwinter, Briggs et al. (1987) estimated 9,900 Surf Scoters distributed along the mainland coast of the SCB and 2,000 birds near the Channel Islands. Using coastal transect data, we estimated 13,250 ± 2,650 Surf Scoters from 1999–2002 in the study area during January (Table 1.10).

We identified only three White-winged Scoters during our surveys. Briggs et al. (1987) noted that White-winged Scoters accounted for 5–10% of the total scoters observed south of the northern Channel Islands. It was difficult to distinguish among Surf and White-winged Scoters from the air and so it was impossible to assess changes in abundance or distribution of White-winged Scoters between studies.

Scolopacidae

We observed two species of phalaropes throughout the study area (Figure 1.43). Red (*Phalaropus fulicarius*) and Red-necked Phalaropes (*P. lobatus*) were difficult to distinguish from the air. Consequently, 64% of all phalarope sightings were classified as unidentified phalaropes (Figure 1.44). At-sea densities of phalaropes differed among seasons ($F_{2,4932} = 6.3$, $P < 0.002$) and subareas ($F_{4,4932} = 8.1$, $P < 0.001$). Greatest densities generally occurred during May and in S1 and S2 (Table 1.3). Few phalaropes occurred on coastal transects (Tables 1.5 and 1.6). At-sea densities were greater during 1975–1983 than during 1999–2002 throughout the entire study area ($\chi^2_1 = 104.1$, $P < 0.001$), S3 ($\chi^2_1 = 17.0$, $P < 0.001$), S4 ($\chi^2_1 = 4.3$, $P < 0.040$), and S5 ($\chi^2_1 = 17.8$, $P < 0.001$). At-sea densities did not differ in S1 ($\chi^2_1 = 0.8$, $P < 0.385$) and S2 ($\chi^2_1 = 0.0$, $P < 0.957$). Briggs et al. (1987) noted both species distributed throughout California from the shoreline to hundreds of kilometers from shore and that only Red Phalaropes were likely to be observed >50 km from shore. We also observed phalaropes throughout the SCB and that Red Phalaropes were distributed farther from shore than Red-necked Phalaropes. An estimated 900,000 phalaropes occurred in the SCB in October (Briggs et al. 1987). We estimated an average maximum abundance of 219,000 ± 37,000 birds occur in the SCB during May (Table 1.7). Given the migration patterns and numbers of observed phalaropes, we may not have surveyed during periods of peak abundance.

Red-necked Phalarope (*Phalaropus lobatus*)

Red-necked Phalaropes winter at sea and migrate south to areas in tropical oceans primarily off the coast of Peru and Chile (Rubega et al. 2000). Departure times for the southward migration are protracted and Red-necked Phalaropes appear in the SCB from mid-June to late October and again when returning north from mid April to early June (Lehman 1994).

From 1999–2002, at-sea densities of Red-necked Phalaropes differed among seasons ($F_{2,4940} = 23.9$, $P < 0.001$) and subareas ($F_{4,4940} = 12.4$, $P < 0.001$) with greatest densities during May and in S1 (Table 1.3). We only observed four Red-necked Phalaropes on coastal transects and all occurred on the north side of the northern Channel Islands. Red-necked Phalaropes were distributed throughout the study area during January, aggregated near point Conception during May, and distributed throughout the western portion of the study area during September (Figure 1.45).

At-sea densities of Red-necked Phalaropes were greater from 1999–2002 than from 1975–1983 throughout the entire study area ($\chi^2_1 = 310.3$, $P < 0.001$), S1 ($\chi^2_1 = 367.3$, $P < 0.001$) and S3 ($\chi^2_1 = 18.5$, $P < 0.001$). We did not compare densities in S2, S4, and S5 because of a lack of data. We estimated an average maximum abundance of 67,750 ± 13.900 Red–necked Phalaropes in the study area during May (Table 1.7).

Red Phalarope (*Phalaropus fulicarius*)

Red Phalaropes are almost entirely pelagic outside the breeding season, but may occur on bays and coastal estuaries (Johnsgard 1981). Briggs et al. (1987) noted that Red Phalaropes migrated into the SCB between April and May and migrated out between August and November. From 1999–2002, Red-necked Phalaropes were rare during January, scattered throughout the study area during May, and distributed north of the northern Channel Islands and Point Conception during September (Figure 1.46).

At-sea densities of Red Phalaropes differed among seasons ($F_{2,4932} = 10.5$, $P < 0.001$) and subareas ($F_{4,4940} = 8.5$, $P < 0.001$) and were greatest during May and in S1 (Table 1.3). We observed only two Red Phalaropes on coastal transects.

At-sea densities of Red Phalaropes were greater from 1999–2002 than from 1975–1983 throughout the entire study area ($\chi^2_1 = 25.6$, $P < 0.001$), S1 ($\chi^2_1 = 133.4$, $P < 0.001$), S2 ($\chi^2_1 = 26.8$, $P < 0.001$), and S5 ($\chi^2_1 = 59.5$, $P < 0.001$) but lower in S3 ($\chi^2_1 = 67.0$, $P < 0.001$) and S4 ($\chi^2_1 = 8.0$, $P < 0.005$). We estimated an average maximum abundance of 33,850 ± 3,850 Red Phalaropes in the study area during January (Table 1.7).

DISCUSSION

We observed average densities of 11.3 seabirds/km^2 on at-sea transects and 70.9 seabirds/km^2 on coastal transects. Off California, Briggs et al. (1987) observed densities of 6 seabirds/km^2 in water deeper than 2000 m and 110 seabirds/km^2 over the continental shelf.

For all seabirds combined, greatest at-sea densities occurred in S3 during January and in S1 during May and September. Abundant species in S3 included Western Grebes, California and Western Gulls, and Cassin's Auklets. Abundant species in S1 during May included Sooty Shearwaters, phalaropes, and Cassin's Auklets. During September in S1, Sooty Shearwaters, phalaropes, Common/Arctic Terns, and Pink-footed Shearwaters were the most abundant species.

Coastal densities were greater along mainland coasts than island coasts primarily due to Western Grebes, Sooty Shearwaters, and Surf Scoters and, to a lesser extent, Caspian and Elegant/Royal Terns. Maximum coastal densities occurred when large rafts of Sooty Shearwaters and, to a lesser extent, Western Grebes were encountered.

For all seabirds, greatest coastal densities occurred along the CMC during January and May and the NMC during September (Table 1.5). Along the CMC, Western Grebes, California and Western Gulls, and Surf Scoters were the most abundant species during January and Western Grebes, cormorants, Western Gulls and Brown Pelicans during May. Along the NMC during September, Sooty Shearwaters, Heermann's and Western Gulls, Brown Pelicans, and cormorants were the most abundant species.

SWDI for at-sea and coastal subareas combined was greatest during May (2.10) and lowest during January (1.80) and September (1.86; Table 1.9). At-sea transects had a greater species diversity (2.56) than did coastal transects (1.95). At-sea, S5 had the greatest species diversity (2.30) and S4 had the lowest (1.79). With island transects removed from at-sea subareas, species diversity decreased in S3 (1.92) but increased in S4 (2.4) and S5 (2.35; Table 1.9). Among coastal subareas, the northern Channel Islands had the greatest species diversity (1.75), whereas the southern Channel Islands had the lowest species diversity (1.17). The number of species was greater in January (46) than in May (40) or September (40; Table 1.9).

Although every effort was made to reduce variability between our study and Briggs et al. (1987), some variability could not be avoided. We sampled three months out of the year, whereas Briggs et al. (1987) sampled throughout the year and thus, would have been more likely to sample maximums of abundance. We did not fly exactly the same transect lines as Briggs et al. (1987) and differences may have occurred due to coverage of different areas.

Species that increased from 1975–1983 to 1999–2002 include Ashy Storm-Petrels, Black Storm-Petrels, Brandt's Cormorants, Brown Pelicans, Double-crested Cormorants, Pelagic Cormorants, Red Phalaropes, Red-necked Phalaropes, Sabine's Gulls, Western Gulls, and Xantus's Murrelets. Many of these species breed in the SCB and probably responded positively to reduced DDE concentrations in the SCB since the mid-1970s. Species that decreased from 1975–1983 to 1999–2002 include Black-legged Kittiwakes, Bonaparte's Gulls, Common Loons, Common Murres, Leach's Storm-Petrels, Northern Fulmars, Pacific Loons, Rhinoceros Auklets, and Sooty Shearwaters. Species that showed no clear increase or decrease were Cassin's Auklet, Heermann's Gulls, Pigeon Guillemots, Pink-footed Shearwaters, Surf Scoters, and Western Grebes.

We found Western Grebes to be increasing in number from 1999–2002 compared with 1975–1983 during January, when they were most abundant. Pierson et al. (2000) estimated 21,600 grebes in the northern half of our study area. Their estimate is half of our estimate for the entire study area but they did not survey the southern mainland coast of the SCB where we observed numerous grebes (Table 1.10). In contrast, data for Puget Sound, Washington have indicated declines in Western Grebe numbers (Nysewander et al. 2001).

Our estimate of Surf Scoter numbers was similar to Briggs et al. (1987) and also to Pierson et al. (2000) indicating little change in population numbers recently. This is contrary to observations for Puget Sound, Washington where scoter numbers have declined by 57% from the late 1970s to the 1990s (Nysewander et al. 2001).

Changes in the marine environment, both biological and anthropogenic, probably have affected seabird abundance and distribution in the SCB. The SCB has been referred to as a complex transition zone between cold and warm temperate biotas with colder, upwelled waters north of Point Conception meeting warmer waters of sub-tropical origin south of Point Conception (Horn and Allen 1978, Murray and Littler 1981). Recent studies have indicated a blurring of this line and a recent northward expansion across Point Conception of some marine species from warmer-water masses (Stepien and Rosenblatt 1991, Sagarin et al. 1999) and it is probable that these same factors have affected seabirds. Briggs et al. (1987) began surveys in the SCB at the end of a cold-water period in the California Current. They surveyed north of Point Conception from 1980–1983 after a transition to warmer water had occurred in the California Current, but north of Point Conception, effects of warmer water may not have been great enough to negatively affect seabird abundances. Ainley et al. (1994, 1996) demonstrated an inverse relationship between seabird reproductive success and ocean temperature at the Farallon Islands. Hyrenbach and Veit (2003) indicate that sea surface temperatures continued to increase from 1987–1998 in the SCB and off Point Conception with concomitant shifts in seabird and phytoplankton distribution. El Niños have occurred throughout history but two of the most severe El Niño events (1982–1983 and 1997–1998) have occurred in the last quarter century and have affected seabird reproductive success in the CCS (Ainley and Hunt 1991, Carter et al. 1992). Gill netting, particularly in central California from 1982–1987, reduced abundances of many seabird species, especially Common Murres, but also cormorants, Pigeon Guillemots, and non-nesting species such as loons, grebes, and Sooty Shearwaters (Takekawa et al. 1990, Ainley and Hunt 1991).

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LITERATURE CITED

AINLEY, D. G. 1995. Ashy Storm-Petrel (*Oceanodroma homochroa*). *in* The Birds of North America, Number 185 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

AINLEY, D. G., and G. L. Hunt, Jr. 1991. Status and conservation of seabirds in California. Pages 103–113 *in* Seabird status and conservation: a supplement (J. P. Croxall ed). International Council for Bird Preservation Technical Publication Number 11, Cambridge, UK.

AINLEY, D. G., and R. J. Boekelheide (eds.) 1990. Seabirds of the Farallon Islands: Ecology and dynamics in an upwelling-system community. Stanford University Press, Palo Alto, CA.

AINLEY, D. G., D. N. Nettleship, H. R. Carter, and A. E. Storey. 2002. Common Murre (*Uria aalge*). *in* The Birds of North America, Number 666 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

AINLEY, D. G., G. S. Strong, T. M. Penniman, and R. J. Boekelheide. 1990. The feeding ecology of Farallon seabirds. Pp. 51–127 *in* Seabirds of the Farallon Islands, ecology, dynamics, and structure of an upwelling community. (D.G. Ainley and R.J. Boekelheide, eds.). Stanford University Press, Palo Alto, CA.

AINLEY, D. G., W. G. Sydeman, and J. Norton. 1996. Apex predators indicate interannual negative and positive anomalies in the California Current food web. Marine Ecology Progress Series 137:1–10.

AINLEY, D. G., W. J. Sydeman, S. A. Hatch, and U. W. Wilson. 1994 Seabird population trends along the West Coast of North America; causes and extent of regional concordance. Studies Avian Biology 15:119–133.

AINLEY, D.G. 1976. The occurrence of seabirds in the coastal region of California. Western Birds 7:33-68.

AIRAME, S., J. E. Dugan, K. D. Laferty, H. Leslie, D. A. McArdle, and R. R. Warner. 2003. Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. Ecological Applications 13 (Suppl. 1): S170–S184.

ANDERSON, D. W, D. J. Reish, R. B. Spies, M. E. Brady, and E. W. Segelhorst. 1993. Human impacts. *in* Ecology of the Southern California Bight. Univ. Calif. Press, Berkeley. pp. 682-766.

ANDERSON, D. W. and F. Gress. 1983. Status of a northern population of California Brown Pelicans. Condor 85:79–88.

ANDERSON, D. W. and I. T. Anderson. 1976. Distribution and status of Brown Pelicans in the California current. American Birds 30:3–12.

ANDERSON, D. W., J. R. Jehl, Jr., R. W. Risebrough, L. A. Woods, L. R. DeWeese, and W. G. Edgecomb. 1975. Brown Pelicans: improved reproduction off the southern California coast. Science 190:806–808.

BAIRD, P. H. 1994. Black-legged Kittiwake (*Rissa tridactyla*). *in* The Birds of North America, Number 92 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

BAIRD, P. H. and P. Gould. 1983. The breeding biology and feeding ecology of marine birds in the Gulf of Alaska. USDC, NOAA OCSEAP Final Rep. 45: (1986):121–505.

BirdLife International. 2003. BirdLife's online World Bird Database: the site for bird conservation. Version 2.0. Cambridge, UK: BirdLife International. Available: http://www.birdlife.org (accessed 31/5/2004)

BONNELL, M. L. and R. G. Ford. 2001. Marine mammal and seabird computer database analysis system (CDAS). Prepared by Ecological Consulting Inc., Portland, Oregon, for the Pacific OCS Region, Minerals Management Service. Contract No. 1435-01-97-PO-14206.

BRIGGS, K .T., D. B. Lewis, W. B. Tyler, and G. L. Hunt, Jr. 1981b. Brown Pelicans in southern California: habitat use and environmental fluctuations. Condor 83:1–15.

BRIGGS, K. T, W. B. Tyler, D. G. Lewis, and K. F. Dettman. 1983a. Seabirds of Central and Northern California, 1980-1983: status, abundance, and distribution. Unpublished report. Center for Marine Studies. University of California, Santa Cruz.

BRIGGS, K. T., and E. W. Chu. 1986. Sooty Shearwaters off California: Distribution, abundance, and habitat use. Condor 88:355–364.

BRIGGS, K. T., E. W. Chu, D. B. Lewis, W. B. Tyler, R. L. Pittman, and G. L. Hunt. 1981a. Final Report: Summary of marine mammal and seabird surveys of the Southern California Bight area 1975–1978. Volume III: Investigator's Reports. Part III. Seabirds Book, Chapter I. Distribution, numbers, and seasonal status of seabirds of the Southern California Bight, Unpublished Report, University of California, Institute of Marine Sciences, Santa Cruz, California.

BRIGGS, K. T., W. B. Tyler, D. B. Lewis, P. R. Kelly, and D. A. Croll. 1983b. Brown Pelicans in central and northern California. Journal of Field Ornithology 54:353–373.

BRIGGS, K. T., W. G. Tyler, D. B. Lewis, and D. R. Carlson. 1987. Bird communities at sea off California, 1975–1983. Studies in Avian Biology 11:1–74.

BURGER, J., and M. Gochfeld. 2002. Bonaparte's Gull (*Larus philadelphia*). *in* The Birds of North America, Number 634 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

BURNESS, G. P., K. LeFevre, and C. T. Collins. 1999. Elegant Tern (*Sterna elegans*). *in* The Birds of North America, No. 404 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

CAMPBELL, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall. 1990. The birds of British Columbia. Vol. 2. R. British Columbia Museum, Victoria.

CARTER, H. R. and K. J. Kuletz. 1995. Mortality of Marbled Murrelets due to oil pollution in North America. *in* Ecology and conservation of the Marbled Murrelet (C. J Ralph, G. L. Hunt, M. J. Raphael, J. F. Piatt eds.) Pacific Southwest Research Station. U.S. Dept. of Agric. Tech Rep. PSW-GTR-152, Albany, CA pp. 261-270.

CARTER, H. R., A. R. Sowls, M. S. Rodway, U. W. Wilson, R. W. Lowe, G. J. McChesney, F. Gress, and D. W. Anderson. 1995. Population size, trends, and conservation problems of the Double-crested Cormorant on the Pacific coast of North America. Colonial Waterbirds18 (Special Publication 1):189–215.

CARTER, H. R., D. L. Whitworth, J. Y. Takekawa, T. W. Keeney, and P. R. Kelly. 2000. At-sea threats to Xantus' Murrelets (*Synthliboramphus hypoleucus*) in the Southern California Bight *in* D. R. Brown, K. L. Mitchell, P. R. Kelly (eds.), Proc. 5th California Islands Symp. 29 Mar-1 Apr 1999. U.S. Minerals Mgmt. Serv., Pac. OCS Reg, Camarillo, CA.

CARTER, H. R., G. J. McChesney, D. L. Jaques, C. S. Strong, M. W. Parker, J. E. Takekawa, D. L. Jory and D. L. Whitworth. 1992. Breeding populations of seabirds in California, 1989–1991. Volume 1. Population estimates. U.S. Fish and Wildlife Service, Davis, CA.

CARTER, H. R., U. W. Wilson, R. W. Lowe, M. S. Rodway, D. A. Mauwal, J. E. Takekawa, and J. L. Yee. 2001. Population trends of the Common Murre (*Uria aalge californica*). Pp. 33-85 *in* Biology and conservation of the Common Murre in California, Oregon, Washington, and British Columbia. Volume 1: Natural History and population trends (D. A. Manuwal, H. R. Carter, and T. S. Zimmerman, eds.) U.S. Geological Survey Info. Tech. Report USGS/BRD/ITR-2000-0012. Washington, D. C.

CHELTON, D. B. 1984. Seasonal variability of alongshore-geostrophic velocity off central California. Journal of Geophysical Research 89(C3):3473–3486.

CUTHBERT, F. J. and L. R. Wires. 1999. Caspian Tern (*Sterna caspia*). *in* The Birds of North America, Number 403. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

DAILEY, M. D., J. W. Anderson, D. J. Reish, and D. S. Gorsline. 1993. The Southern California Bight: background and setting. Pp. 1-18 in M. D. Dailey, D. J. Reish, and J. W. Anderson (eds.), Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles.

DAY, R. H., I. J. Stenhouse, and H. G. Gilchrist. 2001. Sabine's Gull (*Xema sabini*). *in* The Birds of North America, Number 634 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

DENNER, W. D., D. R. Sides, J. C. Mueller, L. C. Breaker, and K. T. Briggs. 1988. Final report California seabird ecology study. Volume II. Satellite data analysis. Publication PB89-126692, U.S. Department of Commerce, National Technical Information Service, Springfield, VA.

DROST, C. A. and D. B. Lewis. 1995. Xantus' Murrelet (*Synthliboramphus hypoleucus*) *in* The Birds of North America, Number 164. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

EVERETT, W. T. 1988. Biology of the Black-vented Shearwater. West. Birds 19:89–104.

EVERETT, W. T. and D. W. Anderson. 1991. Status and conservation of the breeding seabirds on offshore Pacific islands of Baja California and the Gulf of California. Pp. 115–140 *in* Seabird status and conservation: a supplement (J. P. Croxall, ed.). Technical Publication Number 11., International Council Bird PreService, Cambridge, U.K.

EVERETT, W. T. and R. L. Pitman. 1993. Status and conservation of shearwaters in the North Pacific, Pp. 93–100. *in* K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey (eds.), The status, ecology, and conservation of marine birds of the North Pacific. Special Publication Canadian Wildlife Service, Ottawa, Canada.

EWINS, P .J. 1993. Pigeon Guillemot (*Cepphus columba*). *in* The Birds of North America, Number 49 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

GASTON, A. J. and I. L. Jones. 1998. The Auks, Alcidae. Oxford University Press, Inc., New York, New York. 349pp.

GASTON, A. J., and S. B. C. Dechesne. 1996. Rhinoceros Auklet (*Cerorhinca monocerata*). *in* The Birds of North America, Number 212 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

GILL, R. E. and L. R. Mewaldt. 1983. Pacific coast Caspian Terns – dynamics of an expanding population. Auk 100 (2): 369-381.

GRESS, F. 1992. Nesting survey of Brown Pelicans on West Anacapa Island, 1991. Unpubl. Rep, Dept. Wildlife and Fisheries Biology, Univ. of California Davis and California Institute of Environmental Studies, Davis, California.

GRESS, F. and D. W. Anderson. 1983. The California Brown Pelican recovery plan. U.S. Fish and Wildlife Service, Portland, OR.

GRESS, F. and D.B. Lewis. 1988. Reproductive success of brown pelicans in the Southern California Bight, 1987. Calif. Dep. of Fish and Game, Nongame Bird and Mammal Sec. Rep., Proj. EW86, Job I-1. 22pp.

GRESS, F., D. W. Anderson, T. Ingram, and H. R. Carter. 1995. Reproductive performance and breeding population size of Brown Pelicans and Double-crested Cormorants in the Southern California Bight, 1990–1994. Unpublished Rep., California Department of Fish and Game, Sacramento, California.

GRESS, F., R. W. Risebrough, D. W. Anderson, L. F. Kiff, and J. R. Jehl, Jr. 1973. Reproductive failures of Double-crested Cormorants in southern California and Baja California. Wilson Bulletin 85:197–208.

GUICKING, D., D. Ristow, P. H. Becker, R. Schlatter, P. Berthold, and U. Querner. 2001. Satellite tracking of the Pink-footed Shearwater in Chile. Waterbirds 24(1):8–15.

HARMS, S. and C. D. Winant. 1998. Characteristic patterns of the circulation in the Santa Barbara Channel. Journal of Geophysical Research 103(C2):3041–3065.

HARRISON, P. 1983. Seabirds: an identification guide. Houghton Mifflin Co., Boston. 448 pp.

HATCH, S. A. and D. N. Nettleship. 1998. Northern Fulmar (*Fulmarus glacialis*) *in* The Birds of North America, Number 361 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

HATCH, S. A. and D. V. Weseloh. 1999. Double-crested Cormorant (*Phalacrocorax auritus*) 1999. *in* The Birds of North America, Number 441 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

HICKEY, B. M. 1993. Physical oceanography. Pages 19-70 in M. D. Dailey, D. J. Reish, and J. W. Anderson (eds.), Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles.

HOBSON, K. A. 1997. Pelagic Cormorant (*Phalacrocorax pelagicus*) *in* The Birds of North America, Number 282 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

HORN, M. H. and L. G. Allen. 1978. A distributional analysis of California coastal marine fishes. Journal of Biogeography 5:23–42.

HOWELL, A. B. 1917. Birds of the islands off the coast of southern California. Pac. Coast Avifauna 12:1–127.

HOWELL, N. G. and S. Webb. 1995. A guide to the birds of Mexico and northern Central America. Oxford University Press, New York.

HUNT, G. L., Jr., R. L. Pitman, M. Naughton, K. Winnet, A. Newman, P. R. Kelly, K. T. Briggs. 1979. Distribution, status, reproductive ecology, and foraging habits of breeding seabirds. *in* Summary of marine mammal and seabird surveys of the southern California Bight area, 1975–1978. U.S. Department of Interior, Bureau of Land Mgmt. Los Angeles, CA.

HUNT, G. L., R. L. Pitman, and H. L. Jones. 1980. Distribution and abundance of seabirds breeding on the California Channel Islands. Pp. 443–459 *in* The California Islands: proceedings of a multidisciplinary symposium (D. M. Power ed.). Santa Barbara Museum Natural History, Santa Barbara, CA.

HUNTINGTON, C. E., R. G. Butler, and R. A. Mauck. 1996. Leach's Storm-Petrel (*Oceanodroma leucorhoa*). *in* The Birds of North America, Number 233 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

HYRENBACH, K. D. and R. R. Veit. 2003. Ocean warming and seabird communities of the southern California Current System (1987-1998): response at multiple temporal scales. Deep Sea Research II 50:2537–2565.

IVEY, G.L. 2004. Conservation assessment and management plan for breeding Western and Clark's Grebes in California. Unpubl. Rep. to the American Trader Trustee Council (U.S.

Fish and Wildlife Service, California Dept. of Fish and Game, and National Oceanic and Atmospheric Administration). Portland, OR, 80 pp.

JAQUES, D. L. 1994. Range expansion and roosting ecology of non-breeding California Brown Pelicans. Unpublished Master's thesis, University of Calif., Davis, California.

JAQUES, D. L., C. S. Strong, and T. W. Keeney. 1996. Brown Pelican roosting patterns and response to disturbance at Mugu Lagoon and other nonbreeding sites in the Southern California Bight. National Biological Service, Technical Report Number 54, Tuscon, Arizona.

JEHL, J. R., Jr., 1973. Studies of a declining population of Brown Pelicans in northwestern Baja California. Condor 75:69–79.

JEHL, J. R., Jr., and S. I. Bond. 1975. Morphological variation and species limits of the genus *Endomychura*. Transactions of the San Diego Society of Natural History 18:9–24.

JOHNSGARD, P. A. 1981. The plovers, sandpipers, and snipes of the world. University of Nebraska Press. Pp. 301–304.

KEITH, J. O., L. A. Woods, Jr., and E. G. Hunt. 1971. Reproductive failure in Brown Pelicans on the Pacific coast. Transactions of the North America Wildlife and Natural Resources Conference 35:56–63.

KEITT, B. S., B. R. Terschy, and D. A. Croll. 2000. Black-vented Shearwater (*Puffinus opisthomelas*). *in* The Birds of North America, Number 521 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

KREBS, C. J. 1989. Ecological Methodology. Harper-Collins Publishers, New York, NY.

LYNN, R. J. and J. J. Simpson. 1987. The California Current system: The seasonal variability of its physical characteristics. Journal of Geophysical Research 92(C12):12947–12966.

MANTUA, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis, 1997: A Pacific decadal climate oscillation with impacts on salmon. Bulletin of the American Meteorological Society, Volume 78, pp 1069–1079.

MANUWAL, D. A. and A. C. Thoresen. 1993. Cassin's Auklet (*Ptychoramphus aleuticus*). *in* The Birds of North America, Number 50 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

MCCHESNEY, G. J., F. Gress, H. R. Carter, and D. L. Whitworth. 2000. Nesting habitat assessment for Xantus' Murrelet and other crevice-nesting seabirds at Anacapa Island, California, in 1997. Unpublished Report, U.S. Geological Survey, Western Ecological Research Center, Dixon, California; and Department of Wildlife, Humboldt State University, Arcata, California

MCCULLAGH, P. and J.A. Nelder. 1989. Generalized Linear Models, 2nd Edition. Chapman and Hall, London. 532 pp.

McGowan, J. A., D. R. Cayan, and L. M. Dorman. 1998. Climate-ocean variability and ecosystem response in the northeast Pacific. Science 281: 210-217.

McIntyre, J. W. and J. F. Barr. 1997. Common Loon (*Gavia immer*). *in* The Birds of North America, Number 313 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

Minobe, S. 1997: A 50–70 year climatic oscillation over the North Pacific and North America. Geophysical Research Letters, Vol 24, pp 683–686.

Murray, K. G., K. Winnett-Murray, Z. A. Eppley, G. L. Hunt, Jr., and D. B. Schwartz. 1983. Breeding biology of the Xantus' Murrelet. Condor 85:12–21.

Murray, S. N. and M. M. Littler. 1981. Biogeographical analysis of intertidal macrophyte floras of southern California. Journal Biogeography 8:339–351.

Nysewander, D. R., J. R. Evenson, B. L. Murphie, and T. A. Cyra. 2001. Report of marine bird and marine mammal component, Puget Sound Ambient Monitoring Program for July 1992 to December 1999 period. Agency Report, Washington Department of Fish and Wildlife, Olympia, WA, 161 pp.

Oedekoven, C. S., D. G. Ainley, and L. Spear. 2001. Variable responses of seabirds to change in marine climate: California Current, 1985-1994. Marine Ecology Progress Series 212: 265–281.

Page, G. W., H. R. Carter and R. G. Ford. 1990. Numbers of seabirds killed or debilitated in the 1986 *Apex Houston* oil spill in central California. Pages 164–174 *in* Sealy, S. G. (ed.), Auks at Sea. Studies in Avian Biology Number 14.

Penniman, T. M., M. C. Coulter, L. B. Spear, and R. J. Boekelheide. 1990. Western Gull. Pp. 218–244 *in* Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling community (D.G. Ainley and R.J. Boekelheide, eds.). Stanford University Press, Palo Alto, CA.

Peterson, W.T. and F. B. Schwing. 2003. A new climate regime in northeast Pacific ecosystems. Geophysical Research Letters 30(17), 1896, doi.10.1029/2003GL017528.

Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. Nysewander. 1990. Immediate impact of the *Exxon Valdez* oil spill on marine birds. Auk 107:387–397.

Pierotti, R. J. and C. A. Annett. 1995. Western Gull (*Larus occidentalis*). *in* The Birds of North America, Number 174 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

Pierson, M. O., M. D. McCrary, and M.L. Bonnell. 2000. Seasonal abundance of coastal seabirds offshore Santa Barbara and Ventura Counties, California. *in* Proceedings of the Fifth

California Islands Symposium (D. R. Browne, K. L. Mitchell, and H. W. Chaney, eds.) Santa Barbara Museum of Natural History. Minerals Management Service, Camarillo, CA.

PITMAN, R. L. and S. M. Speich. 1976. Black storm-petrel breeds in the United States. Western Birds 7:71.

REMSEN, J. V., Jr. 1978. Bird species of special concern in California: An annotated list of declining or vulnerable bird species. California Department of Fish and Game Nongame Wildlife Investigations, Wildlife Management Branch Administrative Rep. Number 78–1.

RISEBROUGH, R. W. 1972. Effects of environmental pollutants upon animals other than man. Proc. Berkeley Symposium on Math Statist. and Prob. 6:443–463.

ROEMMICH, D. 1992. Ocean warming and sea level rise along the southwest U.S. coast. Science 257: 373–375.

RUBEGA, M. A., D. Schamel, and D. M. Tracy. 2000. Red-necked Phalarope (*Phalaropus lobatus*). *in* The Birds of North America, Number 538 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

RUSSELL, R. W. 2002. Pacific Loon (*Gavia pacifica*). *in* The Birds of North America, Number 657 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

SAGARIN, R. D., J. P. Barry, S. E. Gilman, and C. H. Baxter. 1999. Climate-related change in an intertidal community over short and long time scales. Ecological Monographs 69, 4:465–490.

SAVARD, J. L., D. Bordage, and A Reed. 1998. Surf Scoter (*Melanitta perspicillata*). *in* The Birds of North America, Number 363 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, D. C.

SCHIFF, K.C. 2000. Sediment chemistry on the mainland shelf of the Southern California Bight. Marine Pollution Bulletin 40(3): 268-276.

SOWLS, A. L., A. R. DeGange, J. W. Nelson, and G. S. Lester. 1980. Catalog of California seabird colonies. U.S. Department of Interior, Fish Wildlife Service, Biological Service Program, FWS/OBS 37/80.

SPEAR, L. B., and D. G. Ainley. 1997. Flight speed of seabirds in relation to wind speed and direction. Ibis 139(2): 234-251.

SPEAR, L. B., and D. G. Ainley. 1999. Migration routes of Sooty Shearwaters in the Pacific Ocean. Condor 101; 205–218.

SPEICH, S. M. and T. R. Wahl. 1989. Catalog of Washington seabird colonies. U.S. Fish and Wildlife Service Biological Rep. 88(6).

STALLCUP, R. 1990. Ocean birds of the nearshore Pacific. Point Reyes Bird Observatory. Stinson, Beach, CA

STENZEL, L. E., G. W. Page, H. R. Carter, and D. G. Ainley. 1988. Seabird mortality in California as witnessed through 14 years of beached bird censuses. Point Reyes Bird Observatory, Stinson Beach, California.

STEPIEN, C. A. and R. H. Rosenblatt. 1991. Patterns of gene flow and genetic-divergence in the northeastern Pacific clinidae, based on allozyme and morphological data. Copeia 1, 4:873–896.

STORER, R. W. and G. L. Nuechterlein. 1992. Western and Clark's Grebe *in* The Birds of North America, Number 26 (A. Poole, P. Stettenheim, and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

TAKEKAWA, J. E., H. R. Carter, and T. E. Harvey. 1990. Decline of the Common Murre in central California, 1980–1986. Studies in Avian Biology 14:149–163.

U.S. CENSUS BUREAU. 2004. [Internet]. State and County Quickfacts. [cited 2003August 12]. Available from http://quickfacts.census.gov/qfd/states/06000.html.

U.S. FISH AND WILDLIFE SERVICE. 2002. Birds of conservation concern 2002. Division of Migratory Bird Management, Arlington, Virginia. 99 pp.

U.S. FISH AND WILDLIFE SERVICE. 2004. DRAFT Regional Seabird Conservation Plan, U.S. Fish and Wildlife Service, Pacific Region. U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, Pacific Region, Portland, OR.

VEIT, R. R., J. A. McGowan, D. G. Ainley, T. R. Wahl, and P. Pyle. 1997. Apex marine predator declines ninety percent in association with changing oceanic climate. Global Change Biology 3:23–28.

VEIT, R. R., P. Pyle, and J. A. McGowan. 1996. Ocean warming and long-term change in pelagic bird abundance within the California current system. Marine Ecology Progress Series 139:11–18.

VELARDE, E. 1999. Breeding biology of Heermann's Gulls on Isla Rasa, Gulf of California, Mexico. Auk 116(2):513–519.

WALLACE, E. A. H. and G. E. Wallace. 1998. Brandt's Cormorant (*Phalacrocorax penicillatus*). *in* The Birds of North America, Number 362 (A. Poole, P. Stettenheim, and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

WARHAM, J. 1996. The behavior, population biology and physiology of the petrels. Academic Press, New York, NY.

WHITTOW, G. C. 1993a. Laysan Albatross (*Diomedea immutabilis*) *in* The Birds of North America, Number 66 (A. Poole, P. Stettenheim, and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

WHITTOW, G. C. 1993b. Black-footed Albatross (*Diomedea immutabilis*) *in* The Birds of North America, Number 65 (A. Poole, P. Stettenheim, and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

WILBUR, S. R. 1987. Birds of Baja California. University of California Press, Berkeley, CA. 253 pp.

WINKLER, D.W. 1996. California Gull (*Larus californicus*) *in* The Birds of North America, Number 259 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D. C.

WRIGHT, H. and G. Snyder. 1913. Birds observed in the summer of 1912 among the Santa Barbara Islands. Condor 15:86–92.

Table 1.1. Dates of aerial survey flights in southern California from 1999-2002.

1999	2000	2001	2002
	7-Jan-2000	6-Jan-2001	7-Jan-2002
	8-Jan-2000	7-Jan-2001	8-Jan-2002
	9-Jan-2000	10-Jan-2001	9-Jan-2002
	13-Jan-2000	12-Jan-2001	10-Jan-2002
	14-Jan-2000	13-Jan-2001	11-Jan-2002
	18-Jan-2000	14-Jan-2001	12-Jan-2002
	19-Jan-2000	15-Jan-2001	17-Jan-2002
	21-Jan-2000	22-Jan-2001	18-Jan-2002
	22-Jan-2000	23-Jan-2001	19-Jan-2002
	23-Jan-2000	24-Jan-2001	20-Jan-2002
	20-Apr-2000	25-Jan-2001	
8-May-1999	6-May-2000	6-May-2001	
9-May-1999	7-May-2000	7-May-2001	
10-May-1999	8-May-2000	8-May-2001	
11-May-1999	9-May-2000	9-May-2001	
13-May-1999	10-May-2000	10-May-2001	
14-May-1999	12-May-2000	11-May-2001	
15-May-1999	13-May-2000	12-May-2001	
23-May-1999	14-May-2000	13-May-2001	
24-May-1999	15-May-2000	15-May-2001	
25-May-1999	16-May-2000	16-May-2001	
	17-May-2000	17-May-2001	
		18-May-2001	
10-Sep-1999	6-Sep-2000	5-Sep-2001	
11-Sep-1999	7-Sep-2000	6-Sep-2001	
12-Sep-1999	8-Sep-2000	7-Sep-2001	
20-Sep-1999	9-Sep-2000	8-Sep-2001	
21-Sep-1999	10-Sep-2000	17-Sep-2001	
22-Sep-1999	14-Sep-2000	18-Sep-2001	
23-Sep-1999	15-Sep-2000	22-Sep-2001	
28-Sep-1999	20-Sep-2000	23-Sep-2001	
29-Sep-1999	21-Sep-2000	24-Sep-2001	
30-Sep-1999	22-Sep-2000	25-Sep-2001	
	28-Sep-2000		

Table 1.2. Total counts of seabirds on at-sea and coastal transects during January, May, and September from 1999–2002.

Species	At-sea and Coastal			At-sea			Coastal		
	January	May	September	January	May	September	January	May	September
All Seabirds	**64,427**	**28,456**	**34,695**	**12,426**	**10,953**	**10,142**	**52,001**	**17,503**	**24,553**
Loons	**2,852**	**383**	**14**	**501**	**74**	**2**	**2,351**	**309**	**12**
Common	88	35	1	21	1	0	67	34	1
Pacific	1,070	309	1	315	62	0	755	247	1
Red-throated	61	1	0	2	0	0	59	1	0
Grebes	**18,619**	**9,094**	**2,690**	**2,592**	**120**	**32**	**16,027**	**8,974**	**2,658**
Horned	2	0	0	0	0	0	2	0	0
Pied-billed	0	1	0	0	0	0	0	1	0
Western	18,478	9,090	2,684	2,592	120	32	15,886	8,970	2,652
Albatrosses	**6**	**4**	**1**	**6**	**4**	**1**	**0**	**0**	**0**
Black-footed	3	4	1	3	4	1	0	0	0
Laysan	3	0	0	3	0	0	0	0	0
Shearwaters & Fulmars	**509**	**4,894**	**12,203**	**501**	**4,835**	**3,968**	**8**	**59**	**8,235**
Buller's Shearwater	1	0	74	1	0	74	0	0	0
Black-vented Shearwater	171	1	66	171	1	64	0	0	2
Northern Fulmar	216	53	11	214	51	11	2	2	0
Pink-footed Shearwater	22	84	839	22	83	833	0	1	6
Sooty Shearwater	41	4,691	10,606	35	4,651	2,429	6	40	8,177
Storm-Petrels	**74**	**216**	**237**	**74**	**216**	**236**	**0**	**0**	**1**
Ashy	37	99	116	37	99	116	0	0	0
Black	2	42	29	2	42	28	0	0	1
Leach's	8	50	67	8	50	67	0	0	0
Tropicbirds	**0**	**0**	**7**	**0**	**0**	**7**	**0**	**0**	**0**
Red-billed	0	0	3	0	0	3	0	0	0
Pelicans	**728**	**858**	**2,434**	**153**	**77**	**847**	**575**	**781**	**1,587**
Brown	728	858	2,434	153	77	847	575	781	1,587
Cormorants	**1,855**	**1,860**	**1,776**	**189**	**142**	**161**	**1,666**	**1,718**	**1,615**
Brandt's	810	812	654	73	105	107	737	707	547
Double-crested	260	150	187	51	12	14	209	138	173
Pelagic	76	51	3	2	6	1	74	45	2
Sea Ducks	**5,248**	**1,041**	**41**	**125**	**2**	**0**	**5,123**	**1,039**	**41**
Brant	10	23	0	0	1	0	10	22	0
Red-breasted Merganser	21	0	0	0	0	0	21	0	0
Surf Scoter	5,177	1,018	41	125	1	0	5,052	1,017	41
White-winged Scoter	5	0	0	0	0	0	5	0	0
Larids	**31,101**	**6,002**	**13,441**	**5,119**	**1,554**	**3,130**	**25,982**	**4,448**	**10,311**
Gulls	**30,664**	**5,343**	**11,579**	**5,064**	**1,385**	**2,545**	**25,600**	**3,958**	**9,034**
Black-legged Kittiwake	451	4	0	436	4	0	15	0	0
Bonaparte's	197	107	0	102	36	0	95	71	0
California	19,977	285	354	2,926	153	14	17,051	132	340
Glaucous	1	0	0	1	0	0	0	0	0
Glaucous-winged	29	3	6	6	1	1	23	2	5
Heermann's	1,037	20	1,574	240	0	73	797	20	1,501
Herring	10	0	2	2	0	0	8	0	2
Mew	16	0	0	0	0	0	16	0	0
Ring-billed	71	0	1	4	0	0	67	0	1
Sabine's	0	121	112	0	121	112	0	0	0
Western	7,658	4,555	8,966	1,086	1,016	2,172	6,572	3,539	6,794
Terns	**401**	**636**	**1,718**	**19**	**147**	**447**	**382**	**489**	**1,271**
Caspian	21	92	201	6	8	2	15	84	199
Comon/Arctic	3	60	361	3	59	361	0	1	0
Elegant	3	107	239	0	7	15	3	100	224
Elegant/Royal	283	143	825	6	27	40	277	116	785
Forster's	44	85	33	0	10	8	44	75	25
Least	0	90	2	0	19	0	0	71	2
Royal	34	0	22	2	0	5	32	0	17
Jaegers & Skuas	**35**	**21**	**141**	**35**	**20**	**135**	**0**	**1**	**6**
Long-tailed Jaeger	0	1	0	0	0	0	0	1	0
Parasitic Jaegar	2	0	10	2	0	6	0	0	4
Pomarine Jaeger	20	12	57	20	12	56	0	0	1
South Polar Skua	1	2	3	1	2	3	0	0	0
Alcids	**2,379**	**1,236**	**221**	**2,315**	**1,115**	**210**	**64**	**121**	**11**
Cassin's Auklet	1,500	885	63	1,465	880	63	35	5	0
Common Murre	145	20	67	134	20	67	11	0	0
Pigeon Guillemots	2	122	8	0	7	0	2	115	8
Rhinoceros Auklet	591	20	8	583	19	8	8	1	0
Xantus' Murrelet	8	177	5	8	177	5	0	0	0
Phalaropes	**800**	**2,807**	**1,553**	**792**	**2,789**	**1,528**	**8**	**18**	**25**
Red	433	236	155	432	236	154	1	0	1
Red-necked	19	860	149	19	859	146	0	1	3

Table 1.3. Densities (birds/km^2 ± SE) of seabirds within at-sea subareas in the study area during January, May, and September from 1999–2002.

Species	At-Sea Subareas within the study area														
	S1 (North)			S2 (West-Central)			S3 (Central)			S4 (South-East)			S5 (South)		
	January	May	September	January	May	September	January	May	September	January	May	September	January	May	September
All Seabirds	**9.57±1.09**	**22.75±5.76**	**19.37±3.71**	**9.52±2.14**	**4.37±0.81**	**7.21±2.04**	**23.69±5.97**	**20.78±3.56**	**17.87±7.91**	**9.81±1.74**	**5.92±1.20**	**4.57±0.69**	**5.12±0.38**	**5.26±1.47**	**2.53±0.29**
Loons	**0.24±0.07**	**0.38±0.22**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**1.45±0.52**	**0.14±0.06**	**0.00±0.00**	**0.18±0.09**	**0.00±0.00**	**0.00±0.00**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**
Common	0.05±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pacific	0.14±0.06	0.38±0.22	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.88±0.37	0.09±0.04	0.00±0.00	0.17±0.09	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Red-throated	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Grebes	**0.11±0.06**	**0.03±0.02**	**0.08±0.05**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**8.70±4.91**	**0.30±0.12**	**0.06±0.05**	**0.13±0.08**	**0.16±0.12**	**0.02±0.02**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Horned	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pied-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	0.11±0.06	0.03±0.02	0.08±0.05	0.00±0.00	0.00±0.00	0.00±0.00	8.70±4.91	0.30±0.12	0.06±0.05	0.13±0.08	0.16±0.12	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00
Albatrosses	**0.02±0.01**	**0.03±0.02**	**0.00±0.00**	**0.04±0.03**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Black-footed	0.02±0.01	0.03±0.02	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Laysan	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Shearwaters & Fulmars	**0.26±0.06**	**8.56±4.26**	**11.06±3.49**	**0.35±0.08**	**0.56±0.13**	**0.27±0.11**	**0.59±0.19**	**9.99±2.38**	**6.65±3.00**	**0.81±0.51**	**2.29±0.33**	**1.79±0.48**	**0.33±0.05**	**2.96±1.45**	**0.36±0.10**
Buller's Shearwater	0.00±0.00	0.00±0.00	0.04±0.02	0.00±0.00	0.00±0.00	0.09±0.05	0.00±0.00	0.00±0.00	0.05±0.01	0.00±0.00	0.00±0.00	0.07±0.06	0.00±0.00	0.00±0.00	0.11±0.06
Black-vented Shearwater	0.02±0.01	0.00±0.00	0.14±0.14	0.00±0.00	0.00±0.00	0.00±0.00	0.08±0.04	0.00±0.00	0.14±0.07	0.63±0.51	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.01±0.01
Northern Fulmar	0.18±0.05	0.13±0.04	0.01±0.01	0.31±0.08	0.10±0.05	0.00±0.00	0.25±0.07	0.05±0.01	0.02±0.01	0.09±0.02	0.00±0.00	0.01±0.01	0.29±0.05	0.05±0.02	0.01±0.01
Pink-footed Shearwater	0.03±0.01	0.07±0.03	1.06±0.42	0.04±0.02	0.09±0.03	0.10±0.07	0.03±0.02	0.11±0.03	1.11±0.61	0.01±0.01	0.12±0.03	1.34±0.44	0.01±0.01	0.04±0.01	0.10±0.03
Sooty Shearwater	0.03±0.01	8.35±4.26	9.78±3.37	0.00±0.00	0.37±0.12	0.08±0.04	0.05±0.02	9.81±2.37	3.34±1.84	0.05±0.02	2.02±0.32	0.36±0.12	0.02±0.01	2.85±1.45	0.13±0.07
Storm-Petrels	**0.05±0.03**	**0.06±0.02**	**0.28±0.13**	**0.00±0.00**	**0.32±0.09**	**0.24±0.07**	**0.00±0.00**	**0.04±0.01**	**0.19±0.05**	**0.02±0.01**	**0.08±0.03**	**0.18±0.08**	**0.26±0.06**	**0.55±0.08**	**0.29±0.04**
Ashy	0.03±0.02	0.05±0.02	0.20±0.13	0.00±0.00	0.22±0.08	0.12±0.05	0.00±0.00	0.02±0.01	0.09±0.03	0.00±0.00	0.01±0.01	0.10±0.05	0.14±0.04	0.24±0.06	0.09±0.02
Black	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.02±0.01	0.03±0.02	0.00±0.00	0.07±0.02	0.04±0.02	0.01±0.01	0.08±0.02	0.02±0.01
Leach's	0.00±0.00	0.00±0.00	0.06±0.02	0.00±0.00	0.10±0.03	0.07±0.03	0.00±0.00	0.00±0.00	0.03±0.02	0.00±0.00	0.00±0.00	0.02±0.01	0.03±0.01	0.15±0.03	0.16±0.03
Tropicbirds	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.03±0.01**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Red-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Pelicans	**0.33±0.13**	**0.03±0.03**	**0.01±0.01**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**	**0.24±0.05**	**0.18±0.04**	**2.96±2.28**	**0.16±0.06**	**0.11±0.03**	**0.08±0.03**	**0.00±0.00**	**0.00±0.00**	**0.01±0.01**
Brown	0.33±0.13	0.03±0.03	0.01±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.24±0.05	0.18±0.04	2.96±2.28	0.16±0.06	0.11±0.03	0.08±0.03	0.00±0.00	0.00±0.00	0.01±0.01
Cormorants	**0.57±0.37**	**0.04±0.02**	**0.09±0.04**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.29±0.06**	**0.30±0.07**	**0.32±0.11**	**0.05±0.03**	**0.02±0.01**	**0.02±0.01**	**0.08±0.03**	**0.21±0.07**	**0.20±0.10**
Brandt's	0.08±0.05	0.01±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.14±0.03	0.21±0.05	0.21±0.10	0.03±0.02	0.01±0.01	0.01±0.01	0.05±0.02	0.19±0.07	0.16±0.10
Double-crested	0.32±0.30	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.03±0.02	0.04±0.01	0.00±0.00	0.01±0.01	0.00±0.00	0.01±0.01	0.01±0.01	0.01±0.01
Pelagic	0.00±0.00	0.01±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Sea Ducks	**0.10±0.06**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.38±0.14**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Brant	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Red-breasted Merganser	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Surf Scoter	0.10±0.06	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.38±0.14	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
White-winged Scoter	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Larids	**2.70±0.37**	**2.29±0.59**	**2.82±0.65**	**1.00±0.15**	**0.73±0.22**	**1.01±0.20**	**9.02±2.26**	**2.56±0.54**	**6.83±2.93**	**6.94±1.59**	**1.61±0.51**	**1.78±0.35**	**1.87±0.23**	**0.68±0.14**	**1.13±0.19**
Gulls	**2.67±0.37**	**2.10±0.58**	**1.24±0.23**	**0.98±0.15**	**0.52±0.15**	**0.24±0.07**	**8.96±2.26**	**2.42±0.54**	**6.48±2.92**	**6.87±1.59**	**1.35±0.51**	**1.38±0.33**	**1.80±0.22**	**0.58±0.13**	**0.76±0.18**
Black-legged Kittiwake	0.48±0.13	0.04±0.04	0.00±0.00	0.58±0.12	0.00±0.00	0.00±0.00	0.36±0.08	0.00±0.00	0.00±0.00	0.35±0.15	0.00±0.00	0.00±0.00	0.59±0.08	0.00±0.00	0.00±0.00
Bonaparte's	0.01±0.01	0.02±0.01	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.23±0.07	0.10±0.06	0.00±0.00	0.19±0.15	0.03±0.01	0.00±0.00
California	1.30±0.26	0.38±0.22	0.01±0.01	0.16±0.07	0.00±0.00	0.00±0.00	5.47±2.17	0.09±0.03	0.03±0.01	4.66±1.53	0.36±0.35	0.01±0.01	0.30±0.06	0.00±0.00	0.01±0.01
Glaucous	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Glaucous-winged	0.02±0.01	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Heermann's	0.11±0.05	0.00±0.00	0.09±0.04	0.00±0.00	0.00±0.00	0.00±0.00	0.72±0.27	0.00±0.00	0.13±0.04	0.06±0.03	0.00±0.00	0.06±0.02	0.01±0.01	0.00±0.00	0.04±0.04
Herring	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Mew	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Ring-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Sabine's	0.00±0.00	0.53±0.13	0.54±0.17	0.00±0.00	0.30±0.13	0.15±0.06	0.00±0.00	0.05±0.02	0.03±0.02	0.00±0.00	0.04±0.03	0.01±0.01	0.00±0.00	0.05±0.02	0.05±0.02
Western	0.53±0.13	0.96±0.51	0.54±0.12	0.14±0.06	0.20±0.06	0.06±0.03	2.11±0.27	2.20±0.54	5.83±2.68	1.08±0.15	0.82±0.19	1.20±0.32	0.57±0.10	0.48±0.13	0.64±0.17
Terns	**0.00±0.00**	**0.12±0.05**	**1.44±0.60**	**0.00±0.00**	**0.21±0.12**	**0.50±0.13**	**0.03±0.01**	**0.12±0.05**	**0.23±0.07**	**0.03±0.01**	**0.25±0.05**	**0.23±0.05**	**0.01±0.01**	**0.07±0.03**	**0.29±0.06**
Caspian	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	0.01±0.01	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Comon/Arctic	0.00±0.00	0.08±0.04	1.34±0.60	0.00±0.00	0.21±0.12	0.50±0.13	0.00±0.00	0.02±0.01	0.09±0.03	0.00±0.00	0.02±0.01	0.11±0.03	0.01±0.01	0.07±0.03	0.29±0.06
Elegant	0.00±0.00	0.00±0.00	0.07±0.07	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.02±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Elegant/Royal	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.05±0.04	0.06±0.04	0.01±0.01	0.05±0.02	0.07±0.03	0.00±0.00	0.00±0.00	0.00±0.00
Forster's	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.03±0.02	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Least	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.06±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Royal	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00
Jaegers & Skuas	**0.03±0.02**	**0.07±0.03**	**0.14±0.03**	**0.01±0.01**	**0.00±0.00**	**0.27±0.10**	**0.03±0.01**	**0.02±0.01**	**0.11±0.02**	**0.04±0.01**	**0.02±0.01**	**0.16±0.03**	**0.05±0.02**	**0.02±0.01**	**0.08±0.02**
Long-tailed Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Parasitic Jaegar	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Pomarine Jaeger	0.03±0.02	0.02±0.01	0.03±0.01	0.01±0.01	0.00±0.00	0.07±0.03	0.02±0.01	0.00±0.00	0.04±0.01	0.02±0.01	0.02±0.01	0.08±0.03	0.02±0.01	0.02±0.01	0.05±0.02
South Polar Skua	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Alcids	**3.97±0.62**	**1.70±0.76**	**0.94±0.20**	**6.99±2.15**	**0.13±0.05**	**0.11±0.07**	**2.31±0.31**	**3.13±1.63**	**0.20±0.07**	**1.02±0.15**	**0.27±0.15**	**0.02±0.01**	**1.42±0.16**	**0.23±0.05**	**0.03±0.01**
Cassin's Auklet	1.62±0.30	1.46±0.69	0.23±0.09	6.59±2.14	0.10±0.04	0.03±0.03	1.66±0.29	2.75±1.62	0.09±0.04	0.24±0.07	0.05±0.03	0.01±0.01	0.84±0.13	0.02±0.01	0.00±0.00
Common Murre	0.75±0.35	0.01±0.01	0.48±0.16	0.00±0.00	0.00±0.00	0.00±0.00	0.08±0.03	0.07±0.04	0.00±0.00	0.05±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pigeon Guillemots	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Rhinoceros Auklet	1.47±0.29	0.06±0.04	0.04±0.03	0.16±0.05	0.01±0.01	0.00±0.00	0.46±0.07	0.04±0.02	0.01±0.01	0.60±0.13	0.00±0.00	0.00±0.00	0.43±0.08	0.01±0.01	0.00±0.00
Xantus' Murrelet	0.00±0.00	0.16±0.07	0.04±0.04	0.07±0.03	0.03±0.02	0.00±0.00	0.01±0.01	0.22±0.05	0.00±0.00	0.00±0.00	0.22±0.13	0.00±0.00	0.00±0.00	0.18±0.05	0.00±0.00
Phalaropes	**1.20±0.25**	**9.60±2.80**	**4.03±0.99**	**1.10±0.22**	**2.61±0.73**	**5.57±1.94**	**0.57±0.16**	**4.10±1.05**	**0.65±0.16**	**0.45±0.10**	**1.33±1.00**	**0.65±0.29**	**1.13±0.22**	**0.61±0.11**	**0.47±0.08**
Red	0.46±0.11	1.85±1.60	0.41±0.21	0.72±0.19	0.13±0.07	0.17±0.05	0.27±0.10	0.11±0.07	0.03±0.02	0.33±0.09	0.01±0.01	0.02±0.01	0.66±0.14	0.02±0.01	0.26±0.06
Red-necked	0.01±0.01	3.10±1.19	0.56±0.18	0.01±0.01	0.91±0.28	0.12±0.07	0.03±0.02	1.45±0.50	0.08±0.02	0.02±0.01	0.14±0.06	0.12±0.08	0.02±0.01	0.17±0.04	0.02±0.01

Table 1.4. Densities (birds/km^2 ± SE) of seabirds along all coastlines, mainland coastlines only, and island coastlines only within the study area during January, May, and September from 1999–2002.

Species	All Coastlines			Mainland Coastline			Island Coastlines		
	January	May	September	January	May	September	January	May	September
All Seabirds	**114.2±8.58**	**39.77±3.51**	**58.73±15.63**	**141.6±13.99**	**56.23±6.08**	**95.41±31.71**	**83.32±8.69**	**20.18±1.90**	**23.58±3.26**
Loons	**5.16±0.71**	**0.70±0.14**	**0.03±0.01**	**7.27±1.26**	**0.84±0.23**	**0.06±0.02**	**2.79±0.45**	**0.53±0.15**	**0.00±0.00**
Common	0.15±0.03	0.08±0.01	0.00±0.00	0.16±0.04	0.10±0.02	0.00±0.00	0.14±0.04	0.04±0.02	0.00±0.00
Pacific	1.66±0.17	0.56±0.14	0.00±0.00	1.58±0.22	0.67±0.23	0.00±0.00	1.74±0.27	0.43±0.14	0.00±0.00
Red-throated	0.13±0.03	0.00±0.00	0.00±0.00	0.23±0.05	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Grebes	**35.20±4.48**	**20.39±3.02**	**6.36±1.65**	**65.94±7.96**	**37.42±5.34**	**12.97±3.33**	**0.56±0.36**	**0.12±0.06**	**0.02±0.02**
Horned	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pied-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	34.89±4.48	20.38±3.02	6.34±1.65	65.70±7.96	37.40±5.34	12.94±3.33	0.17±0.08	0.12±0.06	0.02±0.02
Albatrosses	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Black-footed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Laysan	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Shearwaters & Fulmars	**0.02±0.01**	**0.13±0.07**	**19.70±14.86**	**0.00±0.00**	**0.00±0.00**	**39.87±30.40**	**0.03±0.03**	**0.29±0.16**	**0.37±0.32**
Buller's Shearwater	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Black-vented Shearwater	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01
Northern Fulmar	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00
Pink-footed Shearwater	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01
Sooty Shearwater	0.01±0.01	0.09±0.07	19.56±14.86	0.00±0.00	0.00±0.00	39.86±30.40	0.03±0.03	0.19±0.14	0.10±0.07
Storm-Petrels	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Ashy	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Black	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Leach's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Tropicbirds	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Red-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pelicans	**1.26±0.12**	**1.77±0.47**	**3.80±0.78**	**1.49±0.20**	**2.58±0.86**	**4.51±0.85**	**1.00±0.14**	**0.81±0.11**	**3.12±1.30**
Brown	1.26±0.12	1.77±0.47	3.80±0.78	1.49±0.20	2.58±0.86	4.51±0.85	1.00±0.14	0.81±0.11	3.12±1.30
Cormorants	**3.66±0.48**	**3.90±0.63**	**3.86±0.73**	**2.54±0.27**	**3.68±0.97**	**2.60±0.45**	**4.92±0.97**	**4.17±0.77**	**5.08±1.36**
Brandt's	1.62±0.17	1.61±0.16	1.31±0.20	1.04±0.17	0.89±0.18	0.61±0.09	2.28±0.31	2.46±0.26	1.98±0.38
Double-crested	0.46±0.07	0.31±0.04	0.41±0.05	0.73±0.12	0.39±0.06	0.70±0.10	0.15±0.03	0.22±0.05	0.14±0.03
Pelagic	0.16±0.02	0.10±0.02	0.00±0.00	0.07±0.02	0.05±0.02	0.00±0.00	0.27±0.05	0.16±0.03	0.00±0.00
Sea Ducks	**11.25±1.92**	**2.36±0.74**	**0.10±0.05**	**12.48±3.30**	**3.85±1.32**	**0.20±0.10**	**9.87±1.68**	**0.59±0.33**	**0.00±0.00**
Brant	0.02±0.02	0.05±0.04	0.00±0.00	0.04±0.04	0.09±0.07	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Red-breasted Merganser	0.05±0.02	0.00±0.00	0.00±0.00	0.09±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Surf Scoter	11.09±1.91	2.31±0.74	0.10±0.05	12.18±3.28	3.75±1.32	0.20±0.10	9.87±1.68	0.59±0.33	0.00±0.00
White-winged Scoter	0.01±0.01	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Larids	**57.06±6.86**	**10.11±0.86**	**24.67±3.78**	**51.40±10.47**	**7.56±0.83**	**34.98±7.51**	**63.45±8.61**	**13.13±1.58**	**14.78±1.48**
Gulls	**56.22±6.85**	**8.99±0.85**	**21.61±3.69**	**50.84±10.46**	**5.53±0.76**	**29.85±7.34**	**62.30±8.59**	**13.11±1.58**	**13.72±1.44**
Black-legged Kittiwake	0.03±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.07±0.03	0.00±0.00	0.00±0.00
Bonaparte's	0.21±0.12	0.16±0.15	0.00±0.00	0.39±0.23	0.30±0.28	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
California	37.45±5.92	0.30±0.06	0.81±0.23	31.45±8.62	0.36±0.10	1.52±0.46	44.21±8.03	0.23±0.07	0.13±0.03
Glaucous	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Glaucous-winged	0.05±0.01	0.00±0.00	0.01±0.01	0.07±0.02	0.00±0.00	0.02±0.02	0.03±0.02	0.00±0.00	0.00±0.00
Heermann's	1.75±0.39	0.05±0.01	3.59±0.64	1.09±0.17	0.07±0.02	5.65±1.25	2.49±0.81	0.01±0.01	1.61±0.30
Herring	0.02±0.01	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	0.01±0.01	0.02±0.01	0.00±0.00	0.00±0.00
Mew	0.04±0.02	0.00±0.00	0.00±0.00	0.06±0.04	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Ring-billed	0.15±0.05	0.00±0.00	0.00±0.00	0.27±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Sabine's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	14.43±3.12	8.04±0.80	16.25±3.46	14.41±5.43	4.15±0.57	20.98±6.91	14.46±2.57	12.67±1.54	11.73±1.38
Terns	**0.84±0.35**	**1.11±0.16**	**3.04±0.54**	**0.56±0.09**	**2.03±0.28**	**5.11±1.00**	**1.15±0.73**	**0.01±0.01**	**1.05±0.43**
Caspian	0.03±0.01	0.19±0.03	0.48±0.09	0.05±0.02	0.34±0.06	0.90±0.17	0.01±0.01	0.01±0.01	0.07±0.03
Comon/Arctic	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Elegant	0.01±0.01	0.23±0.05	0.54±0.12	0.01±0.01	0.42±0.09	1.09±0.23	0.00±0.00	0.00±0.00	0.00±0.00
Elegant/Royal	0.61±0.34	0.26±0.06	1.88±0.46	0.27±0.06	0.48±0.10	2.90±0.82	0.99±0.73	0.00±0.00	0.90±0.43
Forster's	0.10±0.03	0.17±0.04	0.06±0.02	0.18±0.06	0.31±0.07	0.12±0.04	0.00±0.00	0.00±0.00	0.00±0.00
Least	0.00±0.00	0.16±0.07	0.00±0.00	0.00±0.00	0.30±0.12	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Royal	0.07±0.02	0.00±0.00	0.04±0.02	0.02±0.01	0.00±0.00	0.00±0.00	0.13±0.03	0.00±0.00	0.08±0.03
Jaegers & Skuas	**0.00±0.00**	**0.00±0.00**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**	**0.02±0.01**	**0.00±0.00**	**0.00±0.00**	**0.01±0.01**
Long-tailed Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Parasitic Jaegar	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Pomarine Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
South Polar Skua	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Alcids	**0.14±0.05**	**0.27±0.06**	**0.03±0.01**	**0.05±0.02**	**0.15±0.09**	**0.00±0.00**	**0.24±0.10**	**0.42±0.07**	**0.05±0.02**
Cassin's Auklet	0.08±0.04	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.16±0.09	0.02±0.02	0.00±0.00
Common Murre	0.02±0.01	0.00±0.00	0.00±0.00	0.04±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pigeon Guillemots	0.00±0.00	0.26±0.06	0.02±0.01	0.00±0.00	0.15±0.09	0.00±0.00	0.01±0.01	0.39±0.07	0.04±0.02
Rhinoceros Auklet	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.03	0.00±0.00	0.00±0.00
Xantus' Murrelet	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Phalaropes	**0.02±0.01**	**0.04±0.03**	**0.06±0.02**	**0.03±0.02**	**0.00±0.00**	**0.05±0.04**	**0.00±0.00**	**0.08±0.07**	**0.07±0.03**
Red	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Red-necked	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01

Table 1.5. Densities (birds/km^2 ± SE) of seabirds within mainland coastal subareas of the study area during January, May, and September from 1999–2002.

Species	Mainland Coastal Subareas								
	Northern Mainland Coastline			Central Mainland Coastline			Southern Mainland Coastline		
	January	May	September	January	May	September	January	May	September
All Seabirds	**72.12±11.15**	**43.74±12.48**	**253.8±156.7**	**158.7±22.24**	**59.62±9.56**	**66.26±16.79**	**155.0±25.55**	**58.22±9.81**	**43.26±6.90**
Loons	**7.05±1.40**	**1.98±1.14**	**0.05±0.03**	**5.31±1.40**	**0.71±0.16**	**0.08±0.04**	**10.33±3.13**	**0.42±0.19**	**0.04±0.02**
Common	0.34±0.14	0.11±0.05	0.00±0.00	0.14±0.04	0.12±0.03	0.01±0.01	0.08±0.05	0.07±0.03	0.00±0.00
Pacific	2.83±0.58	1.69±1.14	0.00±0.00	1.65±0.33	0.55±0.14	0.00±0.00	0.78±0.34	0.30±0.19	0.01±0.01
Red-throated	0.16±0.08	0.00±0.00	0.00±0.00	0.28±0.07	0.00±0.00	0.00±0.00	0.20±0.09	0.01±0.01	0.00±0.00
Grebes	**17.95±4.82**	**18.88±10.18**	**12.84±5.06**	**69.12±10.84**	**39.40±7.93**	**18.75±6.75**	**88.10±17.47**	**44.55±9.50**	**5.42±2.18**
Horned	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pied-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	17.47±4.82	18.88±10.18	12.72±5.07	68.82±10.84	39.37±7.93	18.74±6.75	88.07±17.47	44.55±9.50	5.42±2.18
Albatrosses	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Black-footed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Laysan	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Shearwaters & Fulmars	**0.00±0.00**	**0.00±0.00**	**201.5±155.4**	**0.01±0.01**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Buller's Shearwater	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Black-vented Shearwater	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Northern Fulmar	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pink-footed Shearwater	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Sooty Shearwater	0.00±0.00	0.00±0.00	201.4±155.4	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Storm-Petrels	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Ashy	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Black	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Leach's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Tropicbirds	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Red-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pelicans	**1.36±0.38**	**1.23±0.45**	**5.09±2.62**	**1.40±0.24**	**4.04±1.80**	**3.73±0.66**	**1.71±0.43**	**1.32±0.24**	**5.19±1.77**
Brown	1.36±0.38	1.23±0.45	5.09±2.62	1.40±0.24	4.04±1.80	3.73±0.66	1.71±0.43	1.32±0.24	5.19±1.77
Cormorants	**2.20±0.51**	**3.31±0.69**	**4.15±0.51**	**3.78±0.47**	**4.96±1.91**	**1.97±0.32**	**0.87±0.18**	**2.14±0.98**	**2.54±1.20**
Brandt's	1.36±0.41	1.55±0.46	1.68±0.34	1.41±0.29	1.01±0.30	0.35±0.09	0.29±0.07	0.38±0.18	0.34±0.12
Double-crested	0.27±0.09	0.43±0.16	0.57±0.18	1.24±0.23	0.49±0.10	1.08±0.18	0.23±0.07	0.24±0.08	0.27±0.09
Pelagic	0.18±0.07	0.25±0.08	0.02±0.02	0.06±0.02	0.01±0.01	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Sea Ducks	**20.49±7.43**	**12.98±6.87**	**0.67±0.45**	**5.33±0.89**	**2.03±0.54**	**0.01±0.01**	**18.76±9.09**	**1.48±0.73**	**0.18±0.15**
Brant	0.00±0.00	0.27±0.27	0.00±0.00	0.00±0.00	0.09±0.09	0.00±0.00	0.13±0.13	0.00±0.00	0.00±0.00
Red-breasted Merganser	0.02±0.02	0.00±0.00	0.00±0.00	0.17±0.07	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Surf Scoter	19.61±7.14	12.70±6.87	0.67±0.45	5.15±0.89	1.94±0.52	0.01±0.01	18.62±9.09	1.48±0.73	0.18±0.15
White-winged Scoter	0.09±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Larids	**22.42±4.88**	**4.29±0.76**	**29.14±10.09**	**73.03±19.78**	**8.35±1.55**	**41.51±15.54**	**35.05±11.01**	**8.23±1.04**	**29.72±4.37**
Gulls	**22.17±4.89**	**4.20±0.75**	**28.06±9.95**	**72.39±19.77**	**7.05±1.49**	**36.22±15.23**	**34.42±11.01**	**4.16±0.69**	**22.48±3.99**
Black-legged Kittiwake	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Bonaparte's	0.00±0.00	0.00±0.00	0.00±0.00	0.80±0.46	0.62±0.58	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00
California	13.60±4.77	0.39±0.20	3.51±1.44	45.55±15.93	0.46±0.19	1.62±0.78	20.22±10.50	0.21±0.07	0.27±0.11
Glaucous	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Glaucous-winged	0.11±0.05	0.00±0.00	0.00±0.00	0.08±0.03	0.01±0.01	0.03±0.03	0.03±0.02	0.00±0.00	0.01±0.01
Heermann's	0.50±0.29	0.02±0.02	11.34±5.44	1.44±0.31	0.04±0.02	4.61±1.18	0.89±0.19	0.13±0.05	3.78±0.83
Herring	0.05±0.03	0.00±0.00	0.02±0.02	0.01±0.01	0.00±0.00	0.01±0.01	0.01±0.01	0.00±0.00	0.00±0.00
Mew	0.05±0.03	0.00±0.00	0.00±0.00	0.03±0.02	0.00±0.00	0.00±0.00	0.13±0.13	0.00±0.00	0.00±0.00
Ring-billed	0.23±0.15	0.00±0.00	0.00±0.00	0.13±0.06	0.00±0.00	0.01±0.01	0.51±0.24	0.00±0.00	0.00±0.00
Sabine's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	5.80±0.89	3.49±0.68	11.39±3.21	21.24±10.86	4.93±1.08	28.92±14.85	8.93±2.87	3.44±0.64	16.00±3.52
Terns	**0.25±0.13**	**0.09±0.06**	**1.09±0.34**	**0.64±0.15**	**1.30±0.34**	**5.27±1.96**	**0.62±0.12**	**4.07±0.62**	**7.21±1.21**
Caspian	0.00±0.00	0.00±0.00	0.22±0.09	0.06±0.02	0.24±0.06	0.79±0.24	0.06±0.03	0.67±0.16	1.44±0.39
Comon/Arctic	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Elegant	0.00±0.00	0.05±0.05	0.10±0.05	0.00±0.00	0.19±0.07	0.72±0.30	0.04±0.04	0.93±0.23	2.16±0.51
Elegant/Royal	0.07±0.04	0.00±0.00	0.62±0.25	0.28±0.11	0.11±0.04	3.62±1.70	0.37±0.09	1.25±0.28	3.25±0.75
Forster's	0.14±0.10	0.00±0.00	0.02±0.02	0.25±0.10	0.31±0.10	0.10±0.04	0.10±0.06	0.48±0.14	0.21±0.11
Least	0.00±0.00	0.05±0.05	0.05±0.05	0.00±0.00	0.29±0.25	0.00±0.00	0.00±0.00	0.44±0.12	0.00±0.00
Royal	0.00±0.00	0.00±0.00	0.00±0.00	0.04±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Jaegers & Skuas	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.02±0.02**	**0.00±0.00**	**0.00±0.00**	**0.03±0.02**
Long-tailed Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Parasitic Jaegar	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.00±0.00	0.03±0.02
Pomarine Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
South Polar Skua	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Alcids	**0.16±0.08**	**0.84±0.46**	**0.00±0.00**	**0.04±0.03**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Cassin's Auklet	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Common Murre	0.11±0.07	0.00±0.00	0.00±0.00	0.04±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pigeon Guillemots	0.00±0.00	0.84±0.46	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Rhinoceros Auklet	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Xantus' Murrelet	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Phalaropes	**0.11±0.11**	**0.02±0.02**	**0.00±0.00**	**0.02±0.02**	**0.00±0.00**	**0.12±0.08**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Red	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Red-necked	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 1.6. Densities (birds/km^2 ± SE) of seabirds from coastal transects around the Channel Islands in the Southern California Bight during January, May, and September from 1999–2002. Northern Islands = San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands. Southern Islands = Santa Barbara, San Nicolas, Santa Catalina, and San Clemente Islands.

Species	Island Coastal Subareas					
	Northern Channel Islands' Coastline			Southern Channel Islands' Coastline		
	January	May	September	January	May	September
All Seabirds	**82.01±10.58**	**22.32±2.41**	**26.77±4.88**	**86.05±15.29**	**15.52±2.90**	**17.67±1.98**
Loons	**3.96±0.64**	**0.74±0.21**	**0.00±0.00**	**0.35±0.08**	**0.08±0.08**	**0.00±0.00**
Common	0.17±0.05	0.07±0.03	0.00±0.00	0.06±0.04	0.00±0.00	0.00±0.00
Pacific	2.46±0.38	0.59±0.20	0.00±0.00	0.25±0.07	0.08±0.08	0.00±0.00
Red-throated	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Grebes	**0.81±0.53**	**0.17±0.08**	**0.03±0.02**	**0.03±0.02**	**0.02±0.02**	**0.01±0.01**
Horned	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pied-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	0.24±0.12	0.17±0.08	0.03±0.02	0.01±0.01	0.02±0.02	0.01±0.01
Albatrosses	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Black-footed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Laysan	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Shearwaters & Fulmars	**0.05±0.04**	**0.42±0.23**	**0.55±0.49**	**0.00±0.00**	**0.00±0.00**	**0.03±0.03**
Buller's Shearwater	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Black-vented Shearwater	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Northern Fulmar	0.01±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pink-footed Shearwater	0.00±0.00	0.01±0.01	0.04±0.02	0.00±0.00	0.00±0.00	0.00±0.00
Sooty Shearwater	0.04±0.04	0.28±0.21	0.14±0.11	0.00±0.00	0.00±0.00	0.03±0.03
Storm-Petrels	**0.00±0.00**	**0.00±0.00**	**0.01±0.01**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Ashy	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Black	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
Leach's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Tropicbirds	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**
Red-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pelicans	**0.94±0.15**	**0.91±0.14**	**3.75±1.98**	**1.14±0.29**	**0.59±0.17**	**1.94±0.49**
Brown	0.94±0.15	0.91±0.14	3.75±1.98	1.14±0.29	0.59±0.17	1.94±0.49
Cormorants	**6.08±1.41**	**5.15±1.11**	**7.02±2.08**	**2.48±0.30**	**2.02±0.41**	**1.46±0.23**
Brandt's	2.52±0.45	2.83±0.34	2.55±0.58	1.75±0.24	1.65±0.39	0.91±0.16
Double-crested	0.14±0.03	0.22±0.06	0.18±0.05	0.16±0.06	0.22±0.07	0.07±0.03
Pelagic	0.39±0.06	0.24±0.04	0.00±0.00	0.03±0.02	0.00±0.00	0.01±0.01
Sea Ducks	**14.28±2.39**	**0.86±0.49**	**0.00±0.00**	**0.62±0.21**	**0.00±0.00**	**0.00±0.00**
Brant	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Red-breasted Merganser	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Surf Scoter	14.28±2.39	0.86±0.49	0.00±0.00	0.62±0.21	0.00±0.00	0.00±0.00
White-winged Scoter	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Larids	**54.90±10.33**	**13.34±1.92**	**15.09±2.08**	**81.40±15.25**	**12.69±2.77**	**14.20±1.73**
Gulls	**54.64±10.34**	**13.33±1.92**	**13.60±2.02**	**78.39±15.18**	**12.65±2.78**	**13.94±1.72**
Black-legged Kittiwake	0.09±0.04	0.00±0.00	0.00±0.00	0.03±0.02	0.00±0.00	0.00±0.00
Bonaparte's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
California	36.92±9.58	0.31±0.11	0.12±0.04	59.51±14.43	0.05±0.04	0.15±0.06
Glaucous	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Glaucous-winged	0.04±0.03	0.00±0.00	0.01±0.01	0.00±0.00	0.02±0.02	0.00±0.00
Heermann's	1.30±0.28	0.01±0.01	1.23±0.27	5.01±2.43	0.03±0.02	2.33±0.68
Herring	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.03	0.00±0.00	0.00±0.00
Mew	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Ring-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Sabine's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Western	15.32±3.37	12.75±1.86	12.08±1.96	12.67±3.64	12.50±2.77	11.07±1.48
Terns	**0.26±0.07**	**0.01±0.01**	**1.48±0.66**	**3.01±2.26**	**0.02±0.02**	**0.27±0.11**
Caspian	0.02±0.02	0.01±0.01	0.08±0.04	0.00±0.00	0.00±0.00	0.04±0.03
Comon/Arctic	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Elegant	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Elegant/Royal	0.07±0.04	0.00±0.00	1.29±0.66	2.93±2.26	0.02±0.02	0.17±0.10
Forster's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Least	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Royal	0.15±0.05	0.00±0.00	0.10±0.04	0.07±0.04	0.00±0.00	0.04±0.03
Jaegers & Skuas	**0.00±0.00**	**0.00±0.00**	**0.01±0.01**	**0.00±0.00**	**0.02±0.02**	**0.00±0.00**
Long-tailed Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00
Parasitic Jaegar	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Pomarine Jaeger	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00
South Polar Skua	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Alcids	**0.35±0.15**	**0.57±0.10**	**0.06±0.03**	**0.01±0.01**	**0.08±0.05**	**0.03±0.03**
Cassin's Auklet	0.24±0.13	0.04±0.02	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Common Murre	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Pigeon Guillemots	0.01±0.01	0.53±0.10	0.04±0.02	0.00±0.00	0.08±0.05	0.03±0.03
Rhinoceros Auklet	0.06±0.04	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Xantus' Murrelet	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Phalaropes	**0.00±0.00**	**0.12±0.11**	**0.10±0.04**	**0.01±0.01**	**0.02±0.02**	**0.00±0.00**
Red	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00
Red-necked	0.00±0.00	0.01±0.01	0.02±0.02	0.00±0.00	0.00±0.00	0.00±0.00

Table 1.7. Population size estimates (±SE) of seabirds within the study area during January, May, and September from 1999-2002. Estimates are based on at-sea transect data and may not be accurate for coastal species. Bolded families include unidentified birds of that family.

Species	At-Sea Population Size Estimate		
	January	May	September
All Seabirds	**981,412 ± 143,940**	**862,103 ± 94,677**	**762,038 ± 171,651**
Loons	**39,256 ± 12,316**	**6,158 ± 2,309**	**0 ± 0**
Common	1,539 ± 770	0 ± 0	0 ± 0
Pacific	24,632 ± 8,467	4,618 ± 1,539	0 ± 0
Red-throated	0 ± 0	0 ± 0	0 ± 0
Grebes	**204,749 ± 113,921**	**9,237 ± 3,079**	**2,309 ± 1,539**
Horned	0 ± 0	0 ± 0	0 ± 0
Pied-billed	0 ± 0	0 ± 0	0 ± 0
Western	204,749 ± 113,921	9,237 ± 3,079	2,309 ± 1,539
Albatrosses	**770 ± 0**	**0 ± 0**	**0 ± 0**
Black-footed	0 ± 0	0 ± 0	0 ± 0
Laysan	0 ± 0	0 ± 0	0 ± 0
Shearwaters & Fulmars	**39,256 ± 10,007**	**380,249 ± 66,197**	**297,887 ± 73,895**
Buller's Shearwater	0 ± 0	0 ± 0	5,388 ± 1,539
Black-vented Shearwater	13,855 ± 9,237	0 ± 0	4,618 ± 2,309
Northern Fulmar	16,934 ± 2,309	3,849 ± 770	770 ± 0
Pink-footed Shearwater	1,539 ± 770	6,158 ± 770	62,349 ± 16,164
Sooty Shearwater	3,079 ± 770	366,394 ± 66,197	182,427 ± 53,112
Storm-Petrels	**6,158 ± 770**	**16,934 ± 1,539**	**17,704 ± 2,309**
Ashy	3,079 ± 770	7,697 ± 1539	8,467 ± 1,539
Black	0 ± 0	3,079 ± 770	2,309 ± 770
Leach's	770 ± 0	3,849 ± 770	5,388 ± 770
Tropicbirds	**0 ± 0**	**0 ± 0**	**770 ± 0**
Red-billed	0 ± 0	0 ± 0	0 ± 0
Pelicans	**12,316 ± 2,309**	**6,158 ± 1,539**	**63,888 ± 47,724**
Brown	12,316 ± 2,309	6,158 ± 1,539	63,888 ± 47,724
Cormorants	**14,625 ± 3,849**	**11,546 ± 2,309**	**12,316 ± 3,079**
Brandt's	5,388 ± 770	8,467 ± 1,539	7,697 ± 3,079
Double-crested	3,849 ± 3,079	770 ± 0	770 ± 0
Pelagic	0 ± 0	770 ± 0	0 ± 0
Sea Ducks	**10,007 ± 3,079**	**0 ± 0**	**0 ± 0**
Brant	0 ± 0	0 ± 0	0 ± 0
Red-breasted Merganser	0 ± 0	0 ± 0	0 ± 0
Surf Scoter	10,007 ± 3,079	0 ± 0	0 ± 0
White-winged Scoter	0 ± 0	0 ± 0	0 ± 0
Larids	**404,111 ± 60,039**	**122,388 ± 16,164**	**235,539 ± 62,349**
Gulls	**400,262 ± 60,039**	**109,302 ± 16,164**	**190,894 ± 61,579**
Black-legged Kittiwake	34,638 ± 3,849	0 ± 0	0 ± 0
Bonaparte's	7,697 ± 3,079	3,079 ± 1,539	0 ± 0
California	230,920 ± 57,730	12,316 ± 6,928	770 ± 0
Glaucous	0 ± 0	0 ± 0	0 ± 0
Glaucous-winged	770 ± 0	0 ± 0	0 ± 0
Heermann's	19,243 ± 6,158	0 ± 0	5,388 ± 1,539
Herring	0 ± 0	0 ± 0	0 ± 0
Mew	0 ± 0	0 ± 0	0 ± 0
Ring-billed	0 ± 0	0 ± 0	0 ± 0
Sabine's	0 ± 0	9,237 ± 1,539	8,467 ± 2,309
Western	85,441 ± 7,697	80,052 ± 12,316	163,184 ± 56,191
Terns	**1,539 ± 770**	**11,546 ± 1,539**	**33,868 ± 6,928**
Caspian	770 ± 0	770 ± 0	0 ± 0
Comon/Arctic	0 ± 0	4,618 ± 1,539	26,941 ± 6,158
Elegant	0 ± 0	770 ± 0	770 ± 770
Elegant/Royal	770 ± 0	2,309 ± 770	3,079 ± 770
Forster's	0 ± 0	770 ± 0	770 ± 770
Least	0 ± 0	1,539 ± 770	0 ± 0
Royal	0 ± 0	0 ± 0	0 ± 0
Jaegers & Skuas	**3,079 ± 770**	**1,539 ± 0**	**10,007 ± 770**
Long-tailed Jaeger	0 ± 0	0 ± 0	0 ± 0
Parasitic Jaegar	0 ± 0	0 ± 0	770 ± 0
Pomarine Jaeger	1,539 ± 0	770 ± 0	3,849 ± 770
South Polar Skua	0 ± 0	0 ± 0	0 ± 0
Alcids	**183,197 ± 16,934**	**87,750 ± 33,868**	**15,395 ± 2,309**
Cassin's Auklet	115,460 ± 15,395	69,276 ± 33,099	4,618 ± 1,539
Common Murre	10,776 ± 3,849	1,539 ± 770	5,388 ± 1,539
Pigeon Guillemots	0 ± 0	770 ± 0	0 ± 0
Rhinoceros Auklet	46,184 ± 4,618	1,539 ± 770	770 ± 0
Xantus' Murrelet	770 ± 0	13,855 ± 3,079	0 ± 0
Phalaropes	**62,349 ± 6,928**	**219,374 ± 37,717**	**114,691 ± 18,474**
Red	33,868 ± 3,849	18,474 ± 13,085	11,546 ± 2,309
Red-necked	1,539 ± 770	67,737 ± 13,855	10,776 ± 2,309

Table 1.8. Change in at-sea densities (birds/km^2 ± SE) of seabirds in Southern California from 1975–1983 during December-February, April-June, and August-October (Briggs et al. 1987) and from 1999–2002 during January, May, and September.

Species	1975–1983			1999–2002			% Change in Density		
	Dec.–Feb.	April–June	Aug.–Oct.	January	May	September	January	May	September
All Seabirds	**14.78±4.02**	**25.93±6.52**	**17.11±2.12**	**12.75±1.87**	**11.20±1.23**	**9.90±2.23**	**-14%**	**-57%**	**-42%**
Loons	**0.99±0.45**	**0.50±0.15**	**0.02±0.01**	**0.51±0.16**	**0.08±0.03**	**0.00±0.00**	**-48%**	**-84%**	**-100%**
Common	0.05±0.01	0.02±0.01	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	-60%	-100%	na
Pacific	0.27±0.19	0.41±0.15	0.01±0.01	0.32±0.11	0.06±0.02	0.00±0.00	19%	-85%	-100%
Red-throated	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	-100%	na	na
Grebes	**0.35±0.18**	**0.04±0.01**	**0.32±0.16**	**2.66±1.48**	**0.12±0.04**	**0.03±0.02**	**660%**	**200%**	**-91%**
Horned	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Pied-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Western	0.33±0.18	0.03±0.01	0.31±0.16	2.66±1.48	0.12±0.04	0.03±0.02	706%	300%	-90%
Albatrosses	**0.00±0.00**	**0.01±0.00**	**0.00±0.00**	**0.01±0.00**	**0.00±0.00**	**0.00±0.00**	**na**	**-100%**	**na**
Black-footed	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	-100%	na
Laysan	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Shearwaters & Fulmars	**0.42±0.09**	**13.90±5.82**	**4.50±1.39**	**0.51±0.13**	**4.94±0.86**	**3.87±0.96**	**21%**	**-64%**	**-14%**
Buller's Shearwater	0.00±0.00	0.00±0.00	0.08±0.06	0.00±0.00	0.00±0.00	0.07±0.02	na	na	-13%
Black-vented Shearwater	0.00±0.00	0.00±0.00	0.00±0.00	0.18±0.12	0.00±0.00	0.06±0.03	na	na	na
Northern Fulmar	0.38±0.08	0.02±0.01	0.08±0.02	0.22±0.03	0.05±0.01	0.01±0.00	-42%	150%	-88%
Pink-footed Shearwater	0.01±0.00	0.38±0.10	0.66±0.15	0.02±0.01	0.08±0.01	0.81±0.21	100%	-79%	23%
Sooty Shearwater	0.01±0.00	10.55±4.87	3.26±1.38	0.04±0.01	4.76±0.86	2.37±0.69	300%	-55%	-27%
Storm-Petrels	**0.10±0.02**	**0.76±0.42**	**0.20±0.02**	**0.08±0.01**	**0.22±0.02**	**0.23±0.03**	**-20%**	**-71%**	**15%**
Ashy	0.01±0.01	0.10±0.09	0.02±0.01	0.04±0.01	0.10±0.02	0.11±0.02	300%	0%	450%
Black	0.00±0.00	0.02±0.01	0.02±0.00	0.00±0.00	0.04±0.01	0.03±0.01	na	100%	50%
Leach's	0.03±0.01	0.13±0.03	0.07±0.01	0.01±0.00	0.05±0.01	0.07±0.01	-67%	-62%	0%
Tropicbirds	**0.00±0.00**	**0.01±0.00**	**0.00±0.00**	**0.00±0.00**	**0.00±0.00**	**0.01±0.00**	**na**	**-100%**	**na**
Red-billed	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	-100%	na
Pelicans	**0.20±0.07**	**0.03±0.01**	**0.43±0.13**	**0.16±0.03**	**0.08±0.02**	**0.83±0.62**	**-20%**	**167%**	**93%**
Brown	0.17±0.07	0.03±0.01	0.40±0.13	0.16±0.03	0.08±0.02	0.83±0.62	-6%	167%	108%
Cormorants	**0.57±0.37**	**0.06±0.02**	**0.04±0.01**	**0.19±0.05**	**0.15±0.03**	**0.16±0.04**	**-67%**	**150%**	**300%**
Brandt's	0.02±0.01	0.02±0.01	0.00±0.00	0.07±0.01	0.11±0.02	0.10±0.04	250%	450%	na
Double-crested	0.00±0.00	0.00±0.00	0.00±0.00	0.05±0.04	0.01±0.00	0.01±0.00	na	na	na
Pelagic	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	na	na	na
Sea Ducks	**0.14±0.03**	**0.14±0.10**	**0.02±0.01**	**0.13±0.04**	**0.00±0.00**	**0.00±0.00**	**-7%**	**-100%**	**-100%**
Brant	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Red-breasted Merganser	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Surf Scoter	0.07±0.02	0.10±0.10	0.01±0.01	0.13±0.04	0.00±0.00	0.00±0.00	86%	-100%	-100%
White-winged Scoter	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	-100%	na	na
Larids	**7.84±3.03**	**2.40±0.47**	**6.33±1.41**	**5.25±0.78**	**1.59±0.21**	**3.06±0.81**	**-33%**	**-34%**	**-52%**
Gulls	**7.72±3.03**	**2.34±0.47**	**5.84±1.41**	**5.20±0.78**	**1.42±0.21**	**2.48±0.80**	**-33%**	**-39%**	**-58%**
Black-legged Kittiwake	0.40±0.11	0.18±0.08	0.01±0.00	0.45±0.05	0.00±0.00	0.00±0.00	13%	-100%	-100%
Bonaparte's	2.99±2.80	0.82±0.37	0.13±0.05	0.10±0.04	0.04±0.02	0.00±0.00	-97%	-95%	-100%
California	1.90±0.57	0.05±0.01	0.34±0.14	3.00±0.75	0.16±0.09	0.01±0.00	58%	220%	-97%
Glaucous	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Glaucous-winged	0.01±0.00	0.00±0.00	0.01±0.01	0.01±0.00	0.00±0.00	0.00±0.00	0%	na	-100%
Heermann's	0.03±0.01	0.01±0.01	0.47±0.25	0.25±0.08	0.00±0.00	0.07±0.02	733%	-100%	-85%
Herring	0.14±0.03	0.03±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	-100%	-100%	-100%
Mew	0.02±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	-100%	na	na
Ring-billed	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Sabine's	0.00±0.00	0.03±0.01	0.01±0.00	0.00±0.00	0.12±0.02	0.11±0.03	na	300%	1000%
Western	0.79±0.15	0.67±0.08	2.35±0.48	1.11±0.10	1.04±0.16	2.12±0.73	41%	55%	-10%
Terns	**0.01±0.00**	**0.03±0.01**	**0.23±0.05**	**0.02±0.01**	**0.15±0.02**	**0.44±0.09**	**100%**	**400%**	**91%**
Caspian	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.01±0.00	0.00±0.00	na	na	na
Comon/Arctic	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.02	0.35±0.08	na	na	na
Elegant	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.01±0.01	na	na	na
Elegant/Royal	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.03±0.01	0.04±0.01	na	na	na
Forster's	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.00	0.01±0.01	na	na	na
Least	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.01	0.00±0.00	na	na	na
Royal	0.01±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.00±0.00	-100%	na	-100%
Jaegers & Skuas	**0.11±0.02**	**0.03±0.01**	**0.25±0.04**	**0.04±0.01**	**0.02±0.00**	**0.13±0.01**	**-64%**	**-33%**	**-48%**
Long-tailed Jaeger	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Parasitic Jaegar	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	0.00±0.00	0.01±0.00	na	na	0%
Pomarine Jaeger	0.08±0.02	0.02±0.01	0.16±0.02	0.02±0.00	0.01±0.00	0.05±0.01	-75%	-50%	-69%
South Polar Skua	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	na	na	na
Alcids	**3.21±0.98**	**1.08±0.22**	**1.55±0.63**	**2.38±0.22**	**1.14±0.44**	**0.20±0.03**	**-26%**	**6%**	**-87%**
Cassin's Auklet	0.68±0.11	0.45±0.09	0.90±0.61	1.50±0.20	0.90±0.43	0.06±0.02	121%	100%	-93%
Common Murre	0.55±0.20	0.11±0.04	0.52±0.18	0.14±0.05	0.02±0.01	0.07±0.02	-75%	-82%	-87%
Pigeon Guillemots	0.00±0.00	0.02±0.01	0.00±0.00	0.00±0.00	0.01±0.00	0.00±0.00	na	-50%	na
Rhinoceros Auklet	0.66±0.11	0.03±0.01	0.02±0.01	0.60±0.06	0.02±0.01	0.01±0.00	-9%	-33%	-50%
Xantus' Murrelet	0.01±0.00	0.08±0.03	0.00±0.00	0.01±0.00	0.18±0.04	0.00±0.00	0%	125%	na
Phalaropes	**0.95±0.20**	**7.00±2.30**	**3.70±0.49**	**0.81±0.09**	**2.85±0.49**	**1.49±0.24**	**-15%**	**-59%**	**-60%**
Red	0.09±0.03	0.26±0.08	0.24±0.11	0.44±0.05	0.24±0.17	0.15±0.03	389%	-8%	-38%
Red-necked	0.00±0.00	0.00±0.00	0.03±0.01	0.02±0.01	0.88±0.18	0.14±0.03	na	na	367%

Table 1.9. Shannon-Weiner Diversity Index (H') values and number of species calculated for subareas, transect types, and survey months from 1999-2002.

	H'	Number of Species
At-sea	2.56	48
Coastal	1.95	38
Subarea One	1.90	46
Subarea Two	2.26	18
Subarea Three	2.07	40
Subarea Three Minus Islands	1.92	40
Subarea Four	1.79	41
Subarea Four Minus Islands	2.40	36
Subarea Five	2.30	33
Subarea Five Minus Islands	2.35	27
Northern Channel Islands	1.75	25
Southern Channel Islands	1.17	21
Northern Mainland	1.56	26
Central Mainland	1.49	27
Southern Mainland	1.52	24
January	1.80	46
May	2.10	40
September	1.86	40

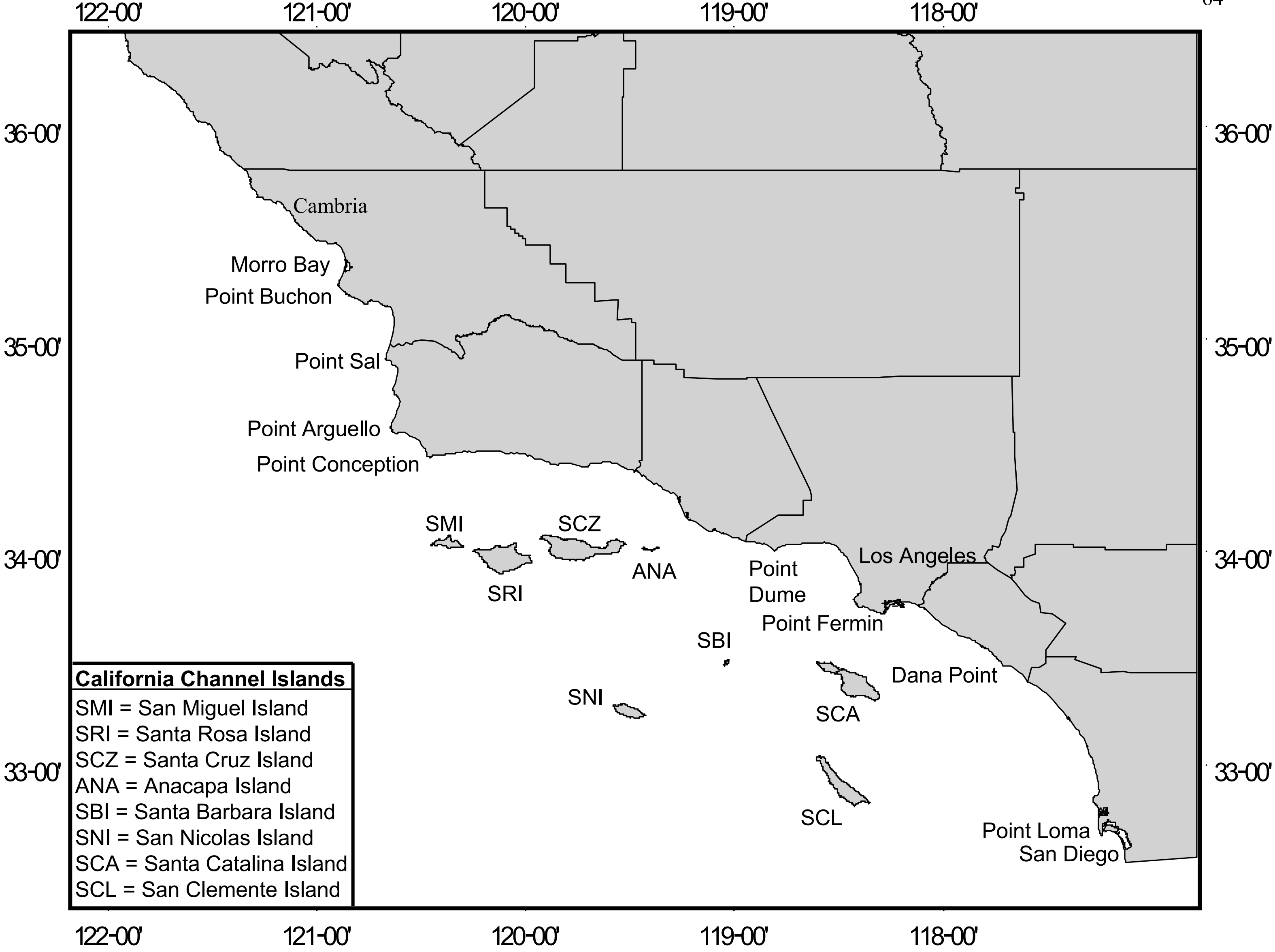


FIGURE 1.1. Map of central and southern California showing locations of county boundaries, major cities, coastal points, and islands.

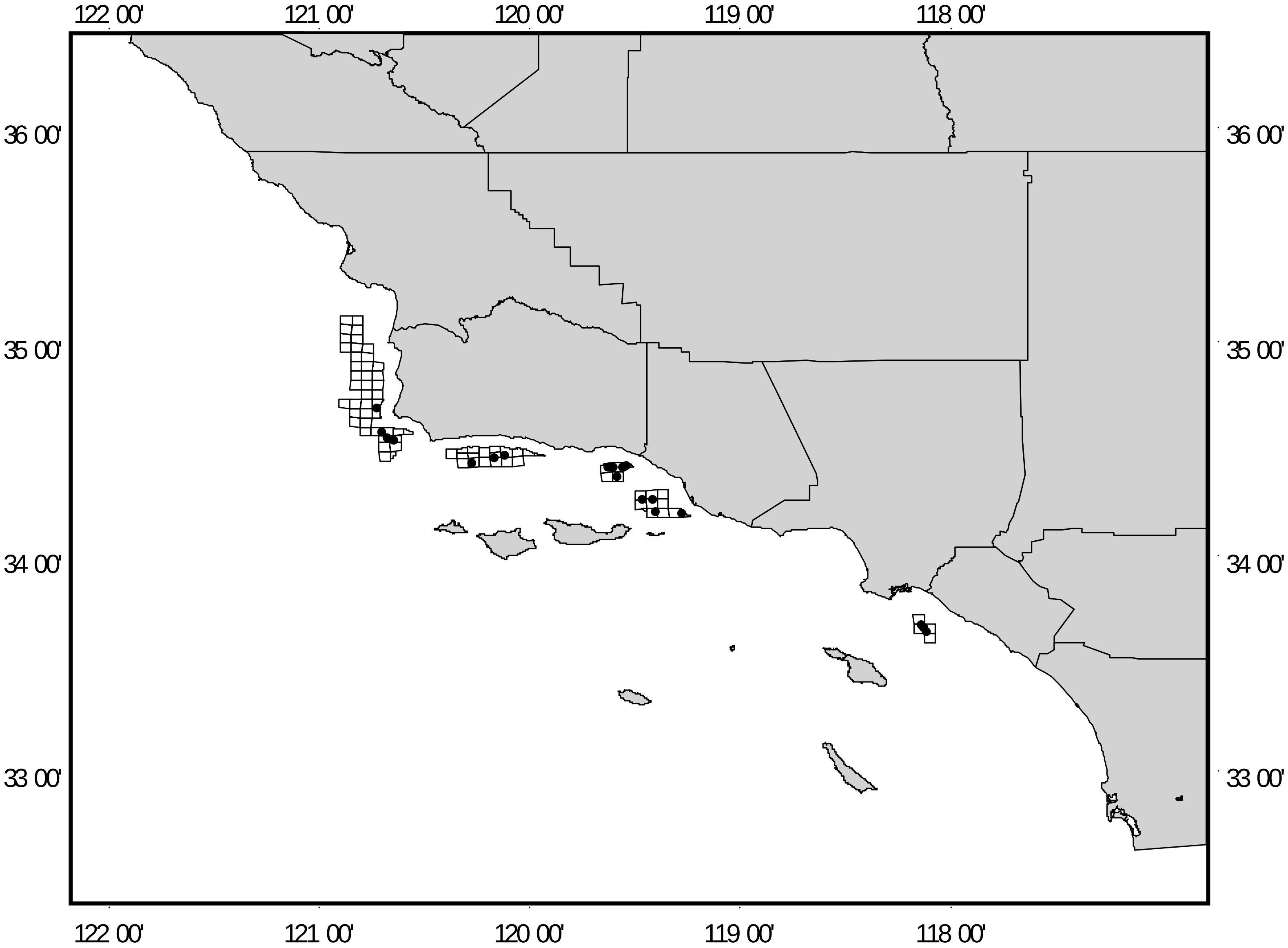


FIGURE 1.2. Map of central and southern California showing oil lease and platform locations. Oil leases are represented by squares. Platforms are represented by solid circles within lease areas.

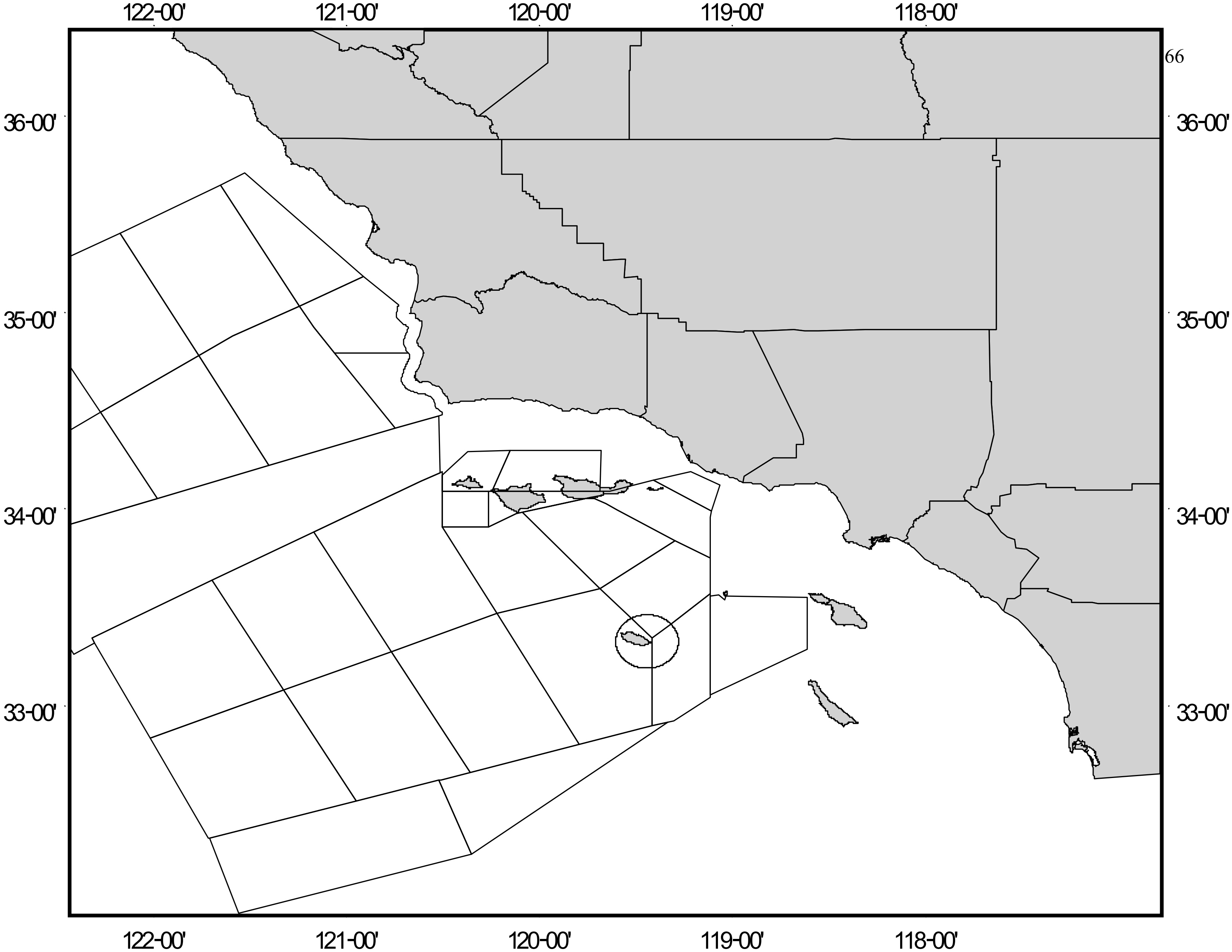


FIGURE 1.3. Map of central and southern California showing boundaries of military sea test ranges.

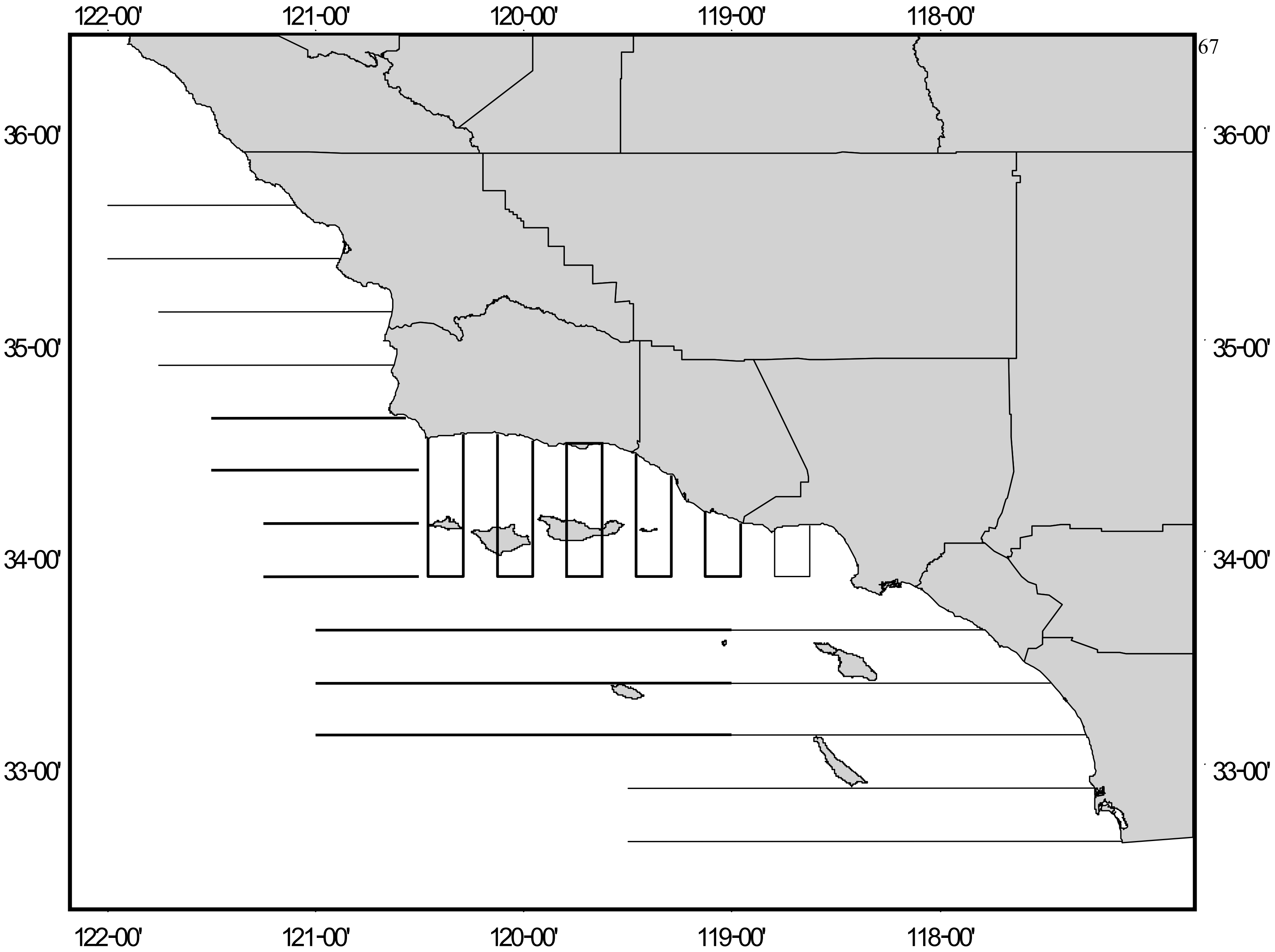


FIGURE 1.4. Map of central and southern California showing locations of core area and non-core area transect lines. Core area transect lines are represented by thicker lines. Non-core area transect lines are represented by thinner lines. The core area was surveyed twice each survey month from 1999–2002.

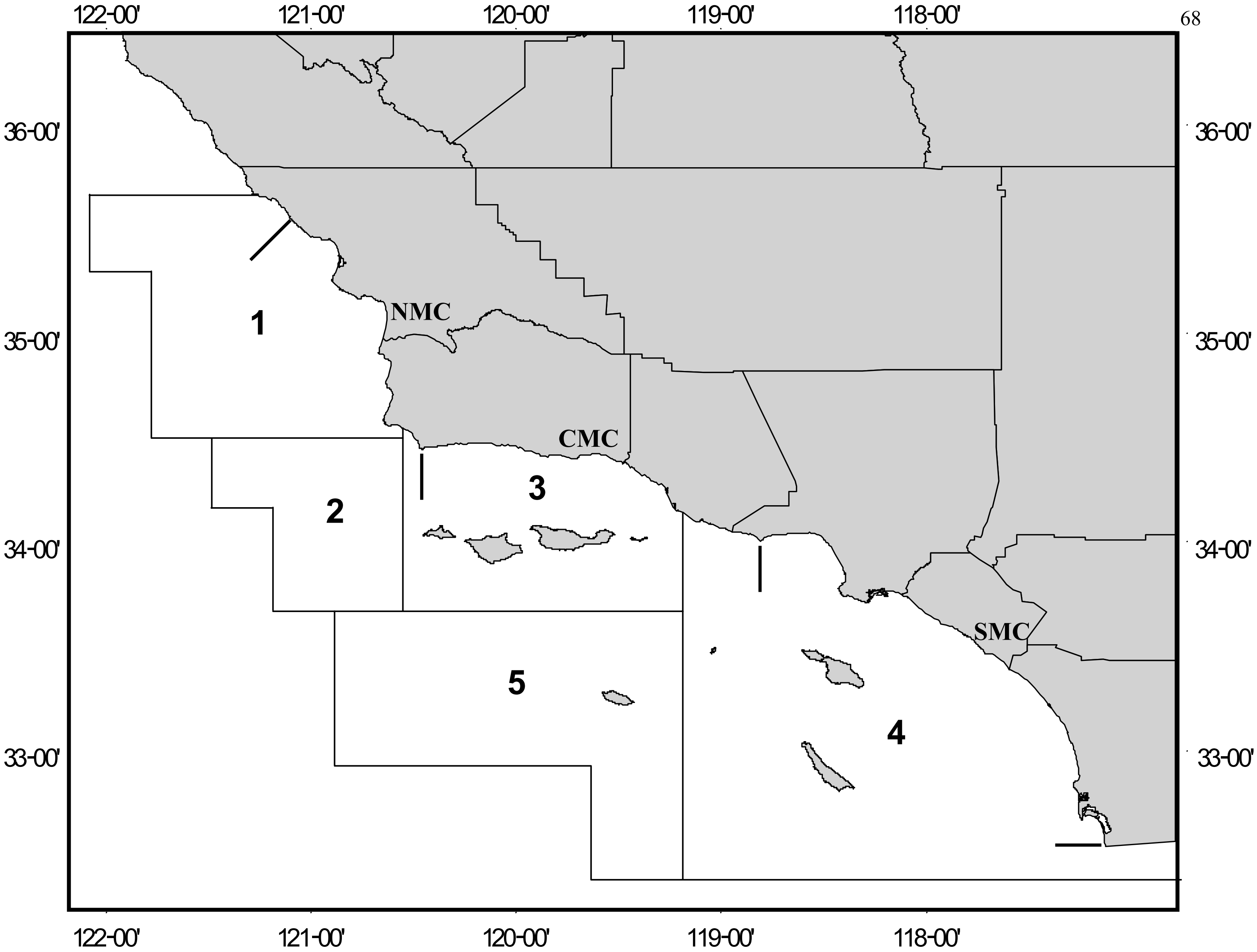


FIGURE 1.5. Map of central and southern California showing locations of at-sea and coastal subareas. At-sea subareas are numbered 1–5. Coastal subarea boundaries are denoted by bars. NMC = northern mainland coast. CMC = central mainland coast. SMC = southern mainland coast.

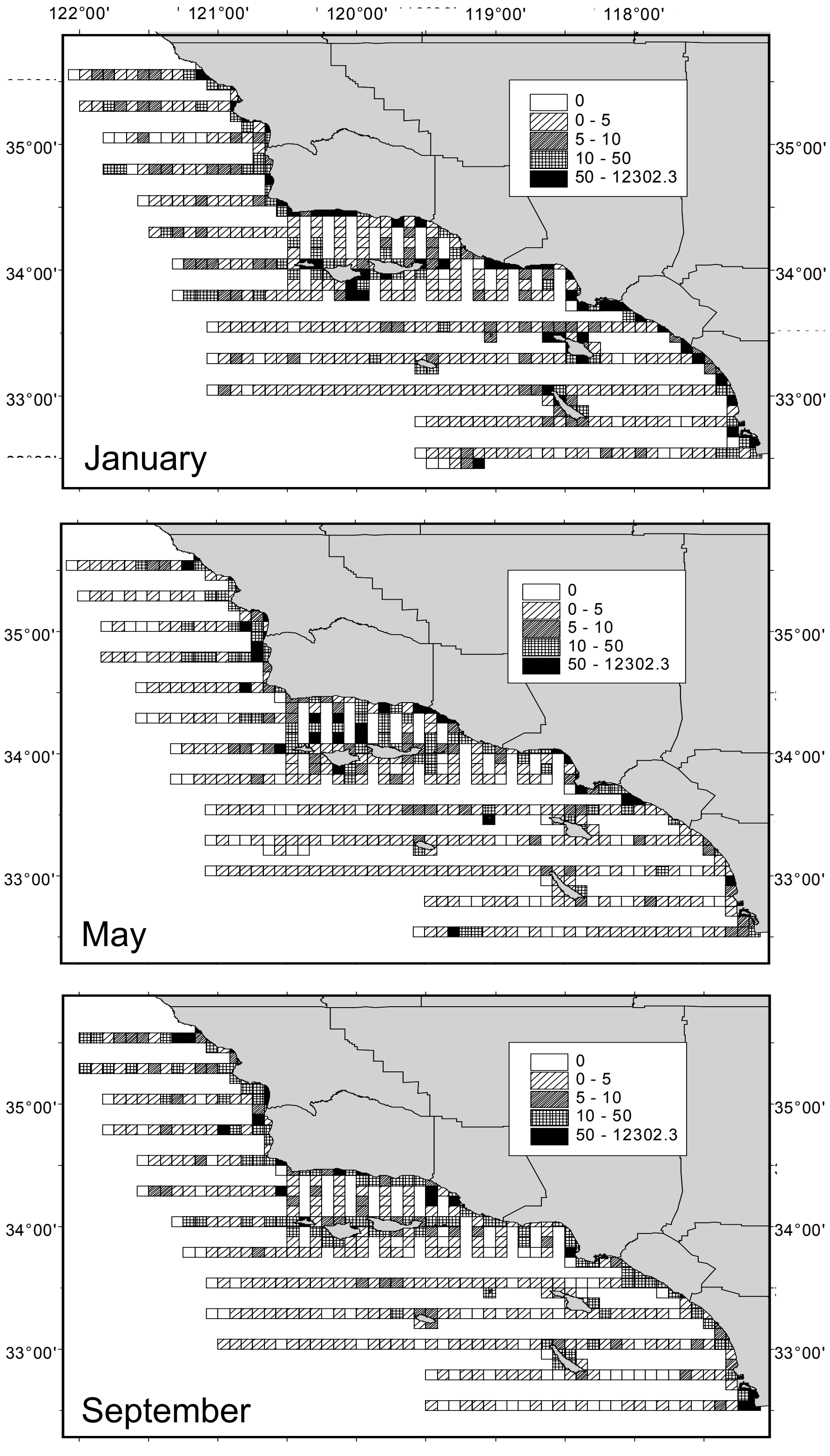


FIGURE 1.6. All seabird densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

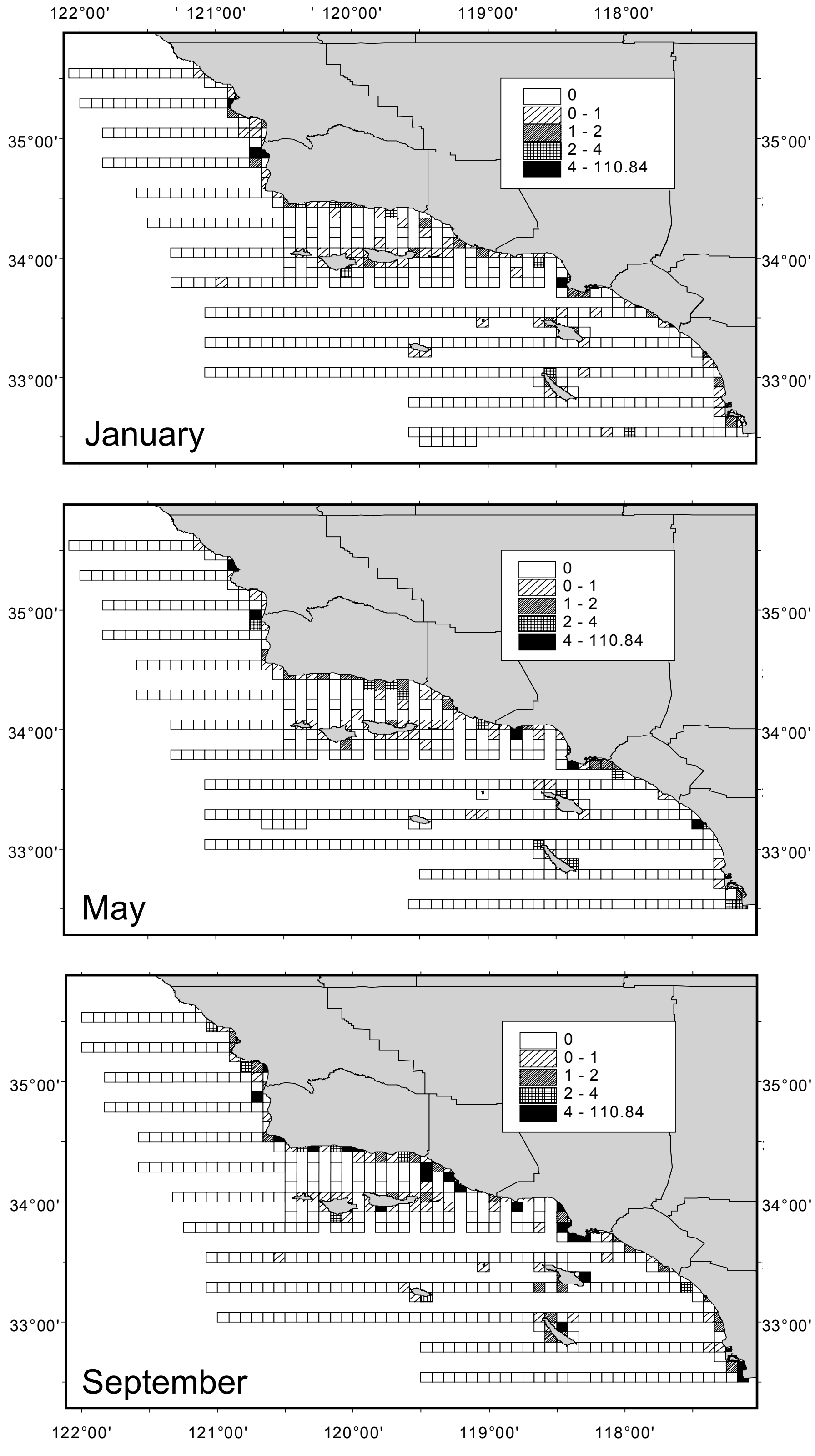


FIGURE 1.7. Brown Pelican densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

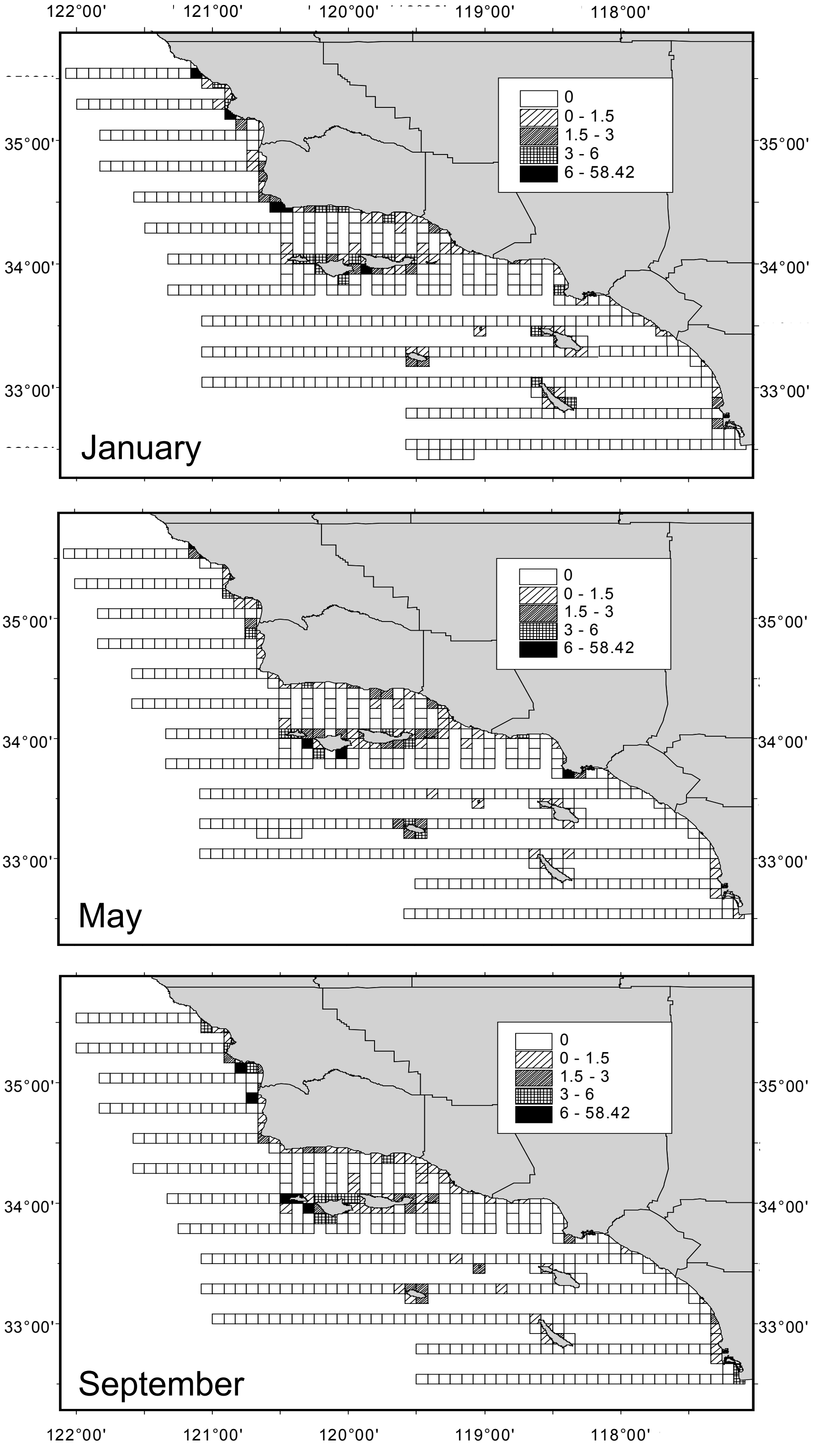


FIGURE 1.8. Cormorant densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

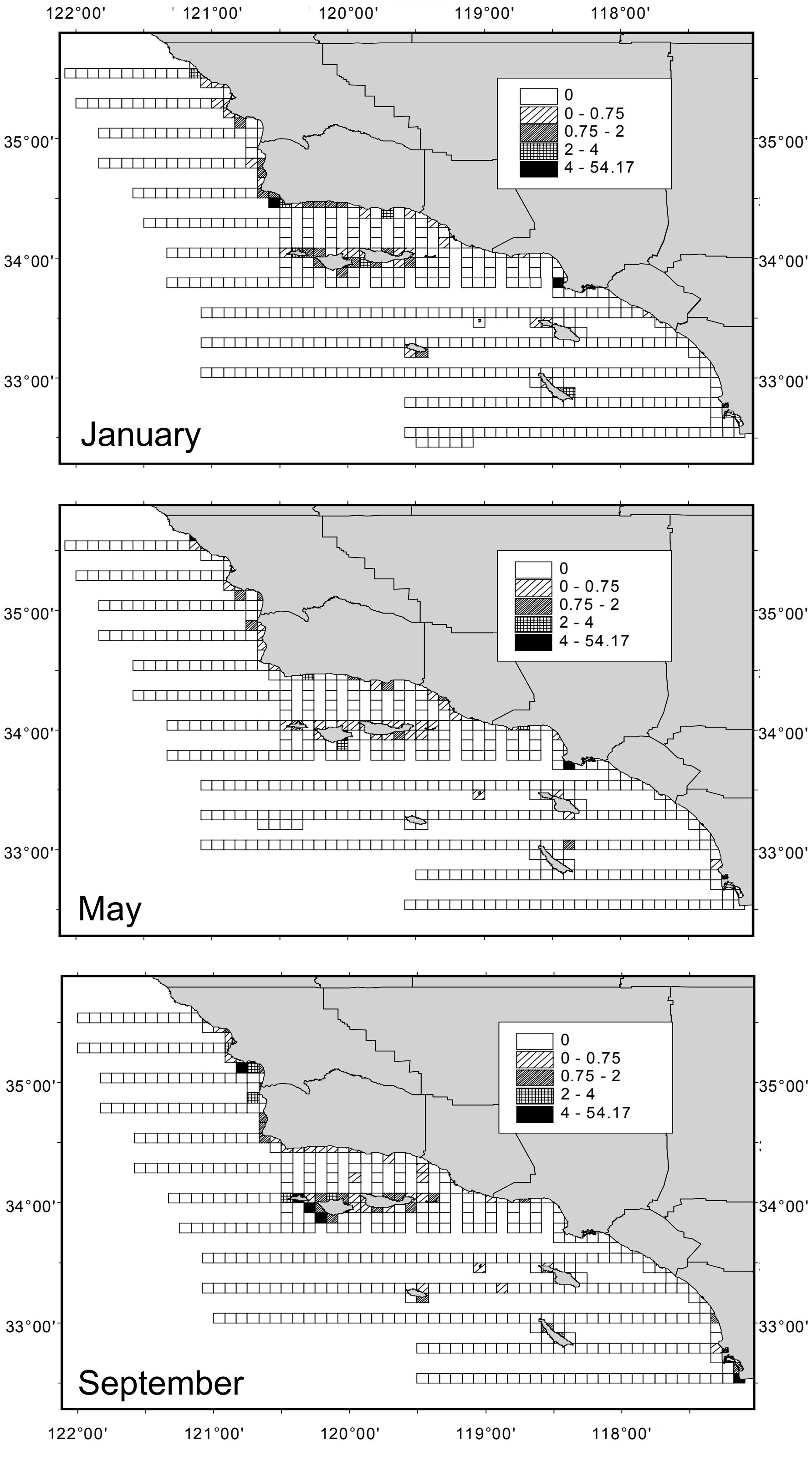


FIGURE 1.9. Unidentified cormorant densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

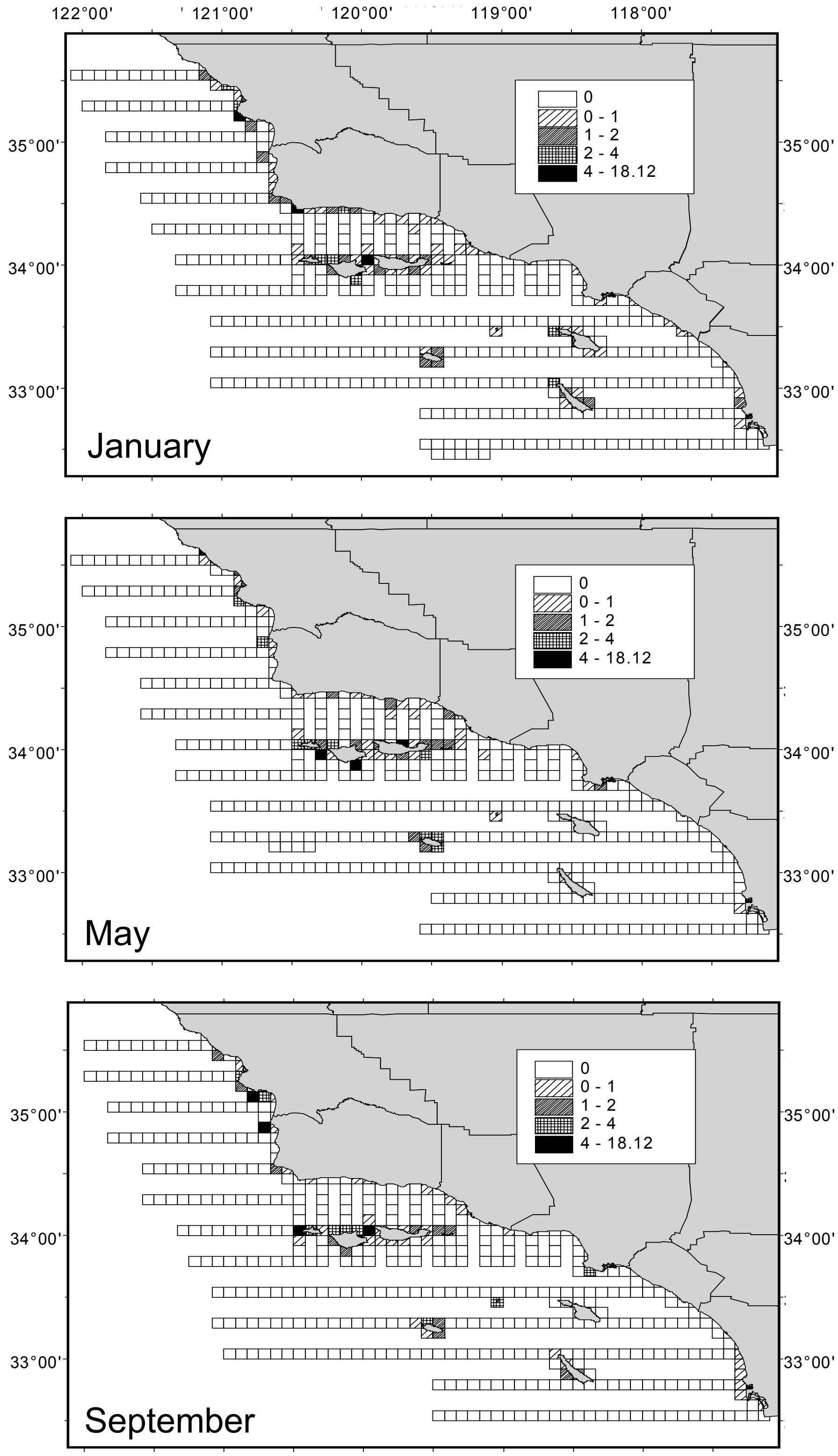


FIGURE 1.10. Brandt's Cormorant densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

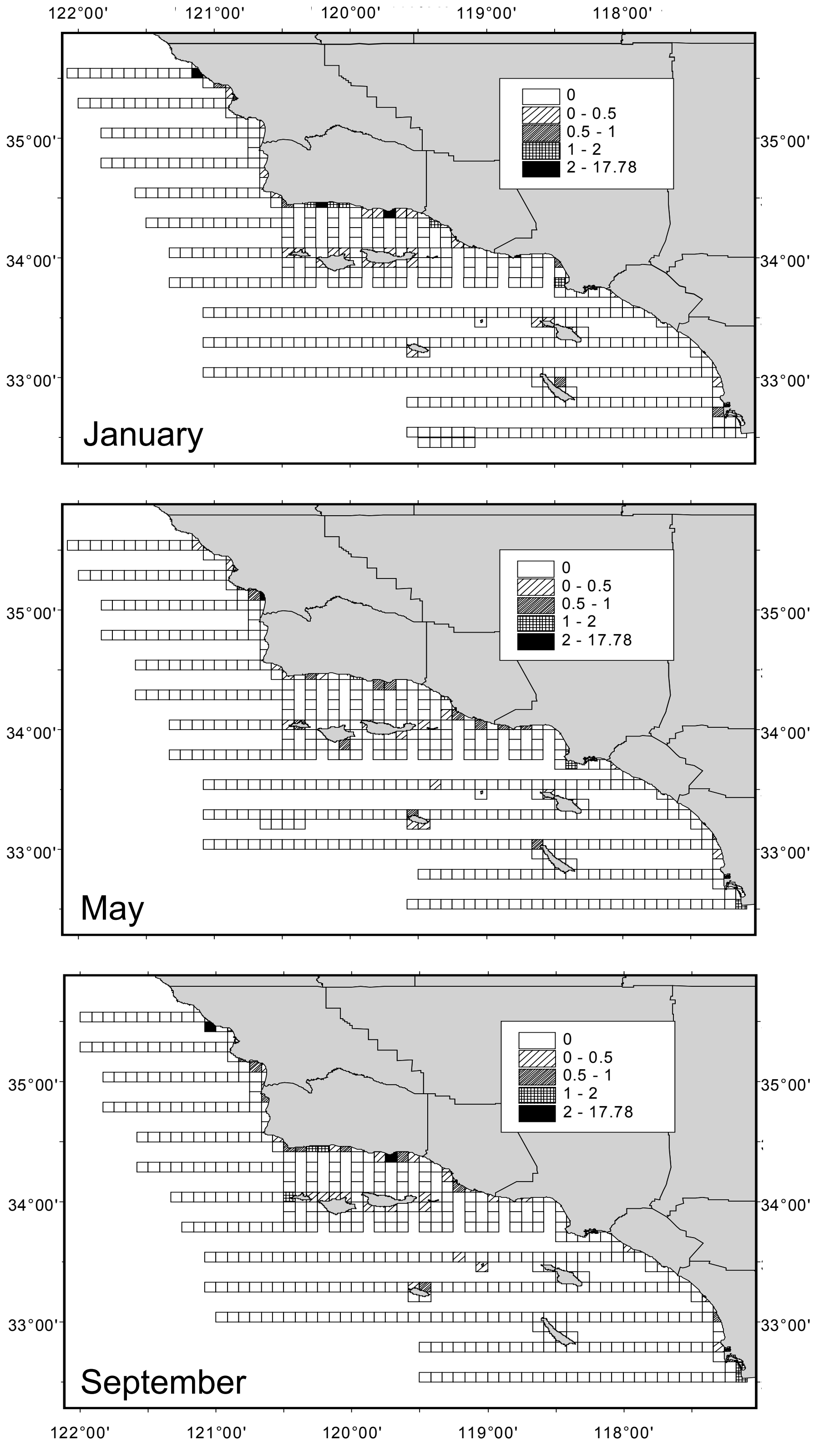


FIGURE 1.11. Double-crested Cormorant densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

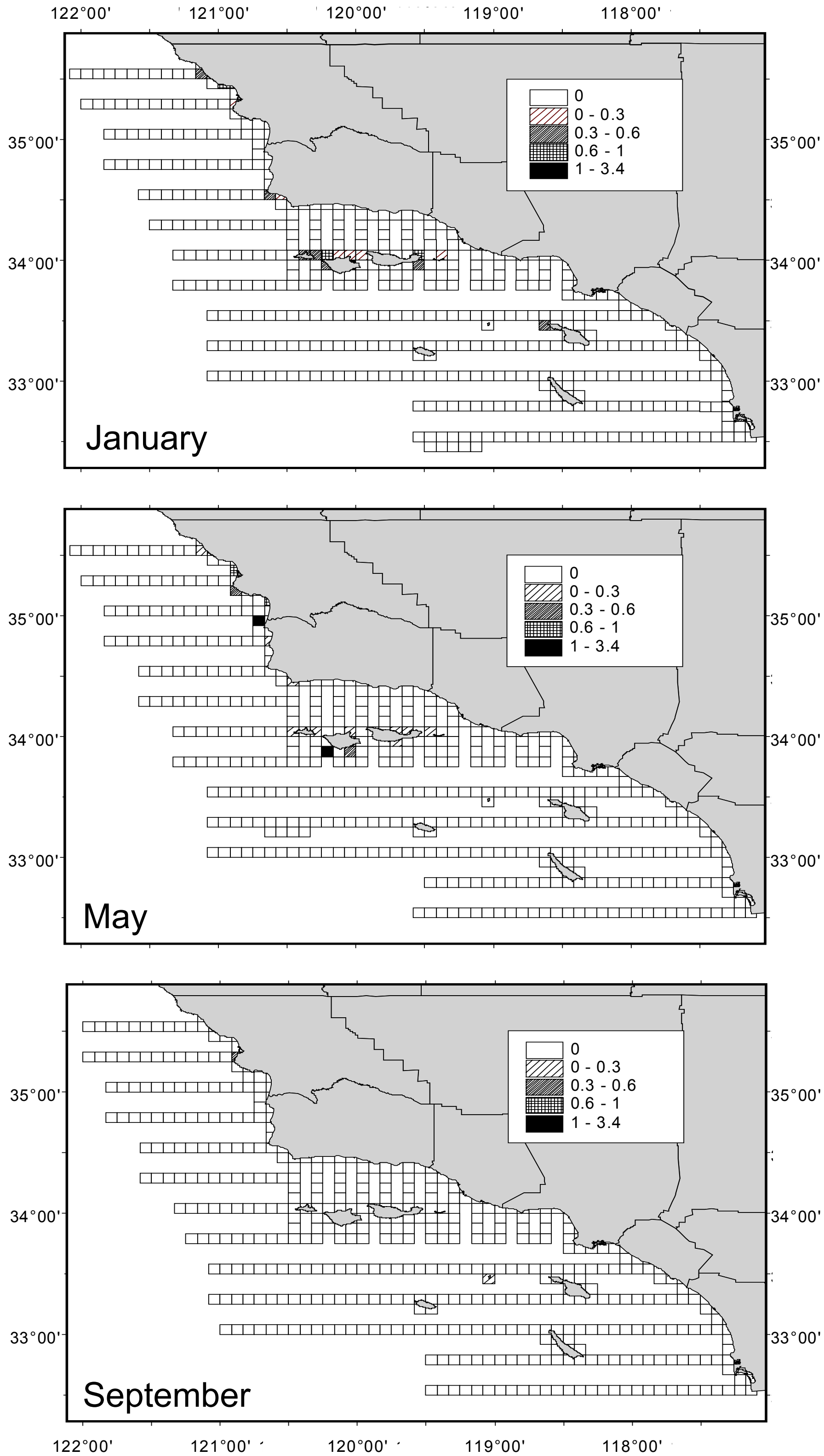


FIGURE 1.12. Pelagic Cormorant densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

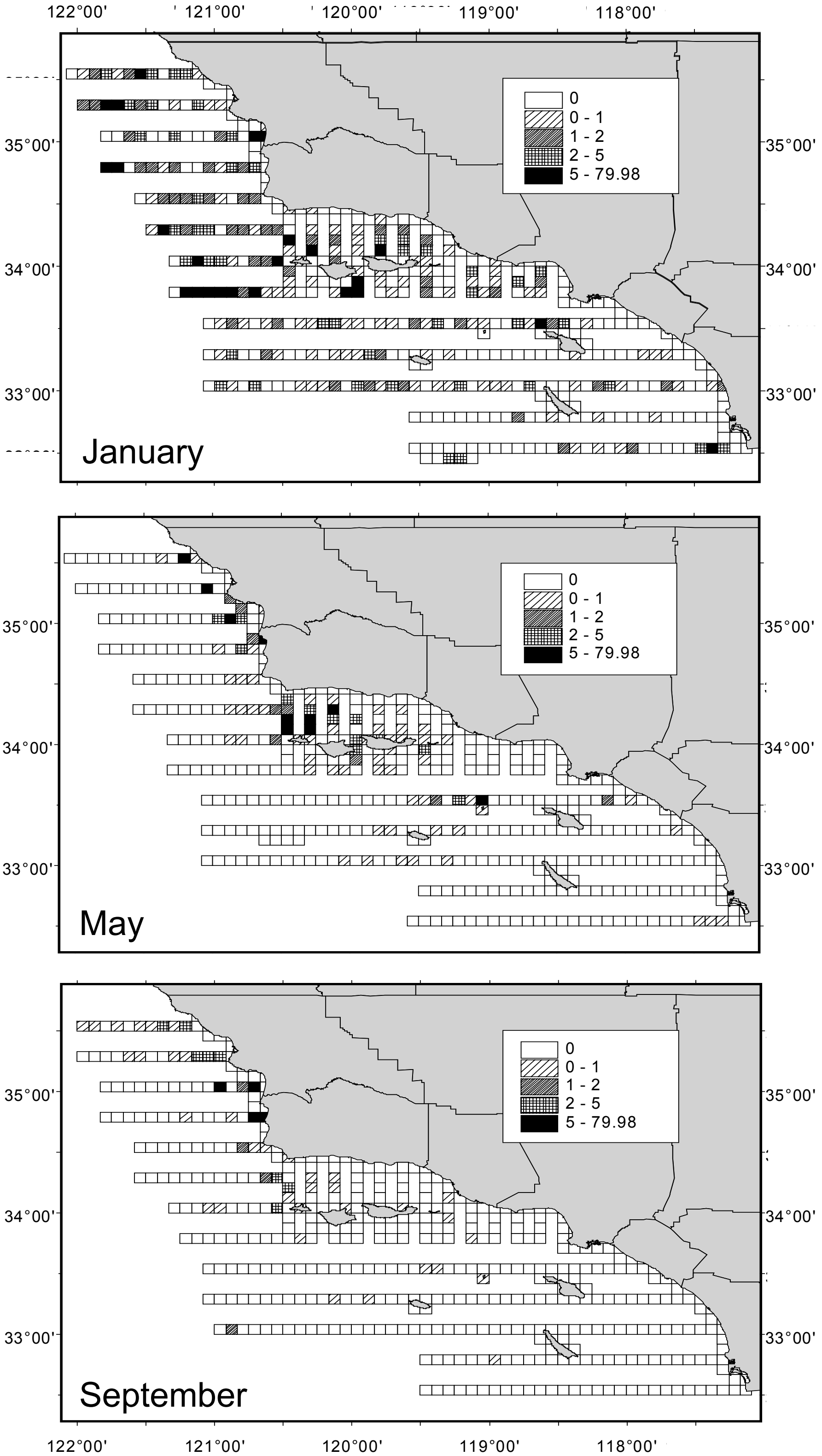


FIGURE 1.13. Alcid densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

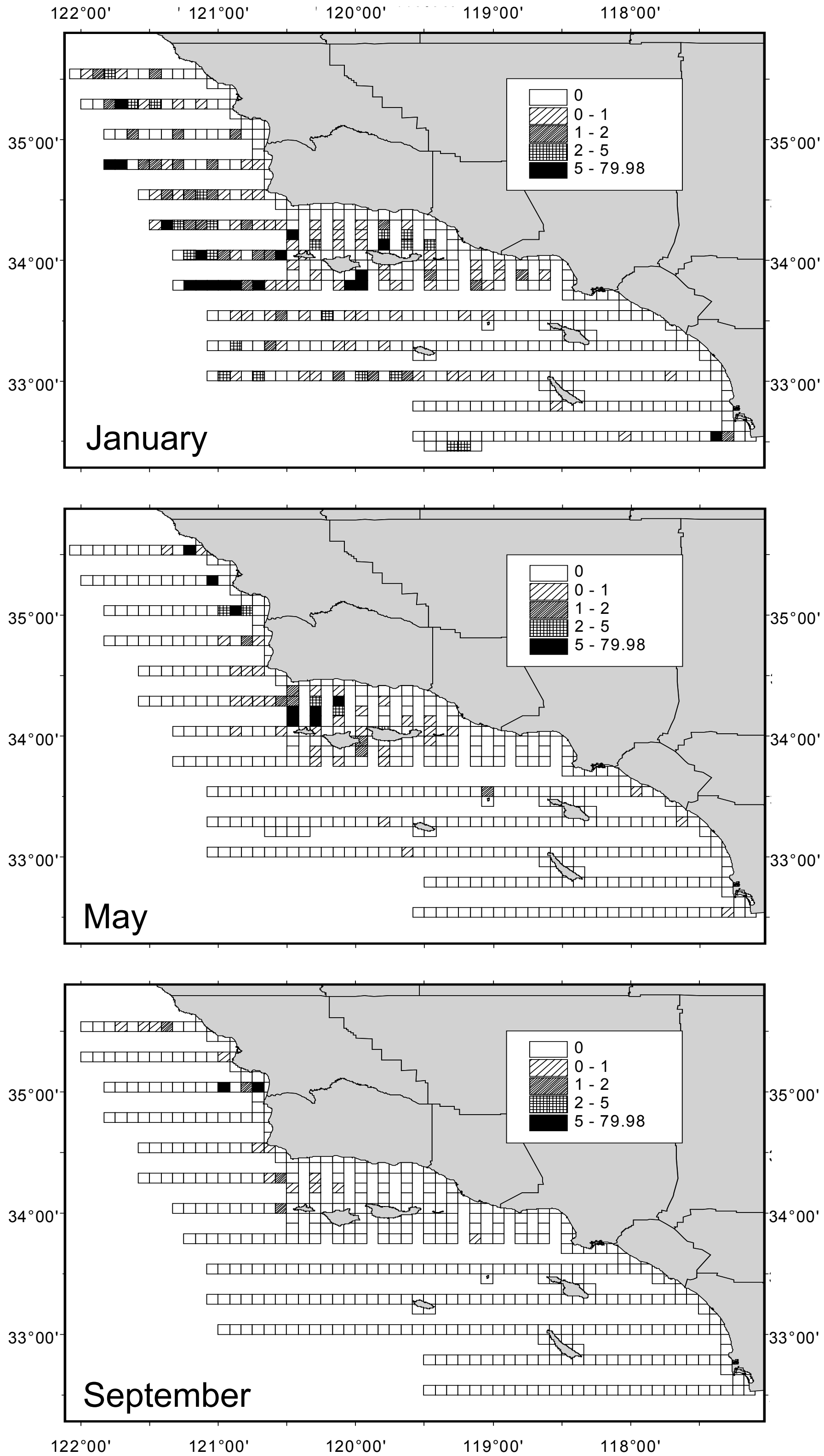


FIGURE 1.14. Cassin's Auklet densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

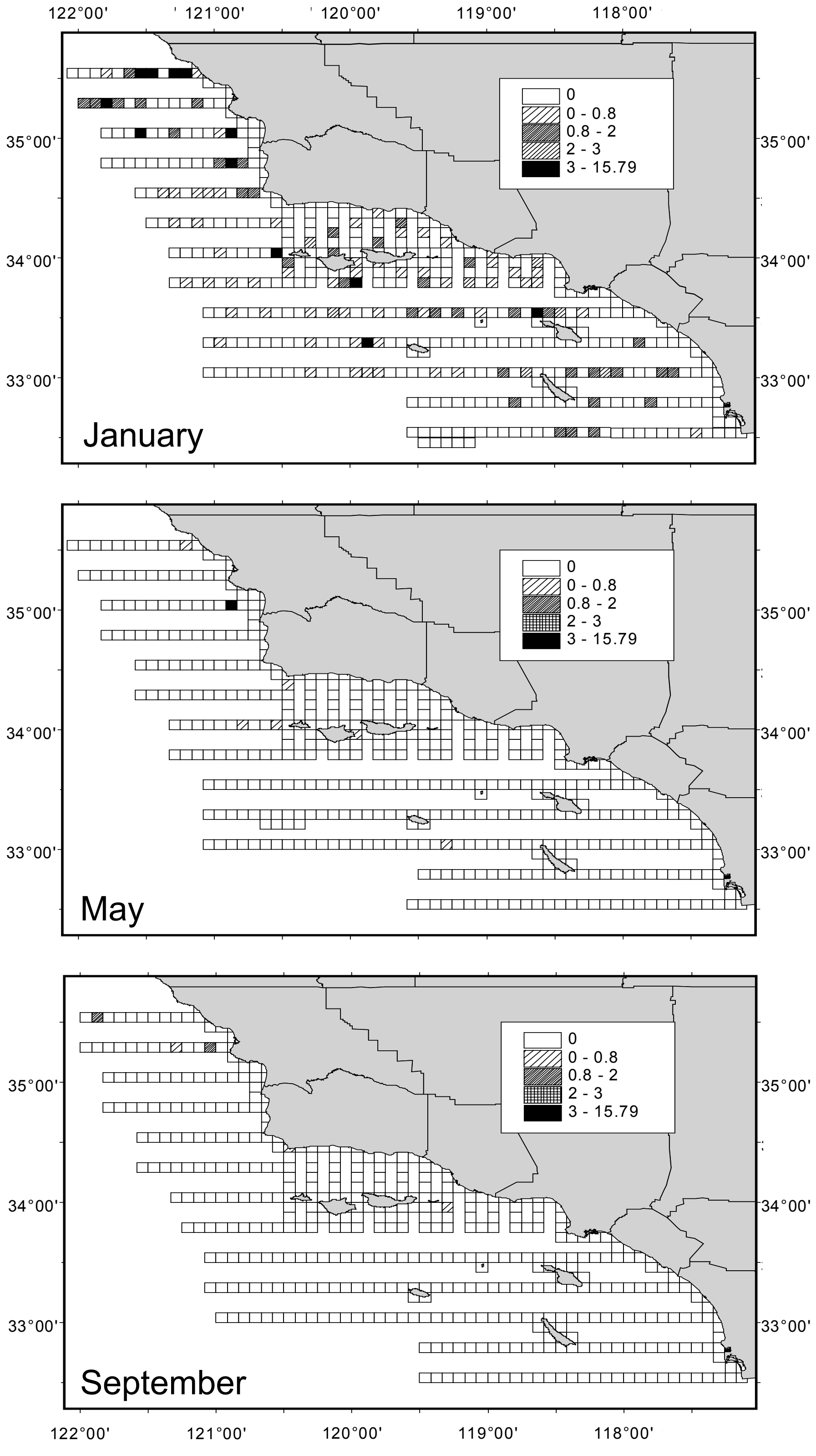


FIGURE 1.15. Rhinoceros Auklet densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

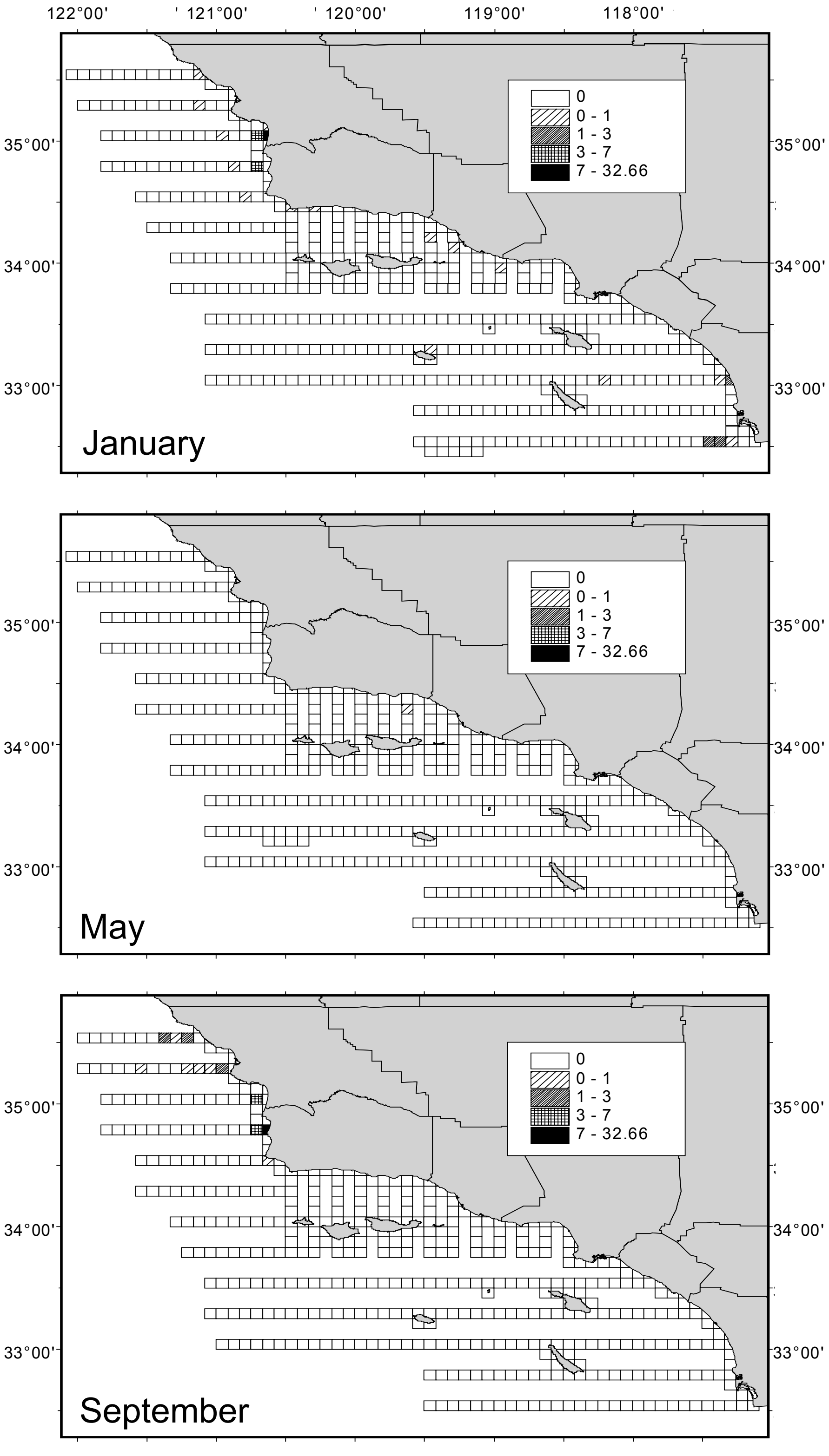


FIGURE 1.16. Common Murre densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

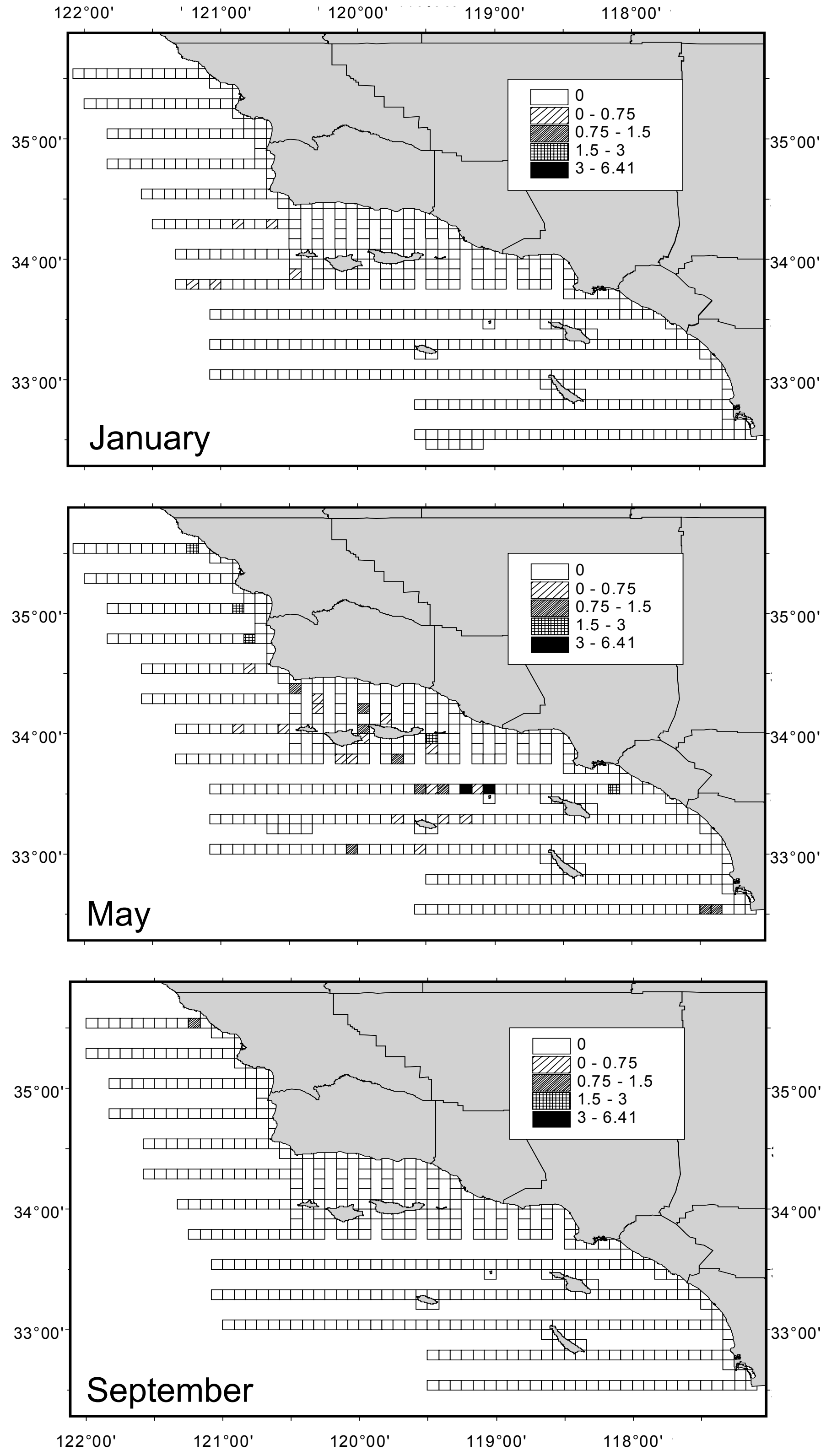


FIGURE 1.17. Xantus's Murrelet densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

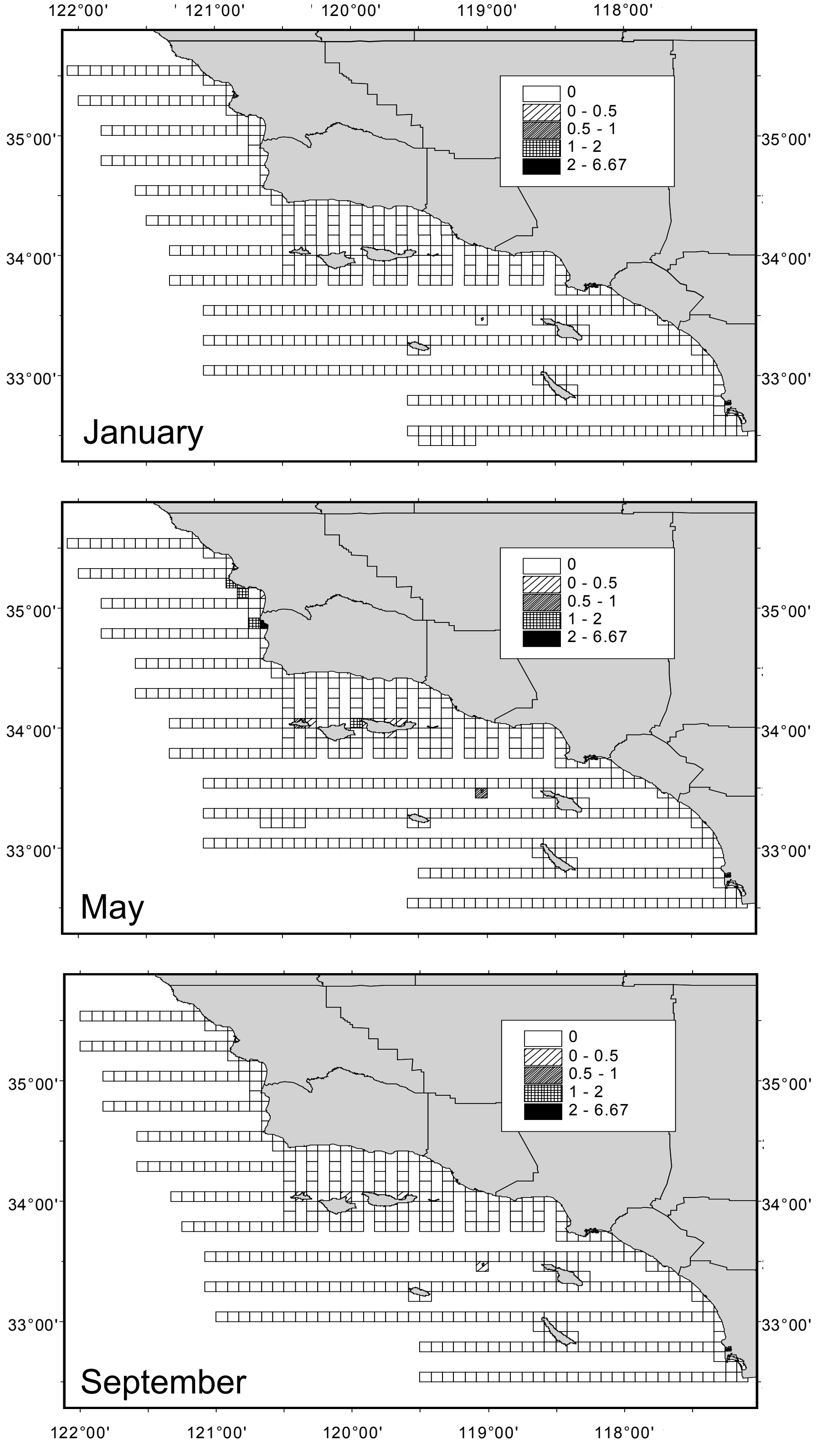


FIGURE 1.18. Pigeon Guillemot densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

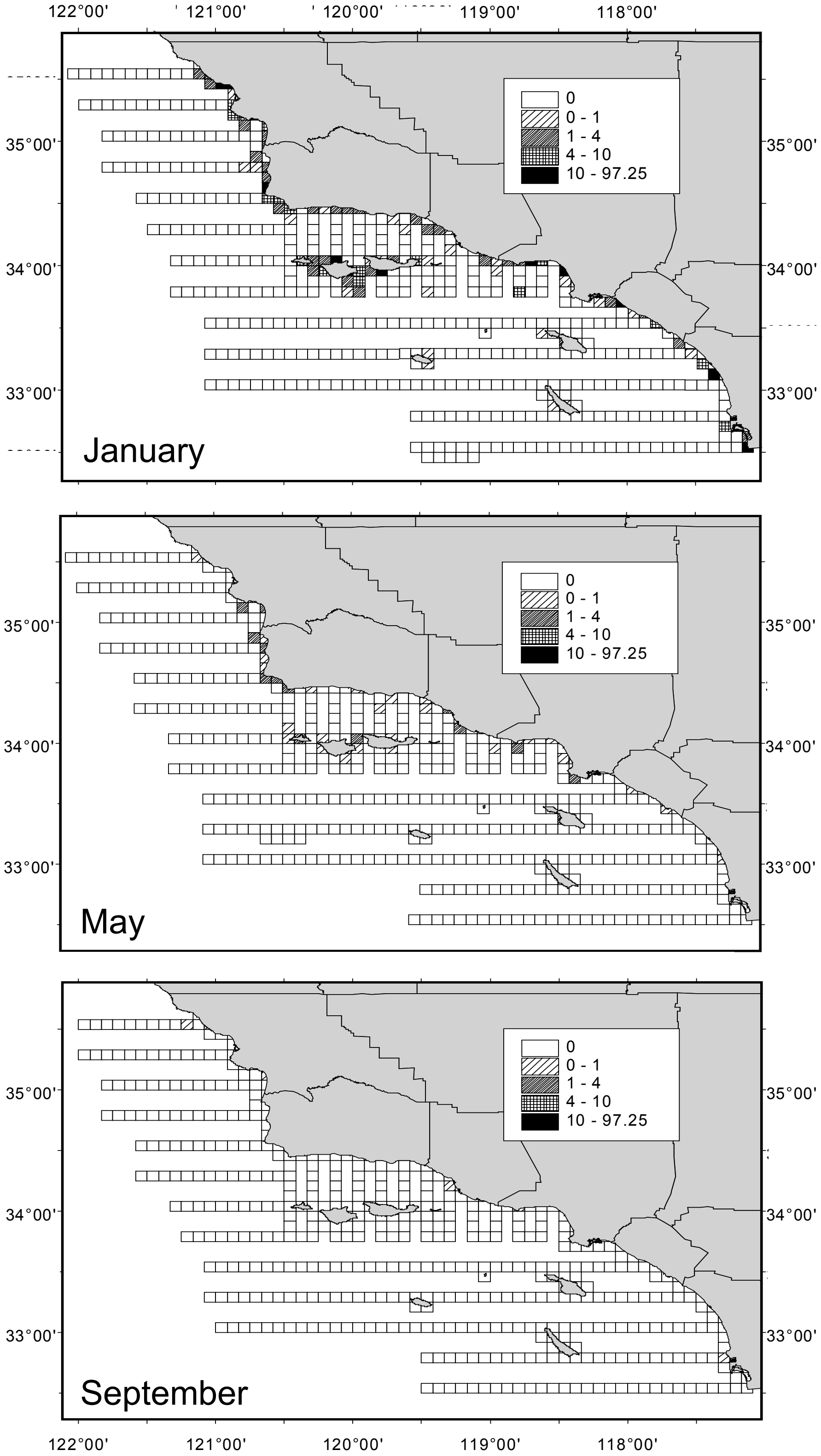


FIGURE 1.19. Loon densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

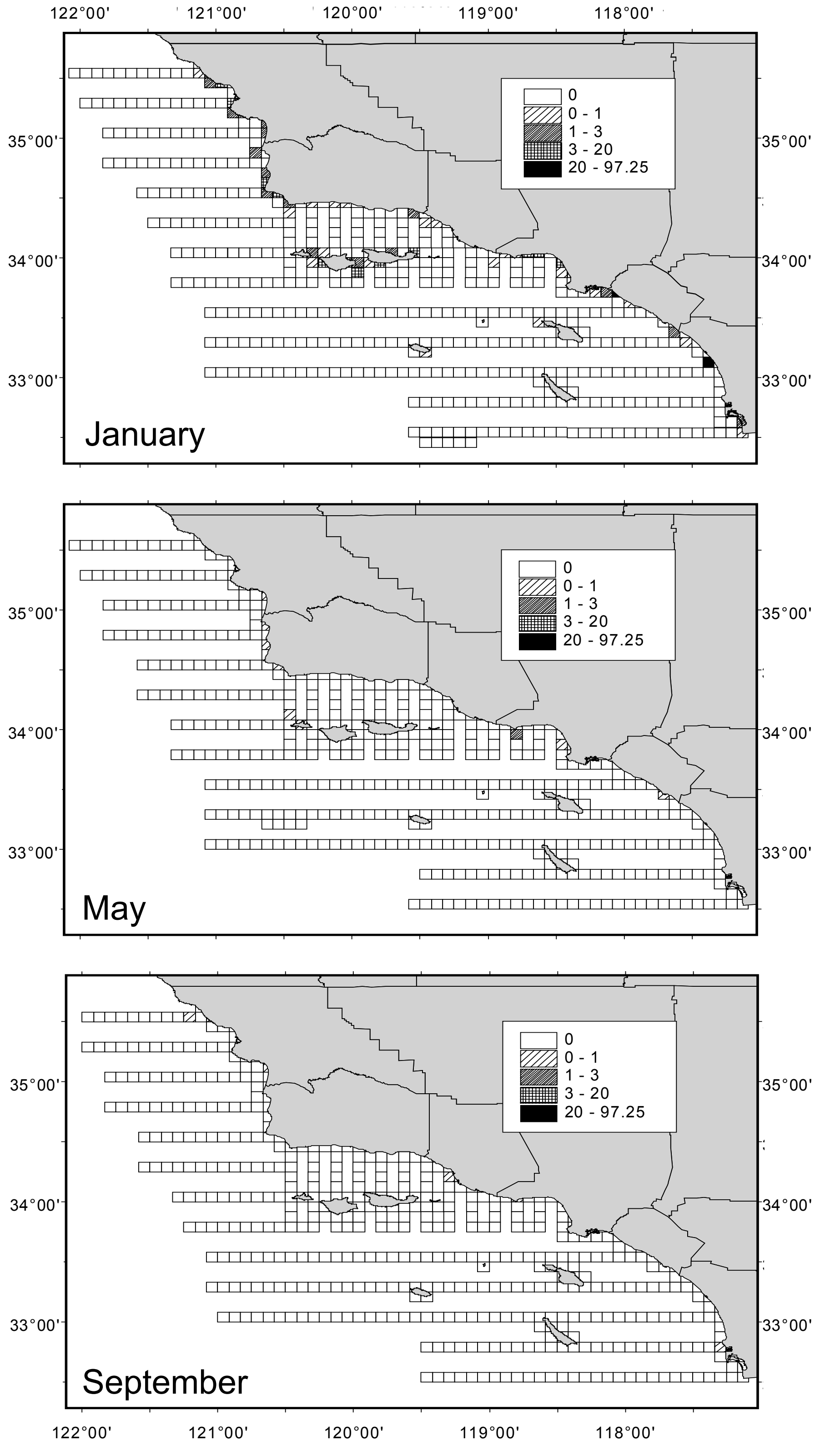


FIGURE 1.20. Unidentified loon densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

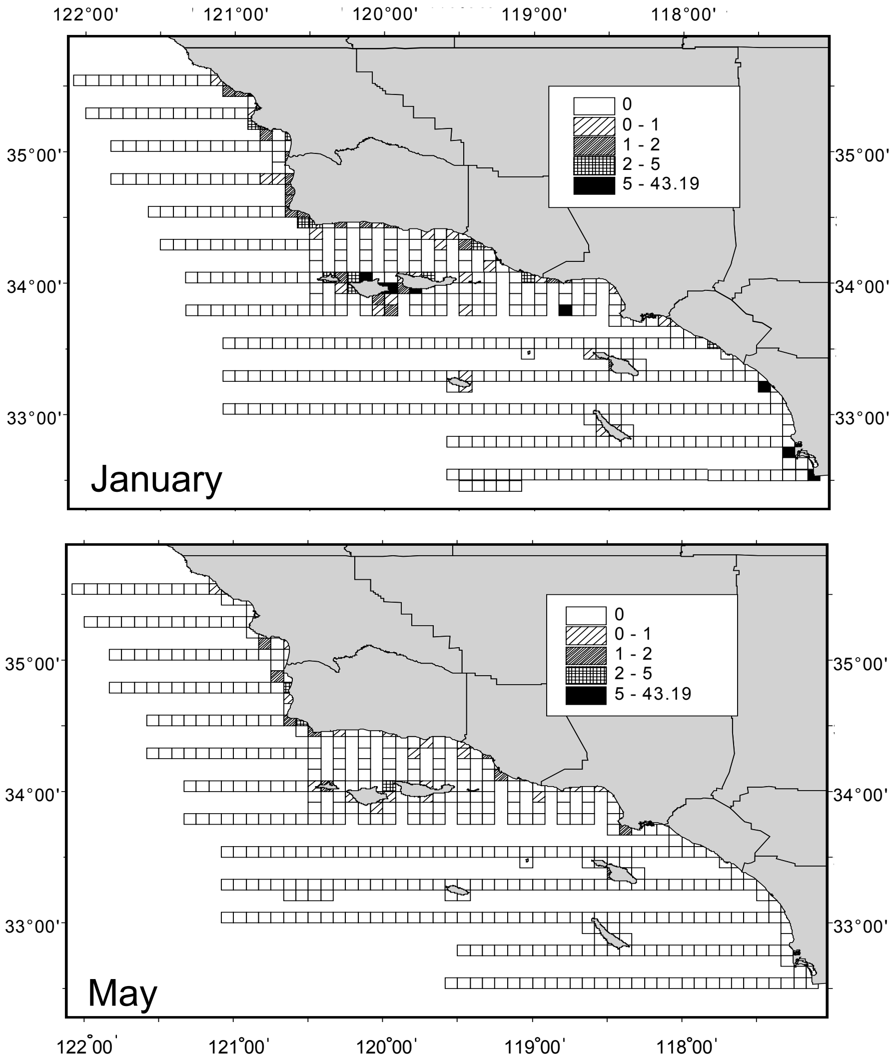
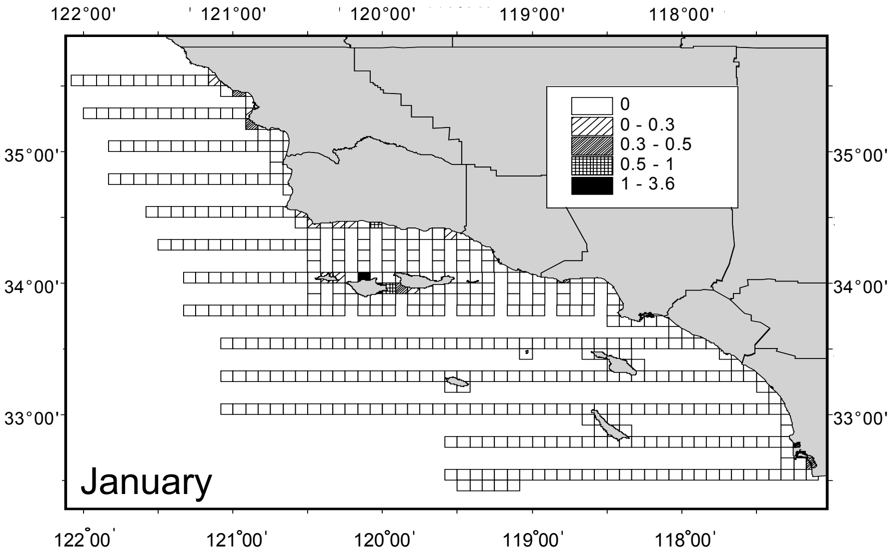


FIGURE 1.21. Pacific Loon densities (birds/km^2) and distribution off southern California from 1999–2002 during January and May. No Pacific Loons were observed during September.



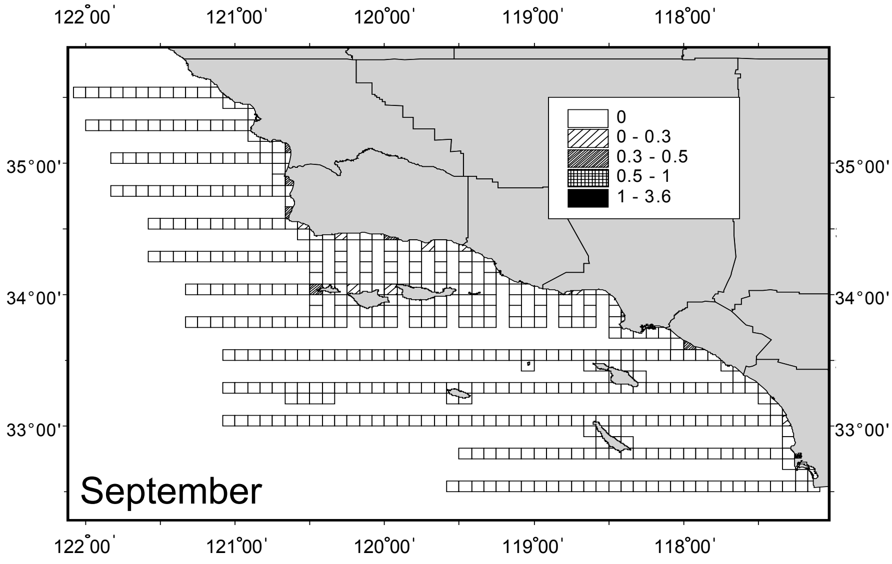


FIGURE 1.22. Common Loon densities (birds/km^2) and distribution off southern California from 1999–2002 during January and September. No Common Loons were observed during May.

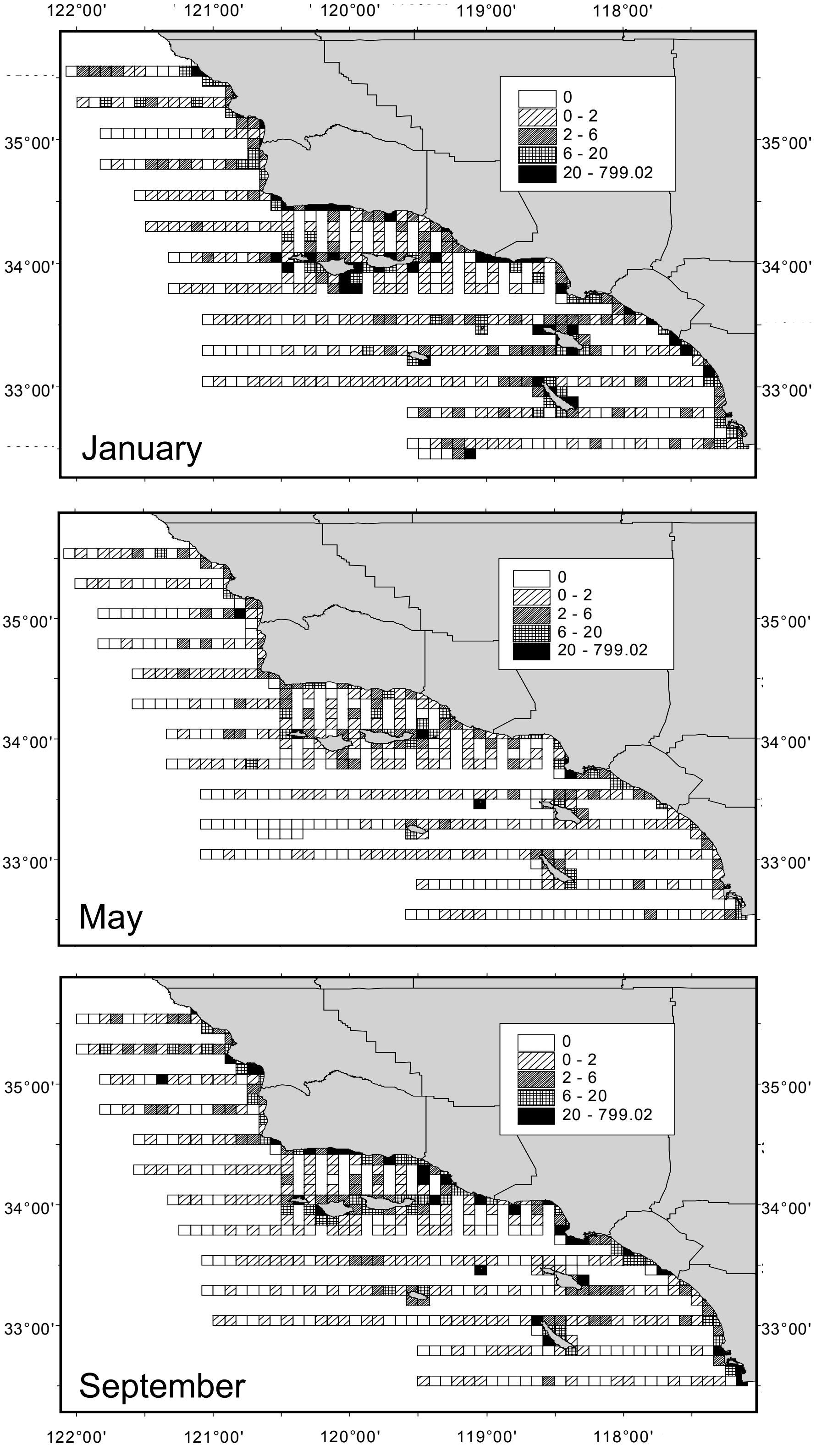


FIGURE 1.23. Larid densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

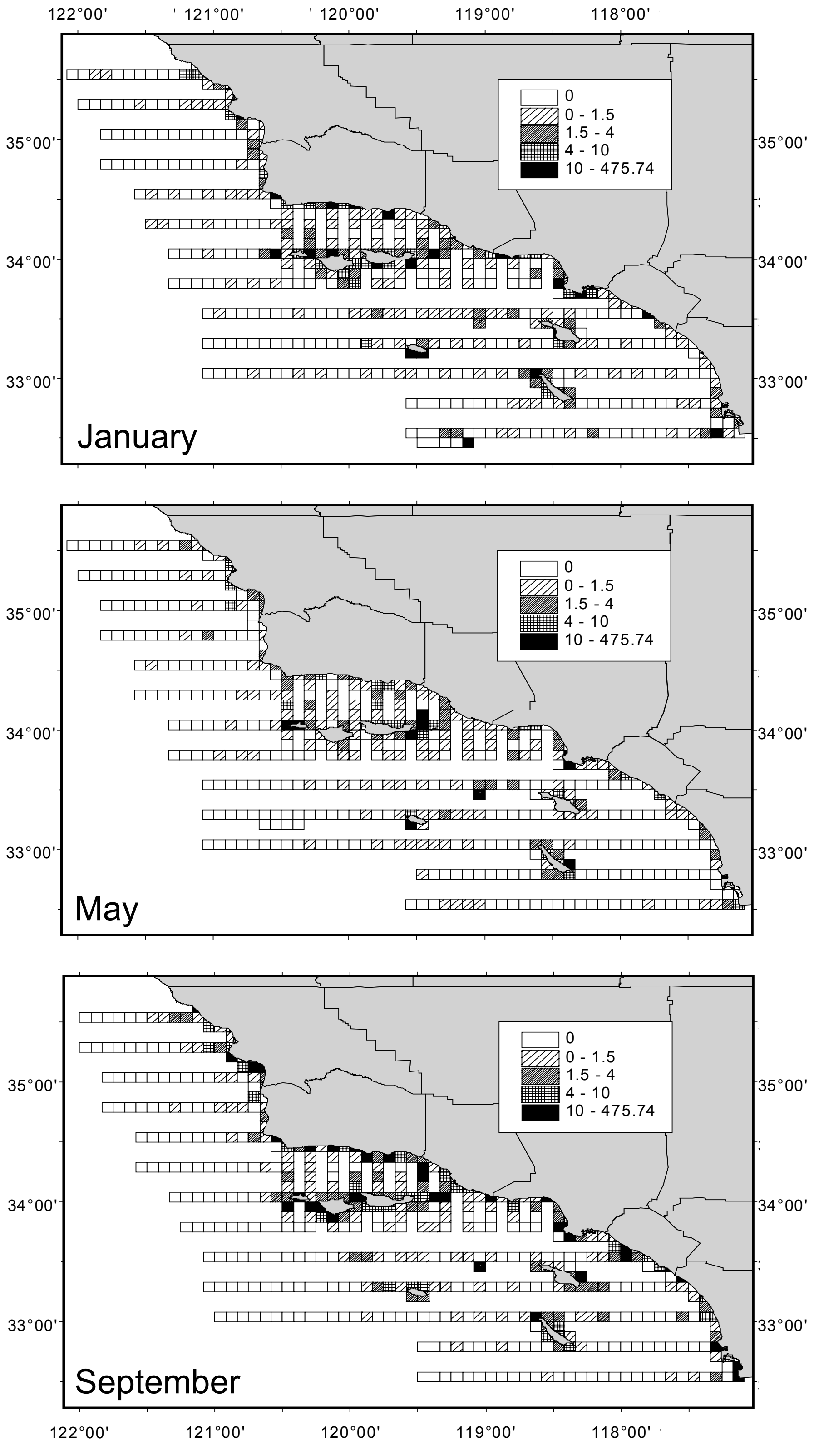


FIGURE 1.24. Western Gull densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

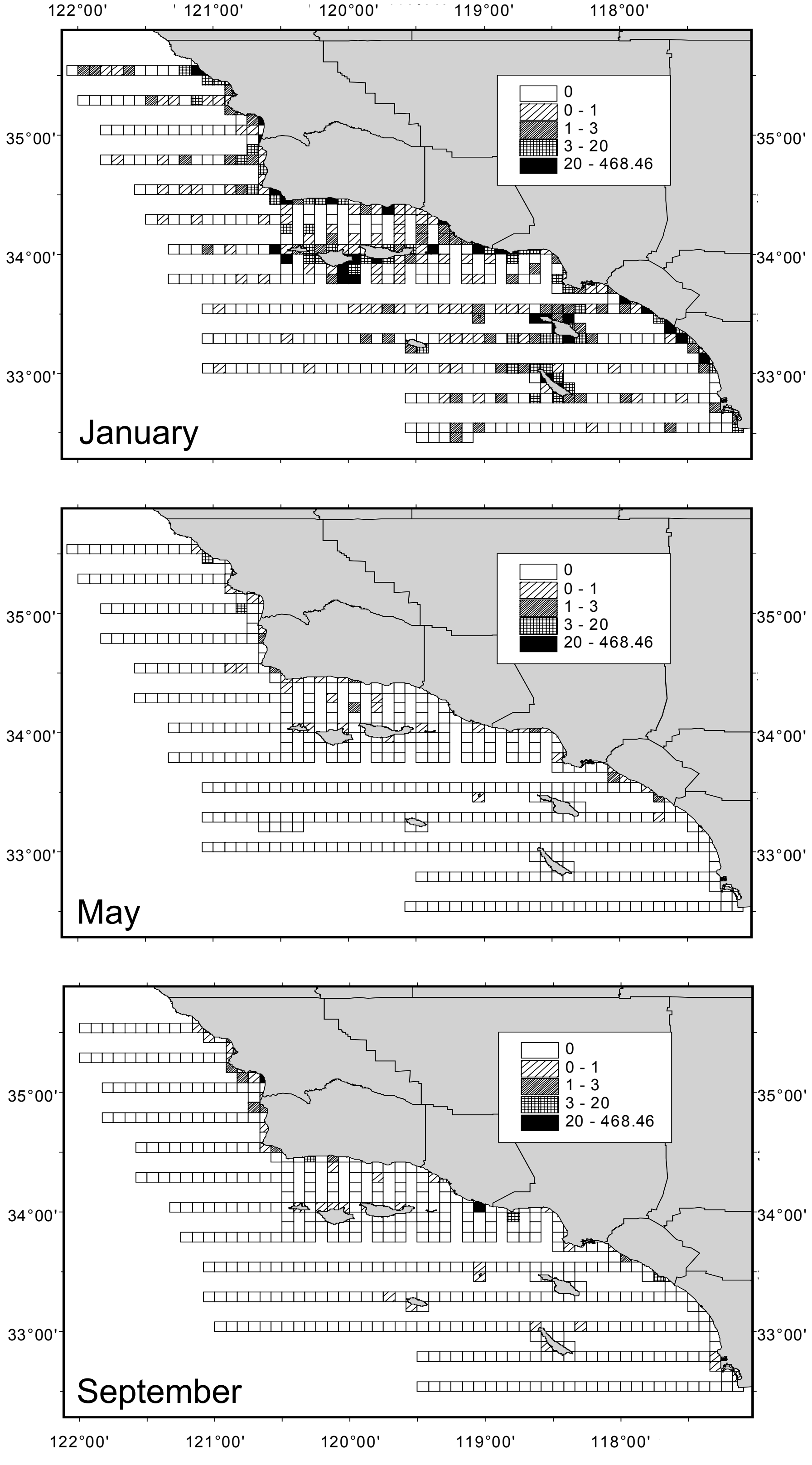


FIGURE 1.25. California Gull densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

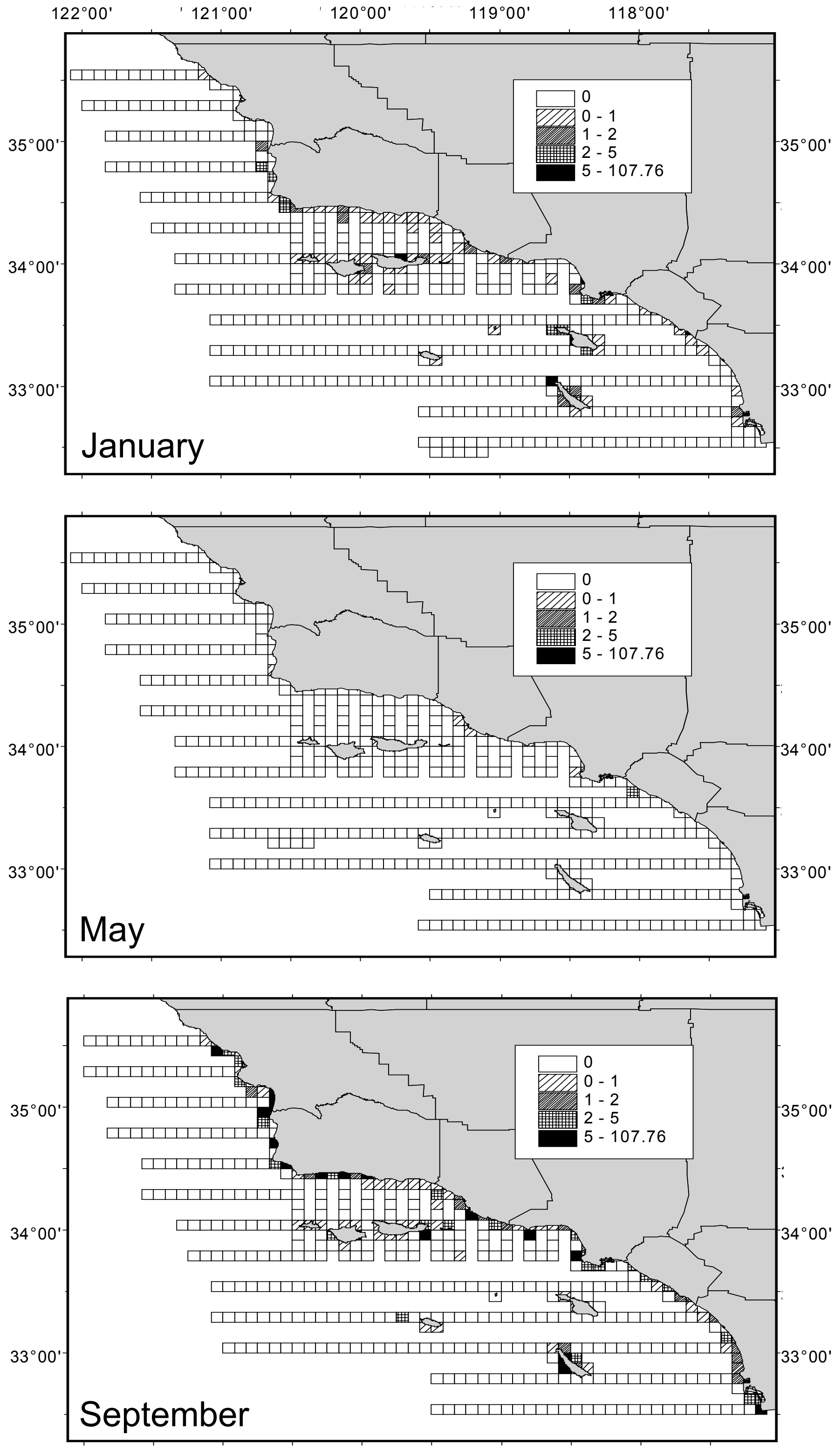


FIGURE 1.26. Heermann's Gull densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

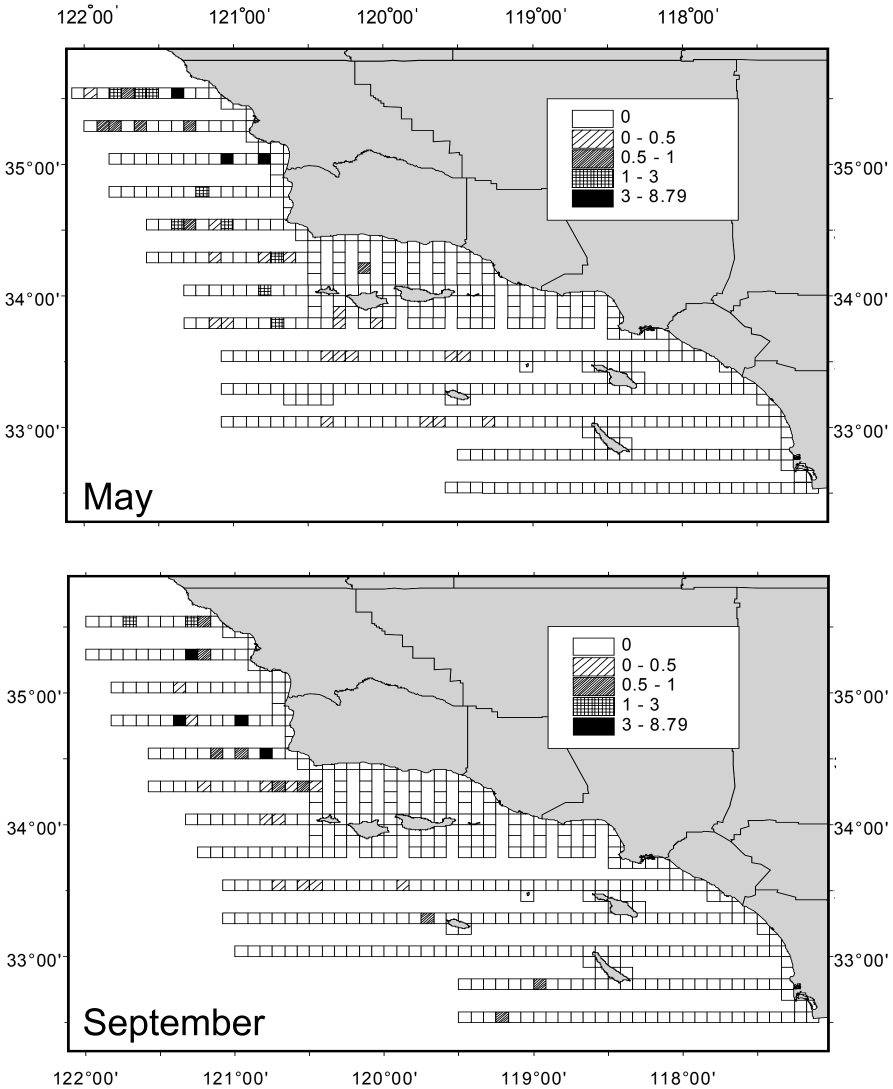


FIGURE 1.27. Sabine's Gull densities (birds/km^2) and distribution off southern California from 1999–2002 during May and September. No Sabine's Gulls were observed during January.

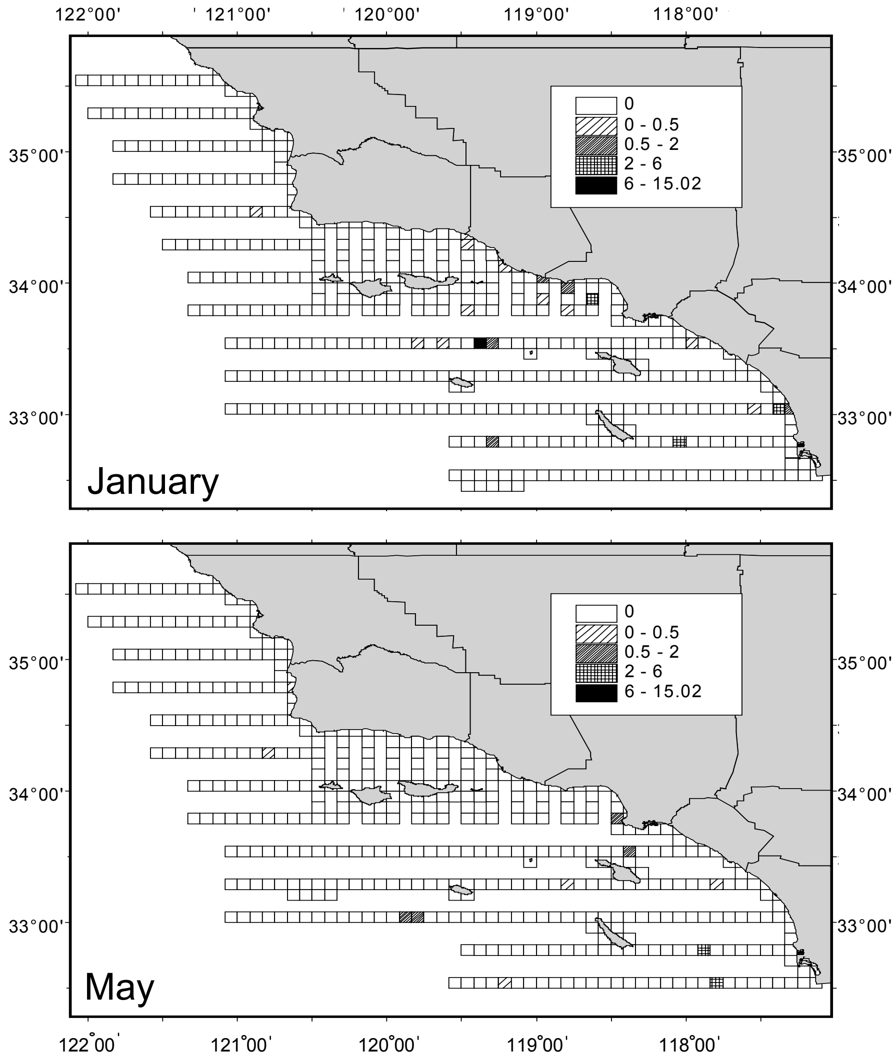


FIGURE 1.28. Bonaparte's Gull densities (birds/km^2) and distribution off southern California from 1999–2002 during January and May. No Bonaparte's Gulls were observed during September.

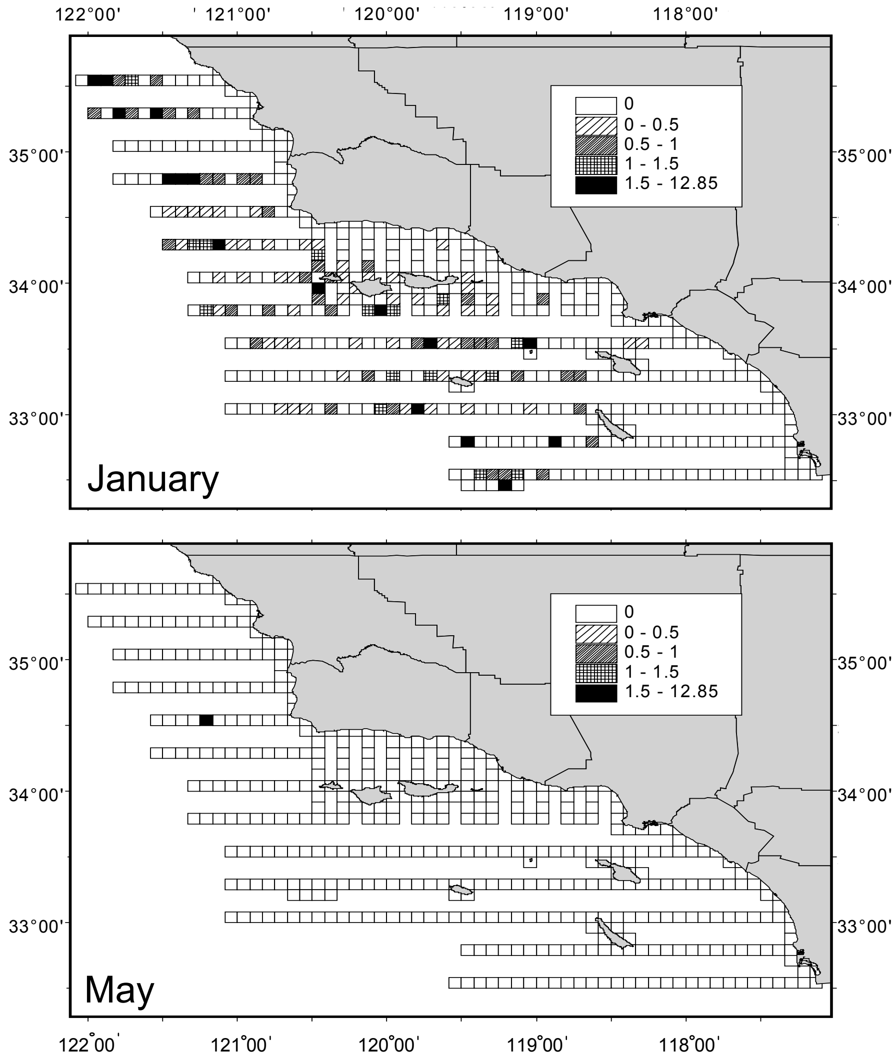


FIGURE 1.29. Black-legged Kittiwake densities (birds/km^2) and distribution off southern California from 1999–2002 during January and May. No Black-legged Kittiwakes were observed during September.

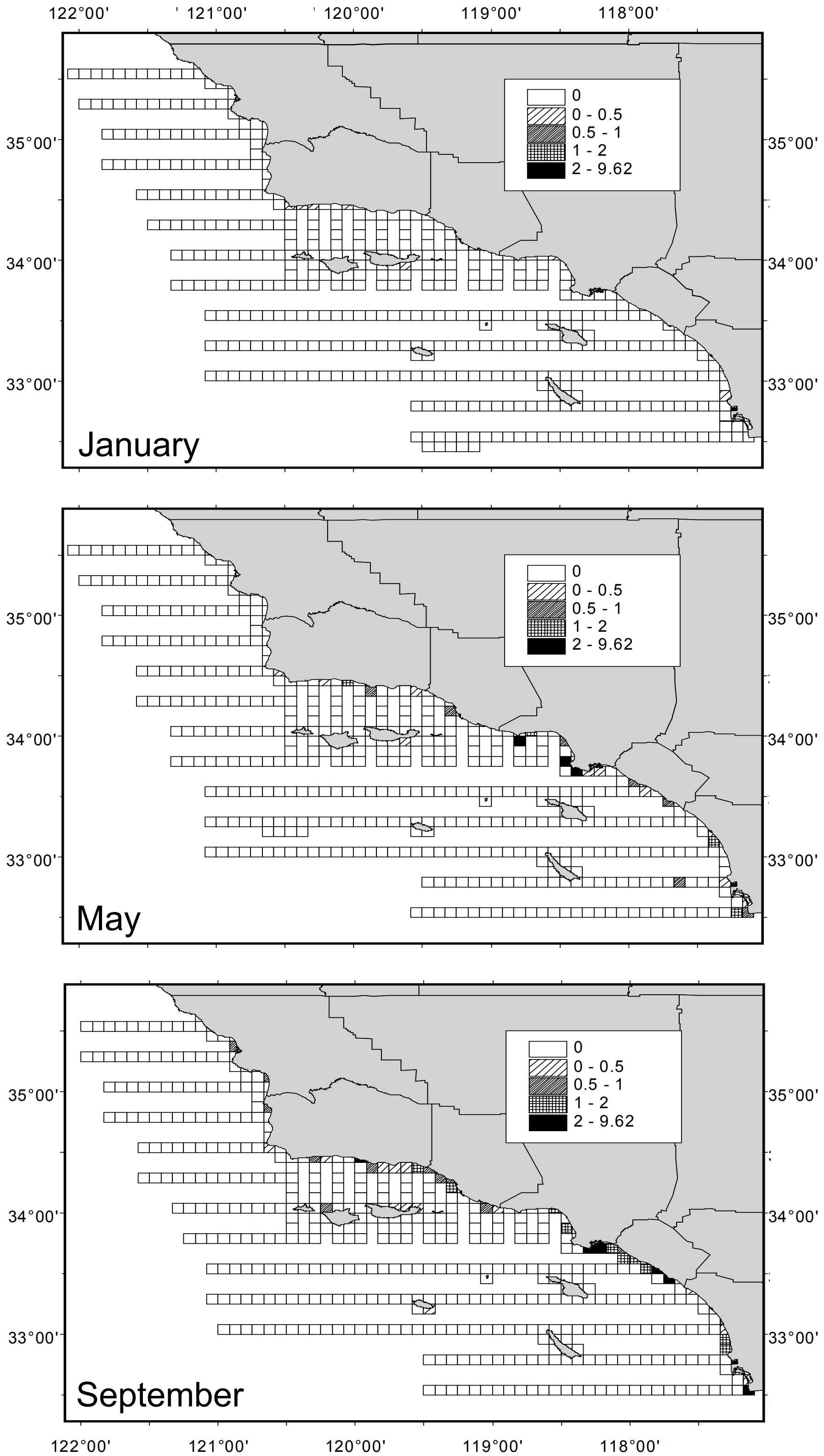


FIGURE 1.30. Caspian Tern densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

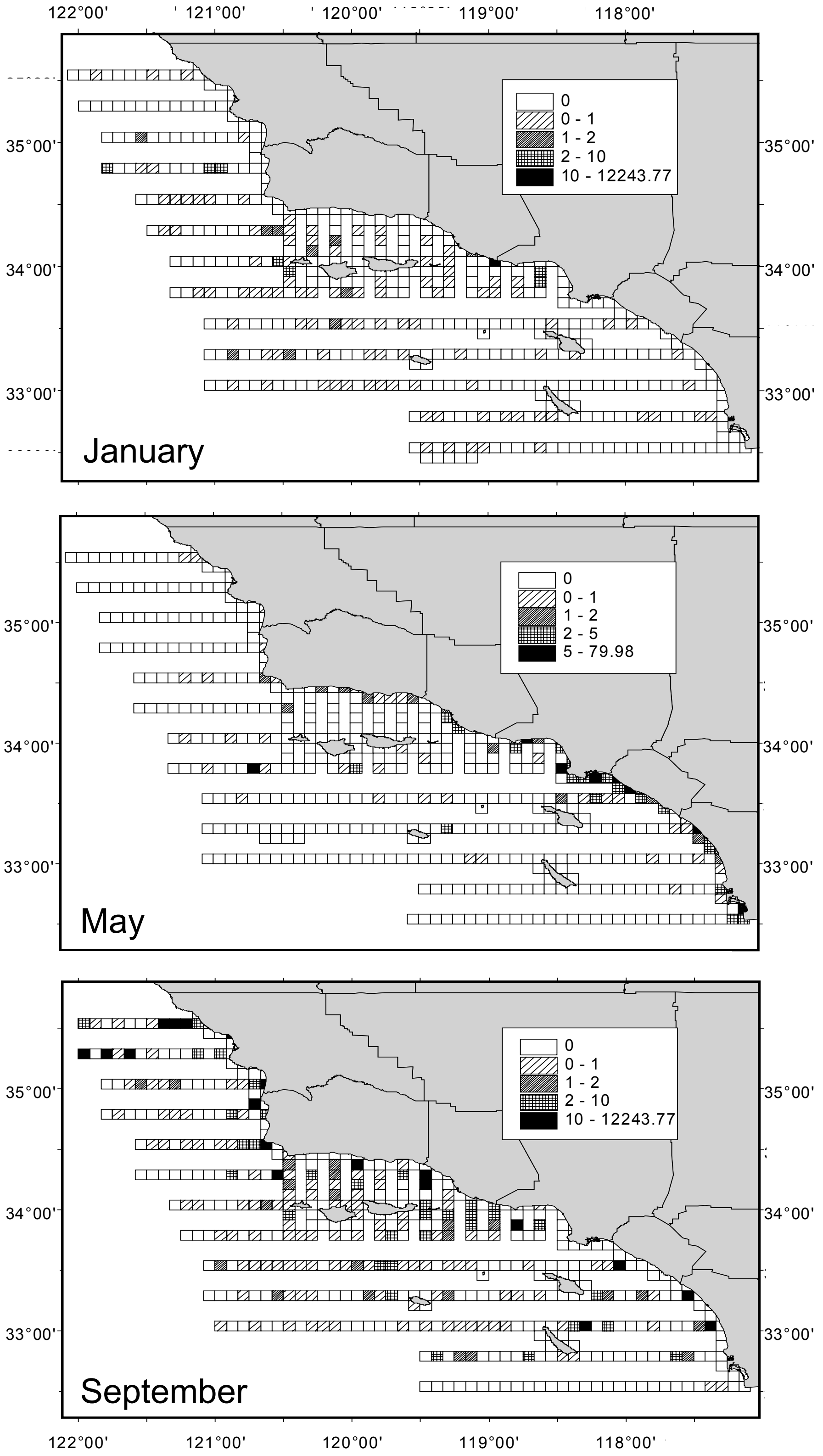


FIGURE 1.31. Procellariid densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

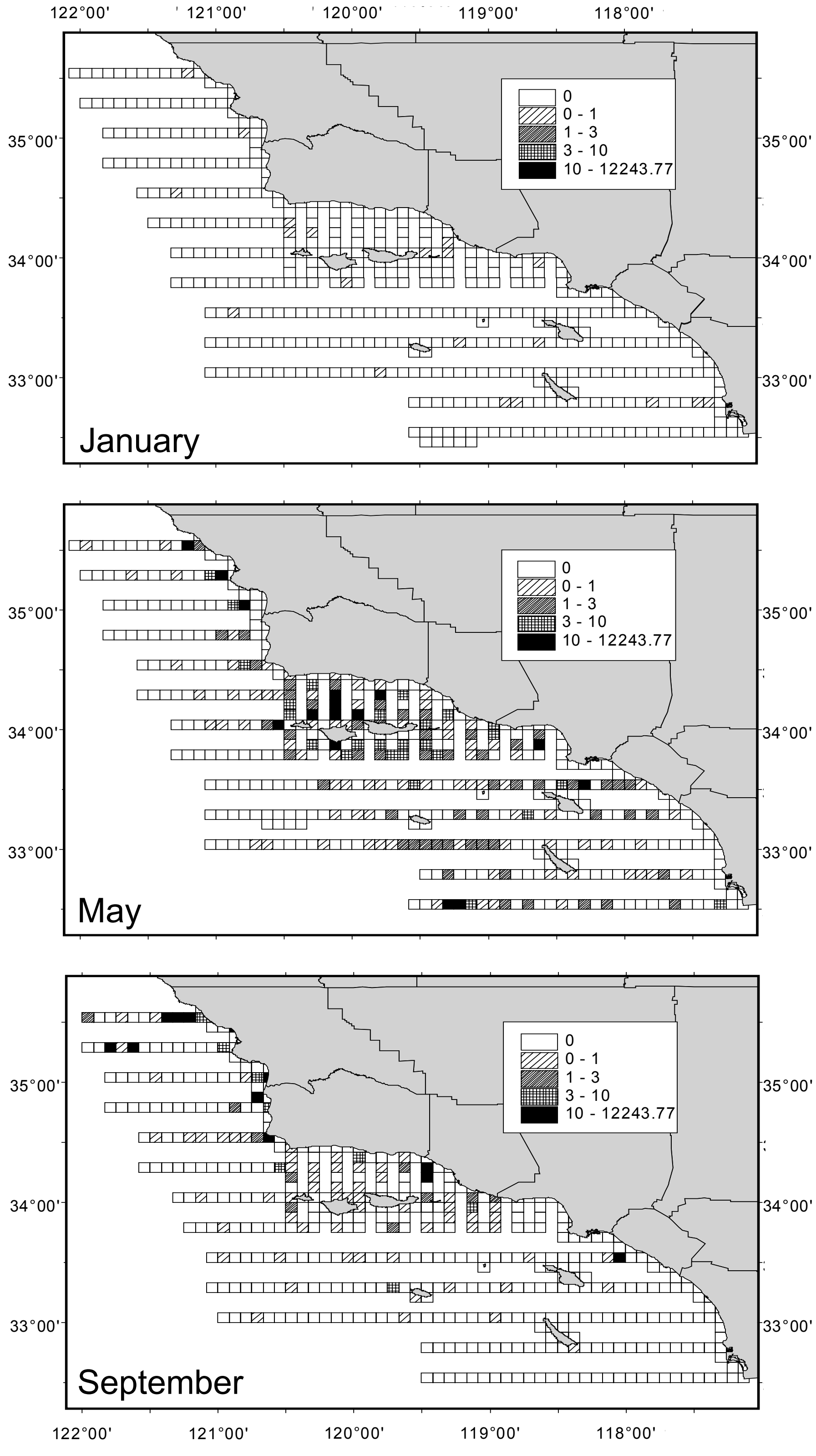


FIGURE 1.32. Sooty Shearwater densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

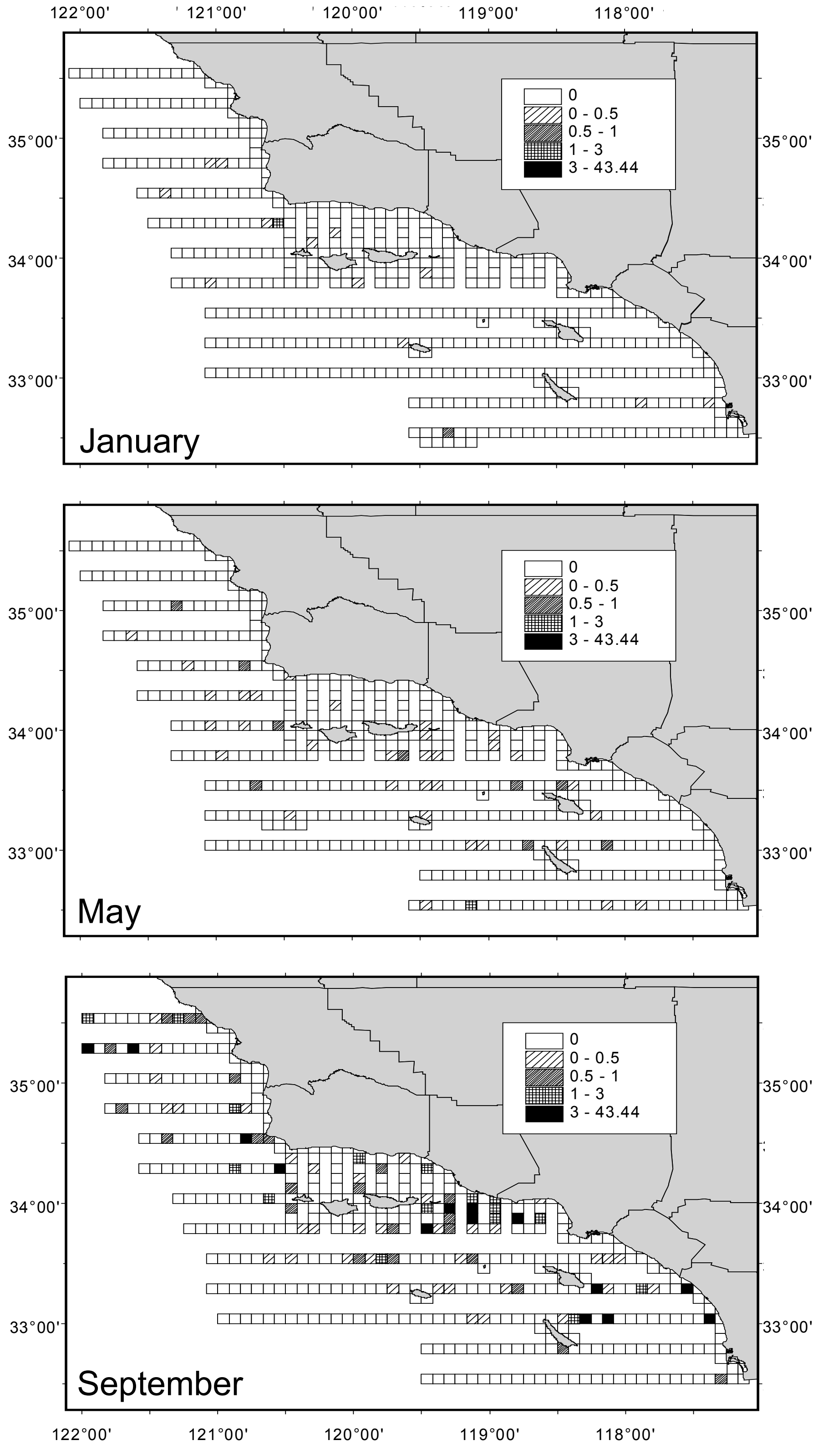


FIGURE 1.33. Pink-footed Shearwater densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

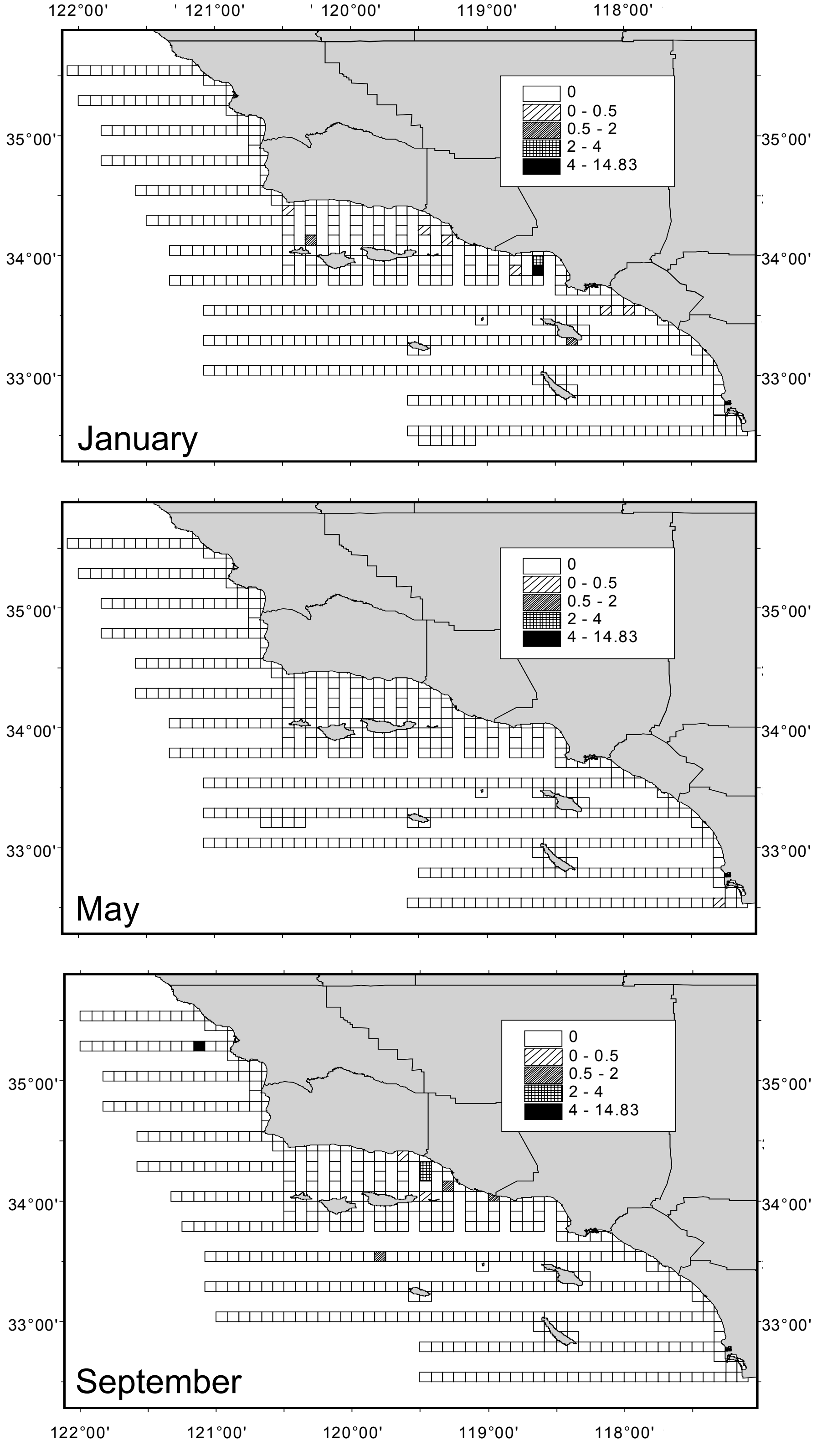


FIGURE 1.34. Black-vented Shearwater densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

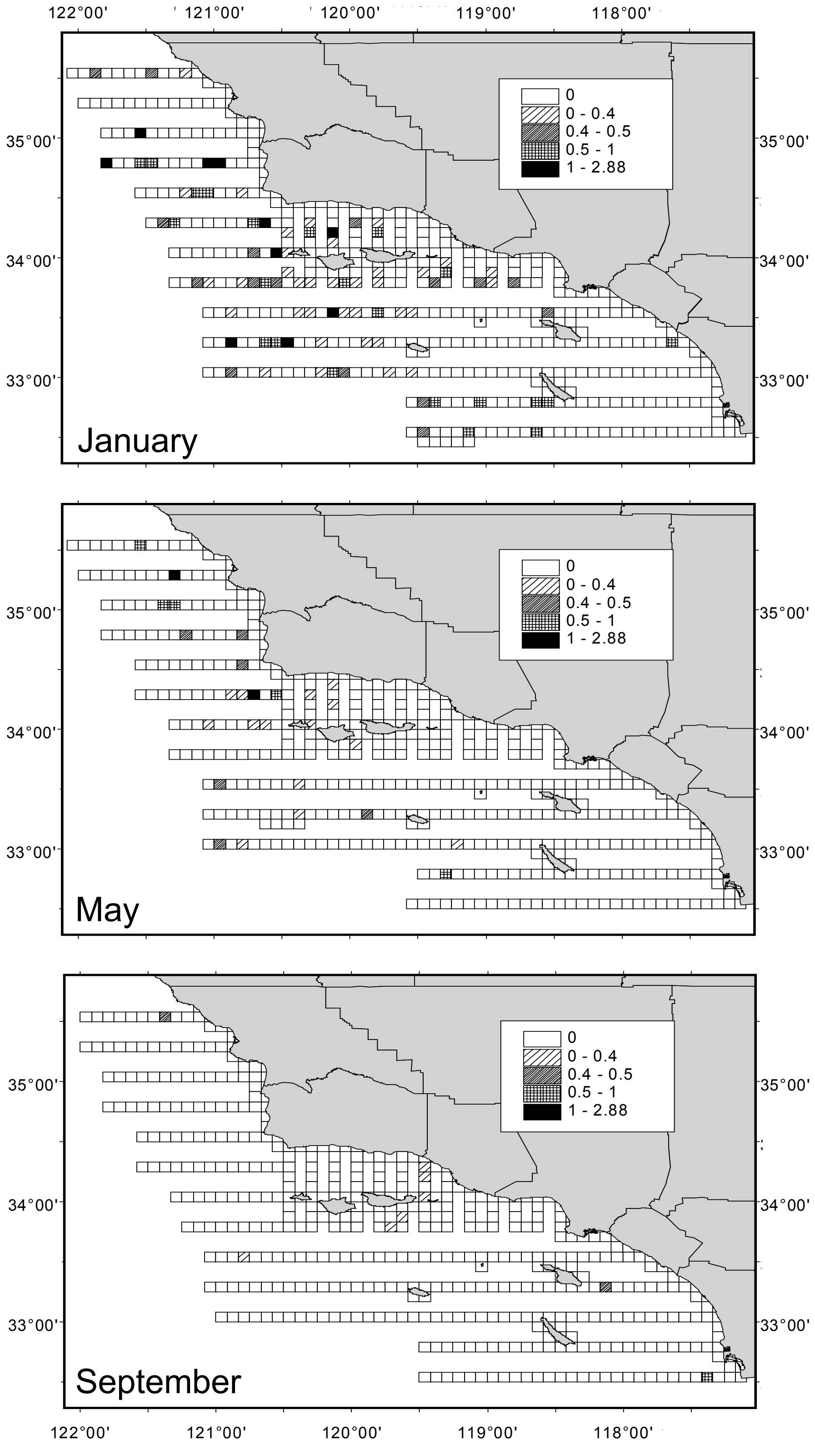


FIGURE 1.35. Northern Fulmar densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

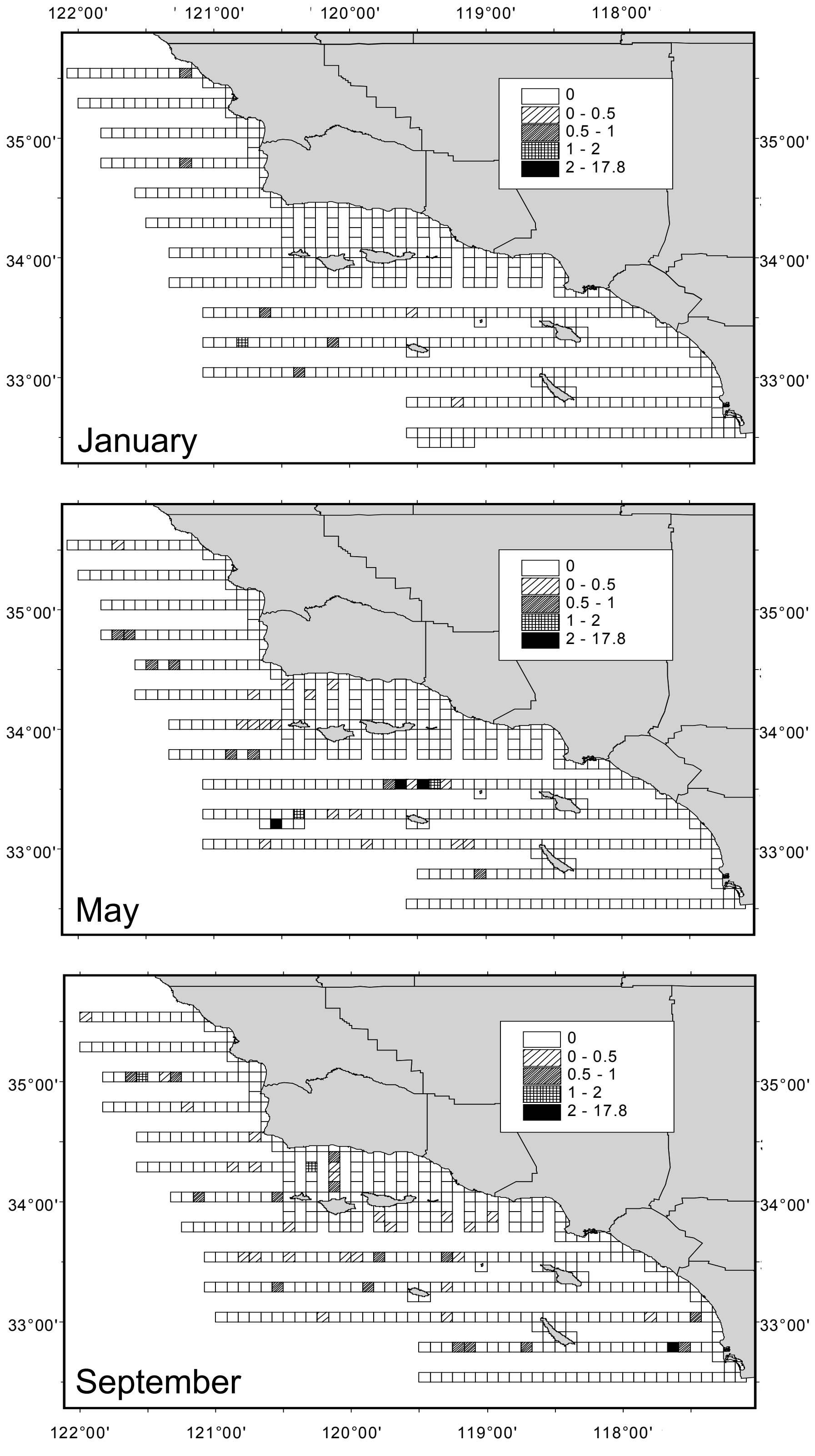


FIGURE 1.36. Ashy Storm-petrel densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

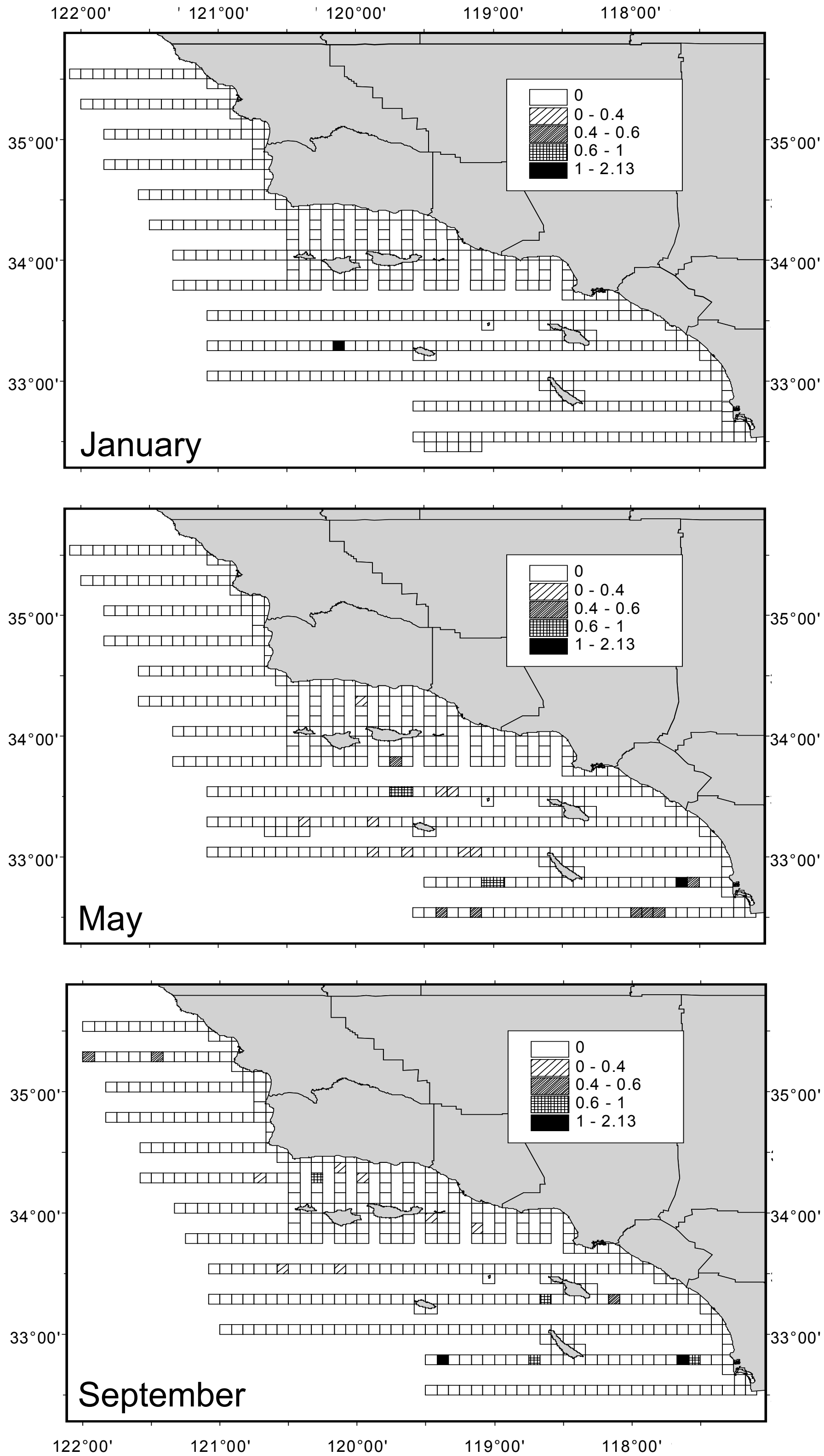


FIGURE 1.37. Black Storm-petrel densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

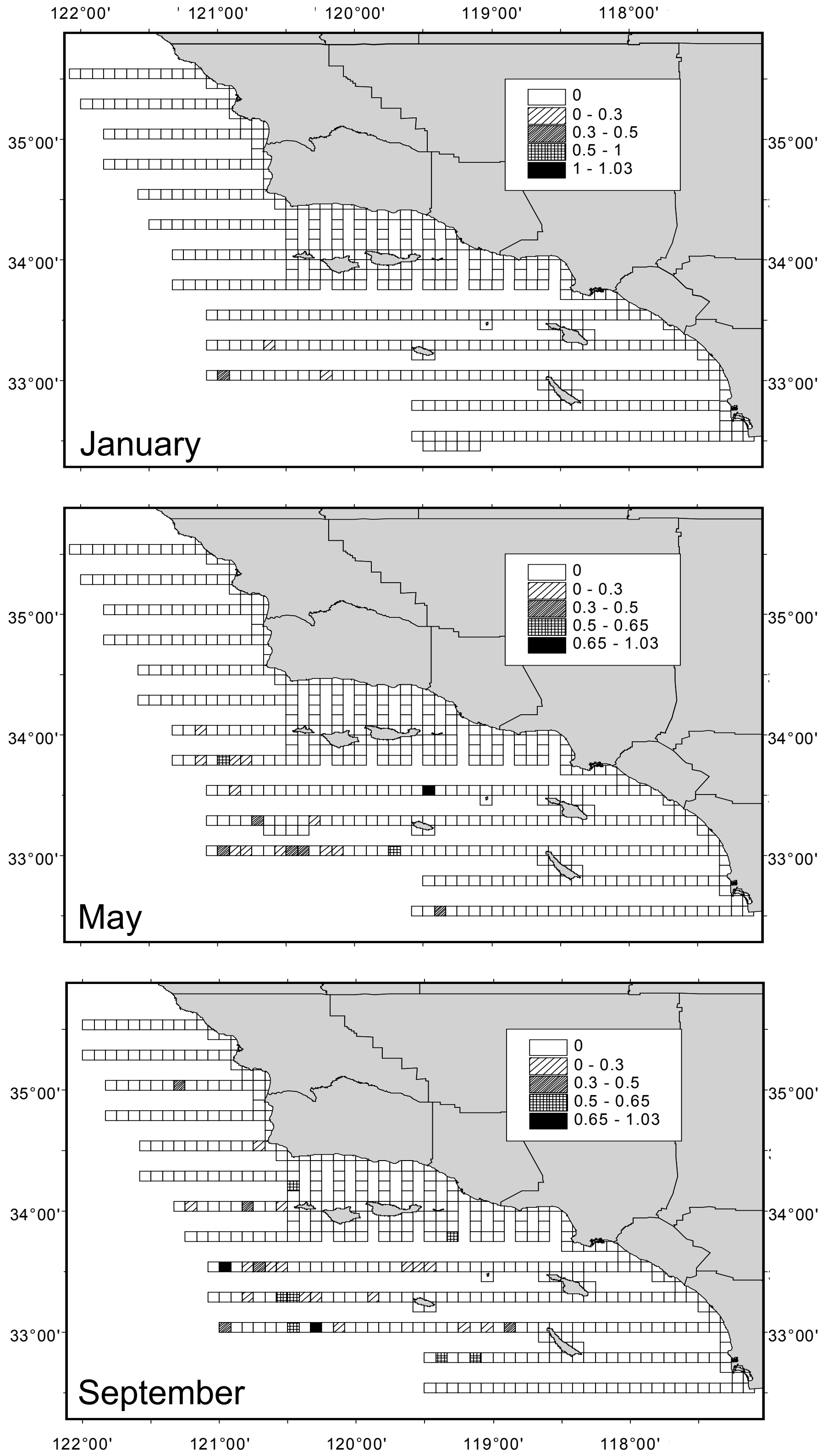


FIGURE 1.38. Leach's Storm-petrel densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

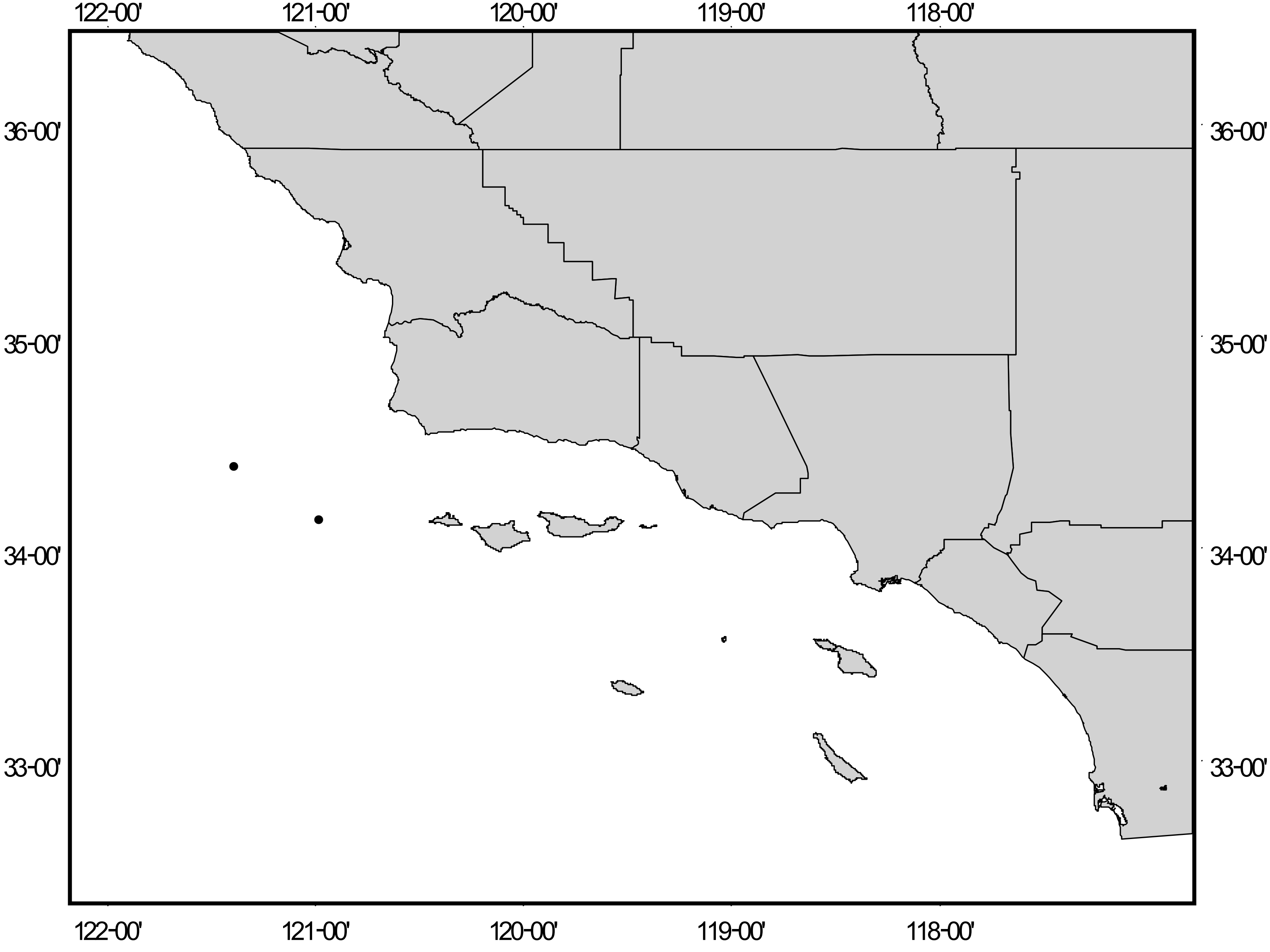


FIGURE 1.39. Laysan Albatross sightings off southern California during January of 2000 and 2001.

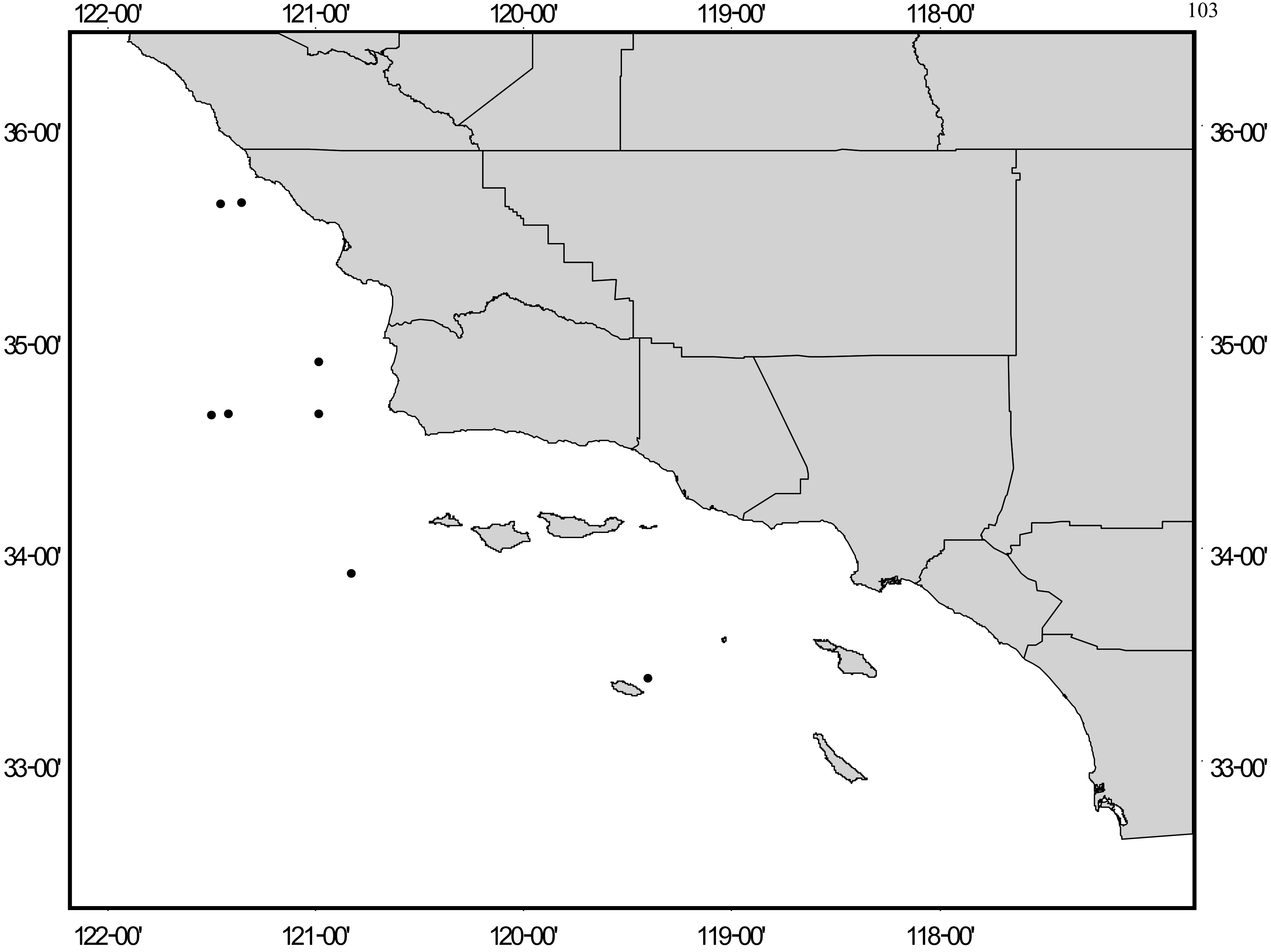


FIGURE 1.40. Black-footed Albatross sightings off southern California during January and May of 2000 and January and September of 2001.

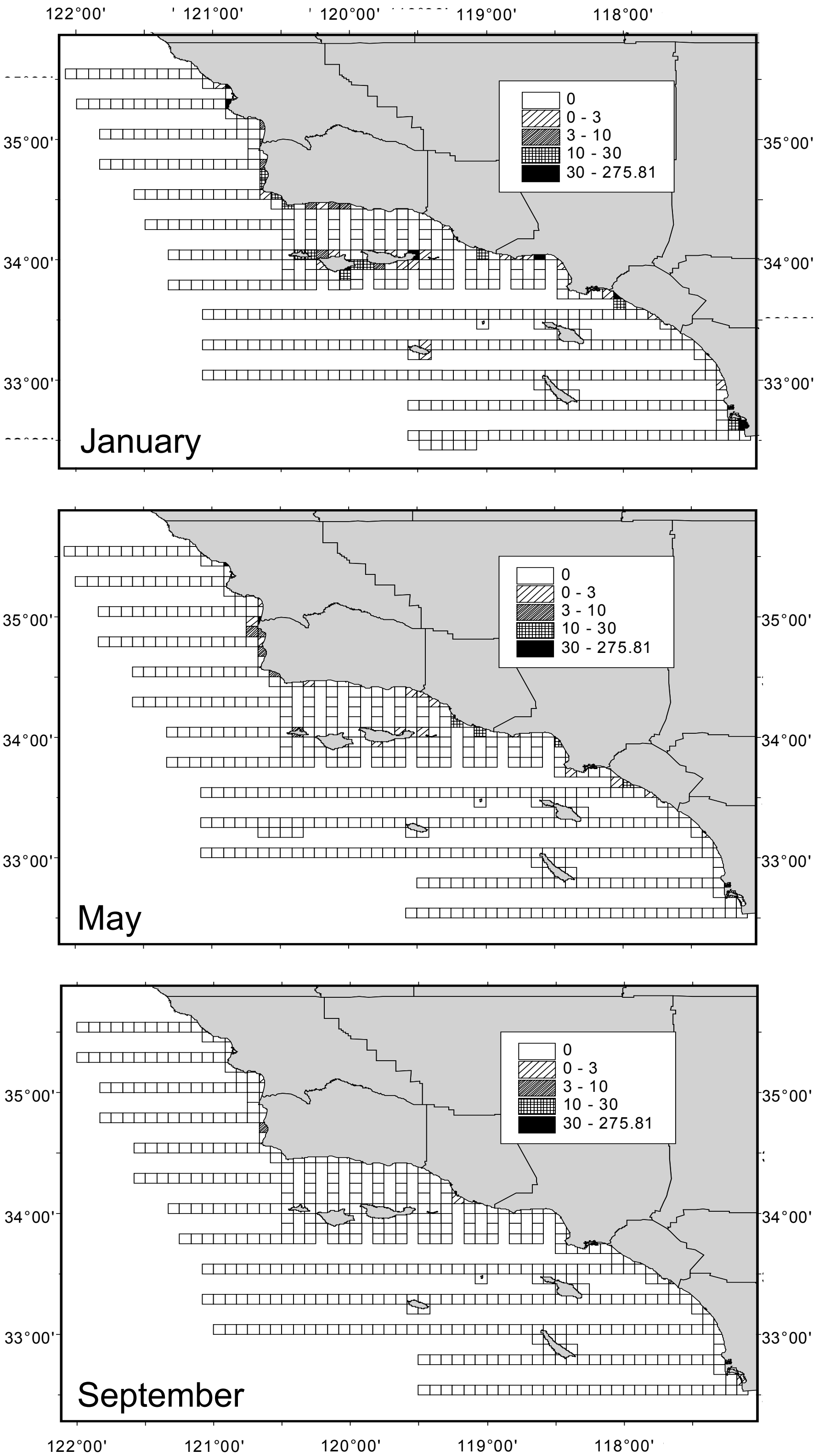


FIGURE 1.41. Surf Scoter densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

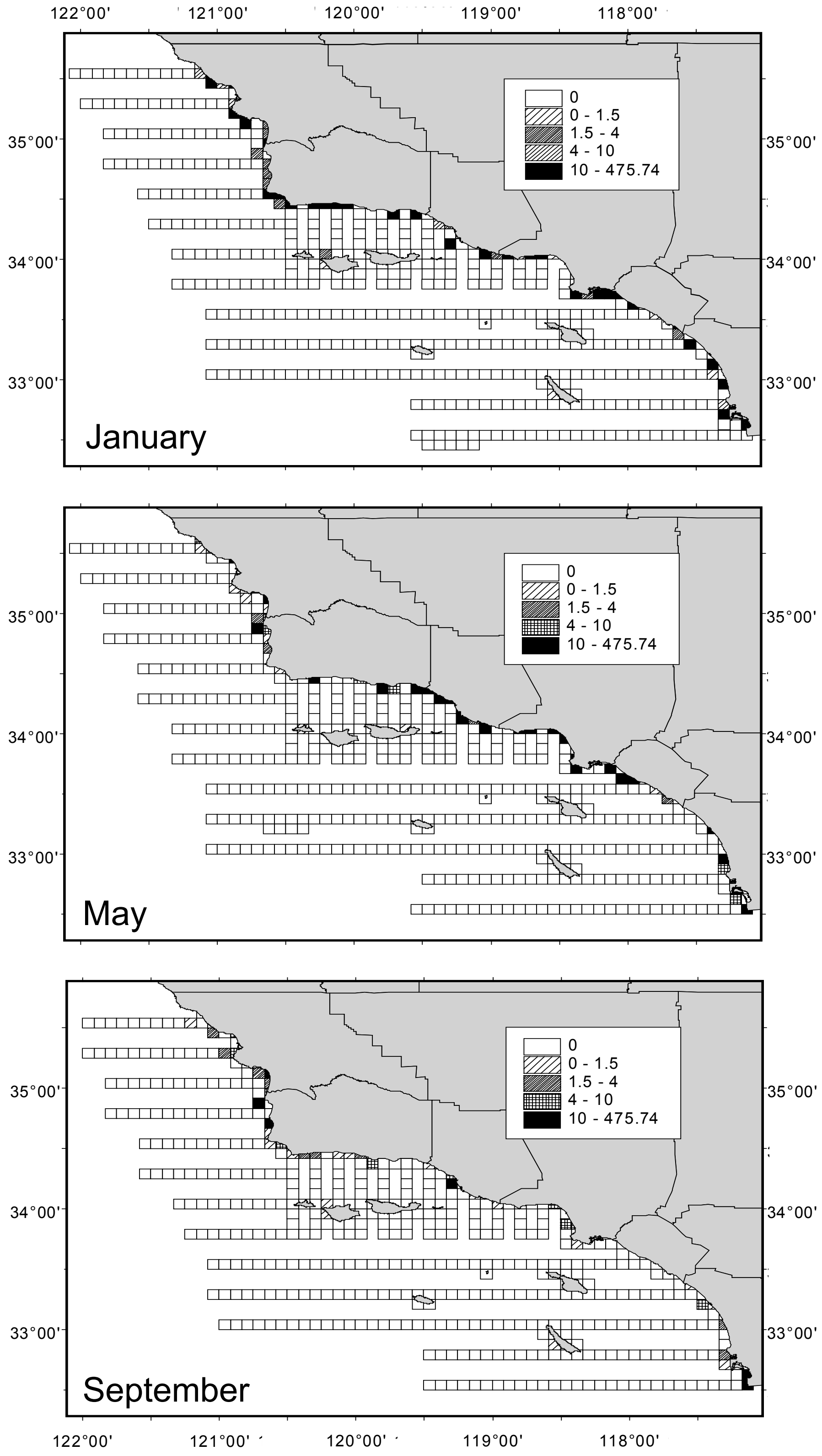


FIGURE 1.42. Western Grebe densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

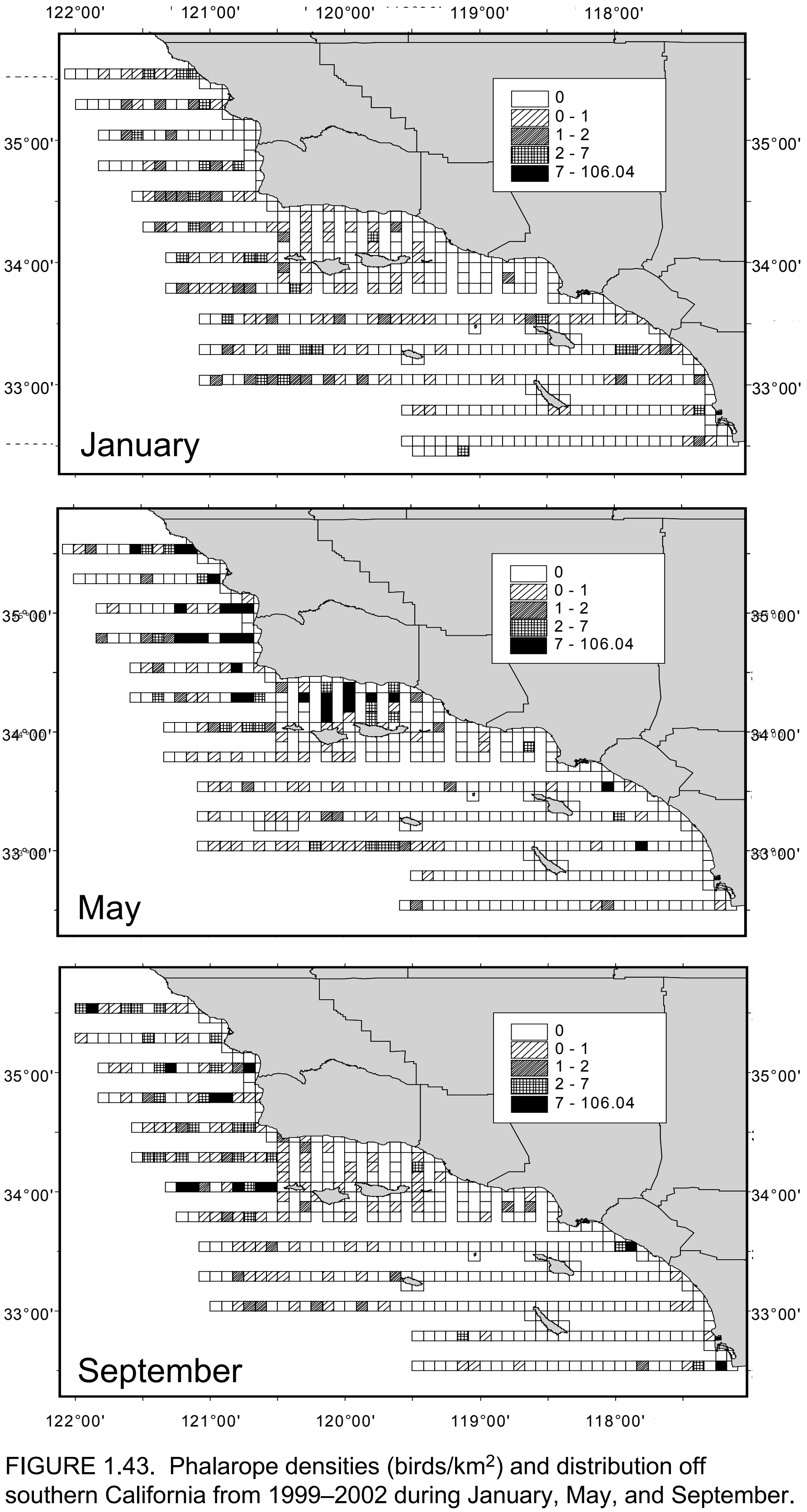


FIGURE 1.43. Phalarope densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

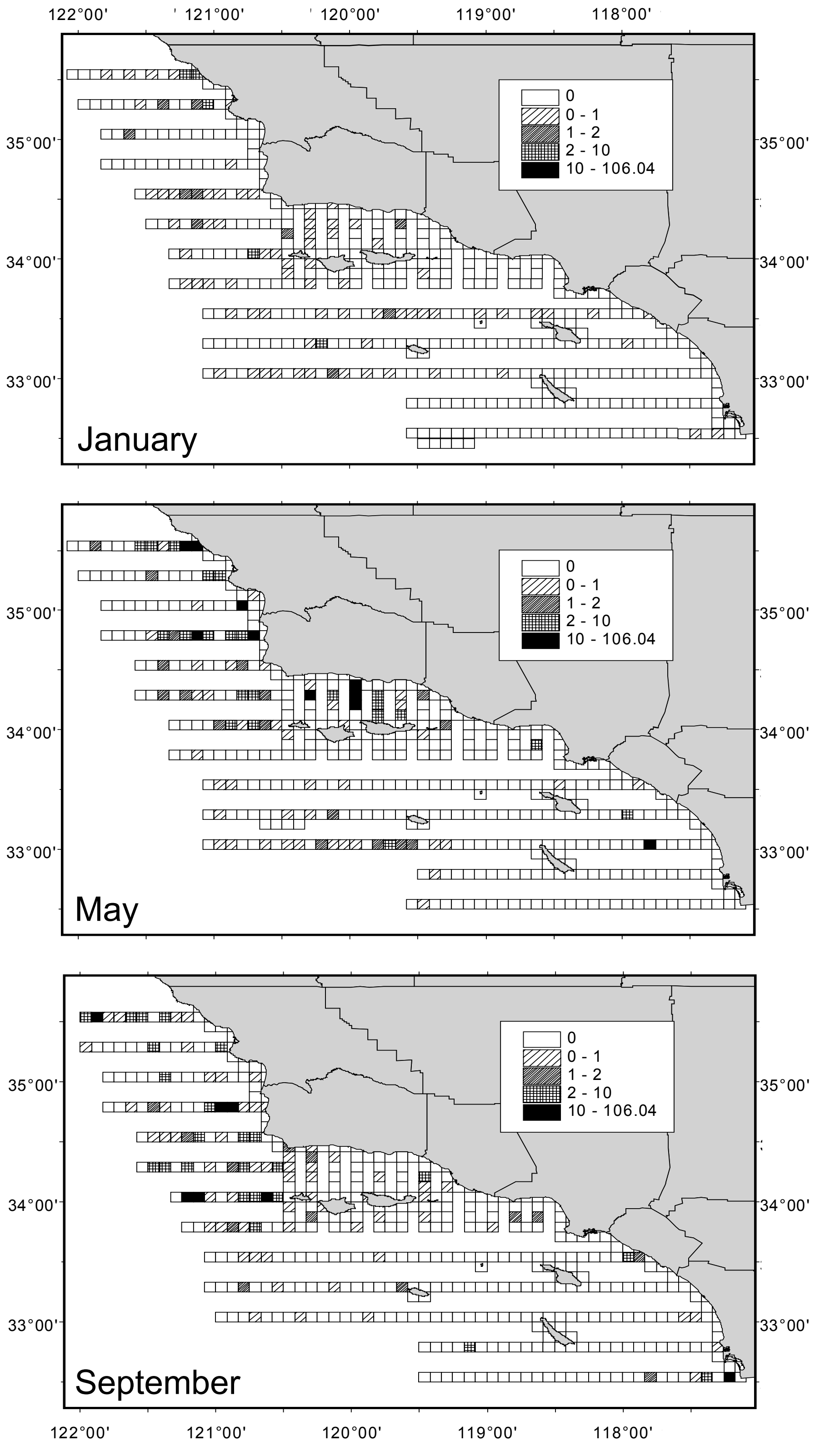


FIGURE 1.44. Unidentified phalarope densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

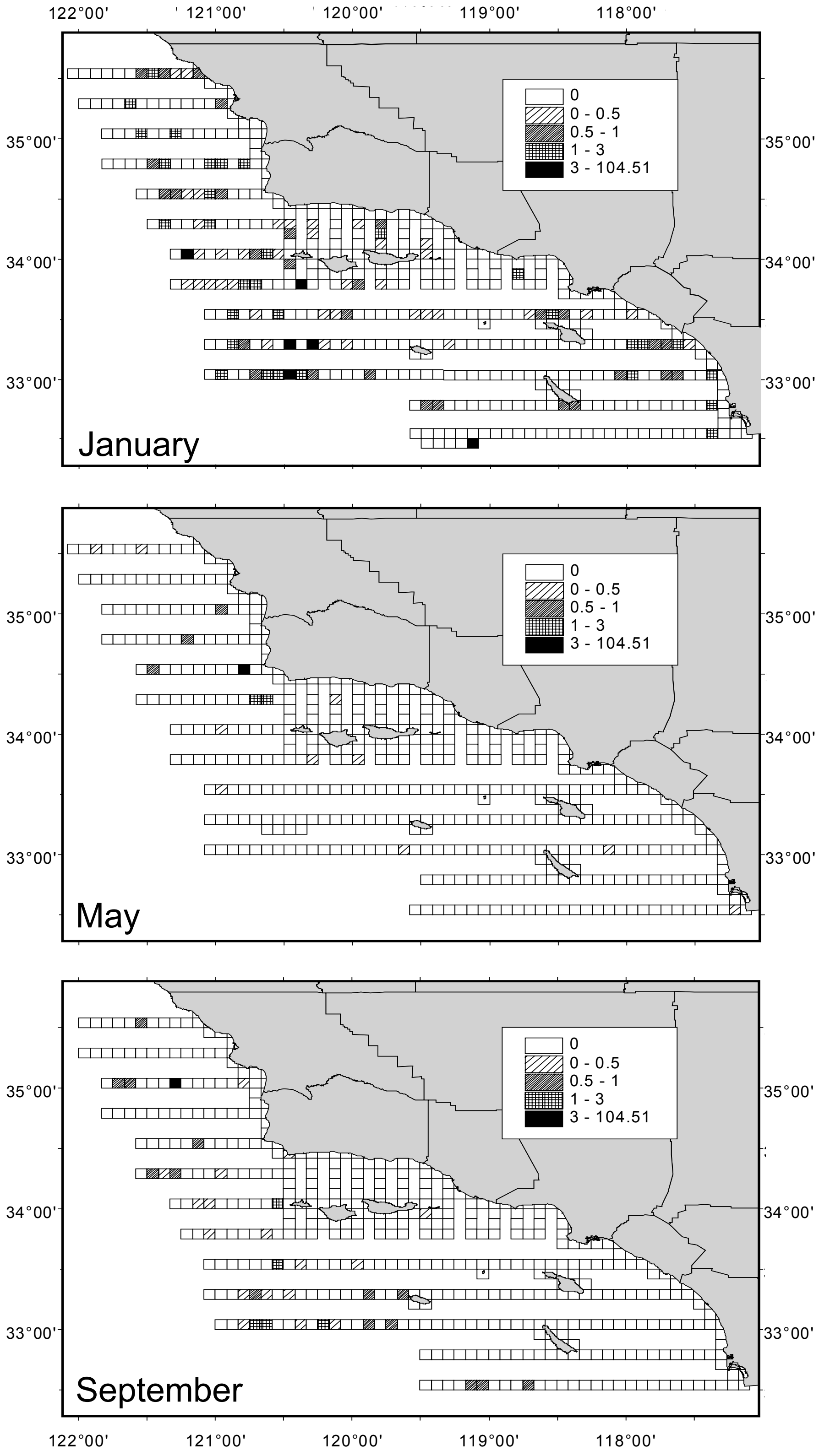


FIGURE 1.45. Red Phalarope densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

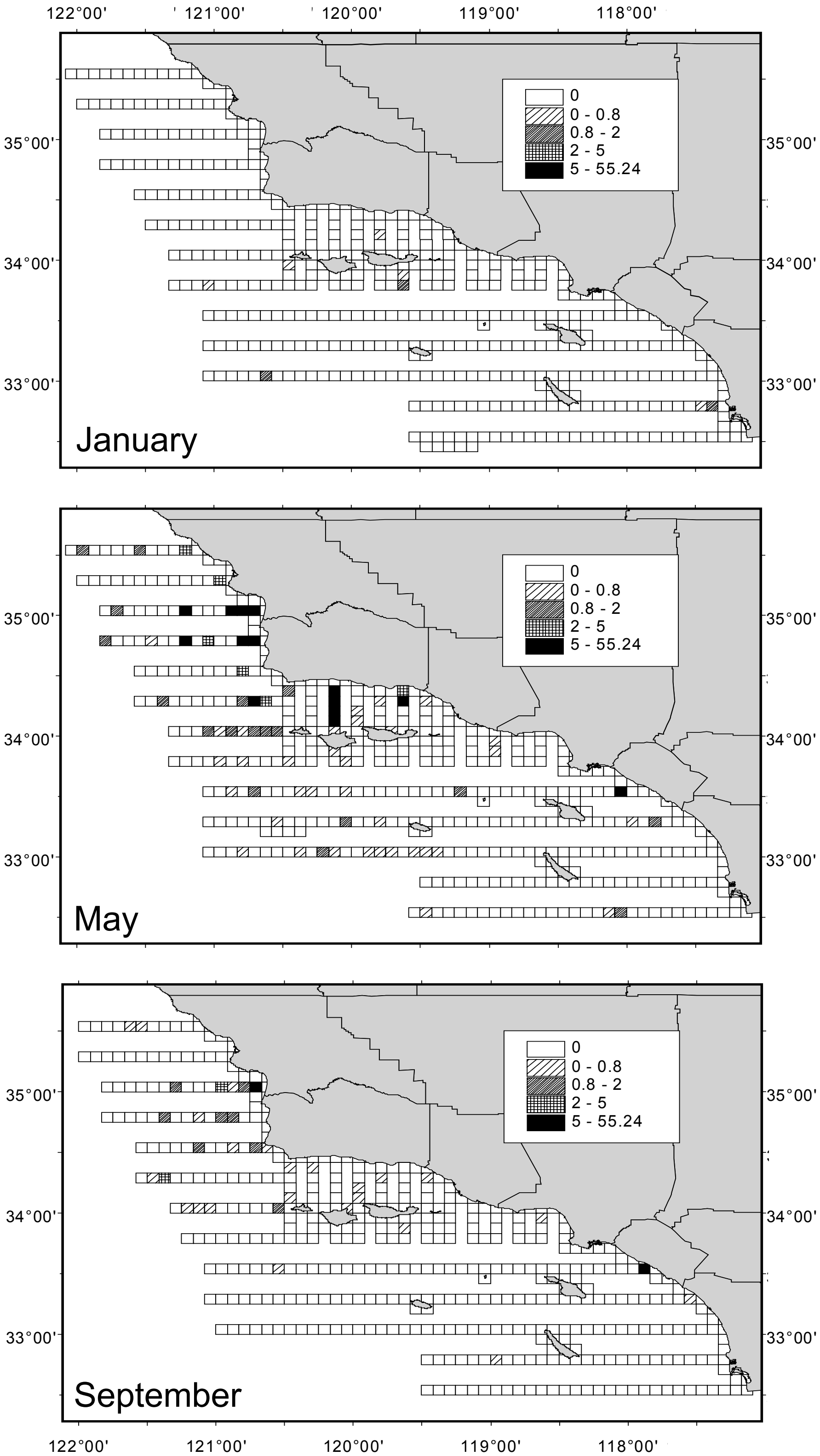


FIGURE 1.46. Red-necked Phalarope densities (birds/km^2) and distribution off southern California from 1999–2002 during January, May, and September.

CHAPTER 2:

AT-SEA AERIAL SURVEYS OF MARINE MAMMALS IN THE SOUTHERN CALIFORNIA BIGHT: 1999–2002

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Abstract: From May 1999 through January 2002, we conducted aerial at-sea and coastline surveys to examine the distribution, diversity, and abundance of marine mammals off southern California, from Cambria to the U.S./Mexican border. We conducted surveys on 102 days, flew more than 54,640 km of transect lines, and completed nine surveys of the entire Southern California Bight during January, May, and September. We identified 20 species of marine mammals—including 4 pinnipeds, 1 carnivore (southern sea otter, *Enhydra lutris nereis*), and 15 cetaceans—and recorded an estimated 68,309 individuals.

We also calculated at-sea densities for five of the most abundant species—common dolphin (*Delphinus delphis/capensis*), Risso's dolphin (*Grampus griseus*), bottlenose dolphin

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(*Tursiops truncatus*), California sea lion (*Zalophus californianus*), and harbor seal (*Phoca vitulina*). The overall mean density for these species was 1.66 animals km^{-2}, with seasonal densities ranging from 1.13 to 2.02 animals km^{-2}. These densities primarily reflect the abundance of common dolphins and California sea lions—the two most common marine mammal species in the study area. Collectively, these two species account for 85.5% of all marine mammals recorded. Mean densities were highest in September when common dolphins were most abundant in the study area, intermediate in January when California sea lions reached peak abundance at sea, and lowest in May.

Mean populations of common dolphins in the study area were estimated at 28,480 ± 8,467 in January, 8,467 ± 5,388 in May, and 93,138 ± 36,947 in September. Estimated mean populations of California sea lions during these months were 88,520 ± 16,934, 54,651 ± 5,388, and 46,954 ± 4,618, respectively.

Overall, observed marine mammal abundance was greatest in the Santa Barbara Channel, near the northern Channel Islands, and from the Santa Rosa–Cortes Ridge to the vicinity of San Nicolas Island. Marine mammal sightings were widespread throughout the study area in January and most restricted in distribution in September, when they centered in the Santa Barbara Channel.

We present detailed accounts for the 20 species of marine mammals identified during the current study and compare calculated densities of the most abundant species to densities recorded by Bonnell et al. (1981, 1983) and Dohl et al. (1981, 1983) during the baseline studies conducted between 1975 and 1983.

INTRODUCTION

The marine mammal population off California includes 8 baleen whale species; more than 20 species of porpoises, dolphins, and other toothed whales; 6 species of pinnipeds; and the sea otter—at least 39 species have been identified from sightings or strandings. Some species are purely migrants that pass through central and southern California waters on their way to calving or feeding grounds elsewhere, some are seasonal visitors that remain for a few weeks or months, and others are resident for much or all of the year. At certain times of the year, hundreds of thousands of marine mammals may be present.

The narrow continental shelf along the Pacific coast, which results in the proximity of both deep-water and shelf habitats, and the presence of the cold California Current sweeping down from Alaska allow many northern forms to reach nearshore waters as far south as Baja California. As a result, the waters of the Santa Maria Basin and Southern California Bight encompass a region of overlap of warm- and cool-water species (Bonnell and Dailey 1993).

Most of the marine mammal species in central and southern California were heavily exploited during the last two centuries for oil, pelts, and other products, and some species are still recovering. Much of the historical information on marine mammal populations is based on accounts by whalers and sealers, and the original sizes of most populations are not well known (Bonnell and Dailey 1993). However, it is known that the populations of many marine mammals were much larger in the past. Recognition of this has led to the passage of several laws regulating human activities where marine mammals might be adversely affected. In the U.S., these include the Marine Mammal Protection Act of 1972, which prohibits the intentional take, import, or export of any marine mammal without a permit, and the Endangered Species Act of 1973, which extends similar protection to species listed as threatened or endangered. The threatened or endangered marine mammal species found in southern California waters include six whales (blue, humpback, fin, sei, right, and sperm whales), two pinnipeds (Guadalupe fur seal and Steller sea lion), and the California sea otter.

In comparison with other areas, California marine mammals have been relatively well studied. Much of the information gathered during recent decades resulted from systematic aerial and vessel surveys sponsored by the Minerals Management Service's (MMS) Environmental Studies Program. From 1975 to 1983, researchers at the University of California at Santa Cruz (Bonnell et al. 1981, 1983; Dohl et al. 1981, 1983; Bonnell and Dailey 1993) conducted the first replicated and quantitative assessments of marine mammals off the California coast using aerial surveys. Their results included a comprehensive large-scale assessment of the distribution, abundance, and diversity of marine mammals in the Santa Maria Basin and the Bight. They documented 27 marine mammal species off California. Pelagic data from these and more recent MMS studies in the area have been computerized, standardized, and compiled in the Marine Mammal and Seabird Computer Database Analysis System (CDAS, Bonnell and Ford 2001).

More recently, pelagic surveys of marine mammals and studies of pinniped populations on land in California have been conducted by the National Marine Fisheries Service and associated institutions (e.g., Barlow 1995; Barlow et al. 1995, 1997; Barlow and Gerrodette 1996; DeLong and Melin 2000; Forney et al. 2000; Stewart and Yochem 2000). Koski et al. (1998) provide a recent synthesis of much of the information generated by these studies for central and southern California waters.

More than two decades have passed since the 1975–1983 baseline studies. In that time, there have been documented changes in some California marine mammal populations, several major El Niño events have occurred, and urbanization of the southern California coast and use of area waters have increased. However, existing and future oil and gas activities offshore southern California involve potential impacts to marine mammals, and there is a continuing need for baseline data.

Therefore, we conducted aerial surveys to examine the current diversity, distribution, and abundance of marine mammals and seabirds off central and southern California. Additionally, we used the aerial survey data collected from 1975–1983 by Bonnell et al. (1981, 1983) and Dohl et al. (1981, 1983) to examine whether current marine mammal distribution and abundance in this area has changed during the past two decades. Specifically, we conducted aerial surveys both at-sea and along mainland and island coastlines during September, January, and May from 1999 to 2002. We then spatially linked our current data set using the Geographical Information System program Arc View to calculate area-specific marine mammal densities for temporal analysis. We also examined the influence of season and subarea within the study area on the diversity and abundance of marine mammals and compared this to historical data. We present detailed accounts for all 20 marine mammal species that we recorded.

STUDY AREA

The study area encompasses continental shelf and slope waters along the central and southern California coast, from 35°35'N (off the city of Cambria, San Luis Obispo County) south to the U.S./Mexico border, and from the mainland shoreline west to 122°W at the northern edge and to 119°30'W at the southern edge of the study area (Figure 2.1). North of Point Conception, the coastline and seafloor are oriented generally north to south. Like most parts of the California coast, the continental shelf gradually slopes westward before dropping precipitously to depths in excess of 3,000 m. At Point Conception, the coastline and bottom topography abruptly turn east and southeastward before resuming a more southerly course between Los Angeles and San Diego. This area is known as the Southern California Bight.

The Bight is characterized by a variety of bathymetric and land features that combine to form what is oceanographically a highly complex region. Circulation patterns in the Bight are unique to the West Coast and result in a transition zone between warmer sub-tropical waters from the south and colder nutrient rich waters from the north (Hunt et al. 1980). Eight major islands, 11 deep-water basins, three major banks and seamounts, and at least 13 major submarine canyons bisect the U.S. portion of the Bight (Dailey et al. 1993, Hickey 1993). These features strongly affect the circulation pattern of the California Current, which turns from its more typical equatorward flow to poleward flow in the Bight, with a predominant eddy that circulates counterclockwise in the Bight (Hickey 1993). The strong coastal upwelling of the northern and central California coasts is much reduced in the southern and inner waters of the Bight, resulting in waters that are considerably warmer and lower in nutrients and primary productivity.

The Bight also is extensively used by humans and is economically important, contributing about $9 billion annually via offshore oil production, oil transportation by tankers, commercial shipping, commercial fishing, military activities (e.g., weapons testing and exercises), and public recreation. The human population bordering the Bight has increased 64% from 1970 to 2000, with concomitant increases in coastal development, sewage discharge, recreational use, and commercial activities. The 2002 census estimated that more than 16 million people reside in the counties rimming the Bight. As a consequence, great concern exists about the potential impacts of human activities on marine mammal and seabird populations.

The islands and, to a much lesser extent, the mainland shores of the study area provide breeding habitat for four species of pinnipeds (Bonnell and Dailey 1993). The California Channel Islands, particularly San Miguel and San Nicolas Islands, host the largest pinniped breeding colonies south of Alaska.

METHODS

Survey Transects

We conducted aerial surveys for marine mammals and seabirds three times a year in January, May, and September from May 1999 to January 2002 (Table 2.1) along fixed strip-transect lines located both at sea and along all mainland and island coastlines in the study area (Figure 2.2). Coastal transects covered the mainland shoreline from Cambria, CA (35º35'N, 121º07'W) to the U.S./Mexican border (32º32'N, 117º07'W) and the shorelines of the eight

Channel Islands. May, September, and January were chosen as survey months primarily because they often coincided with peaks in breeding, post-breeding dispersal, and over-wintering distributions, respectively, for many species of seabirds in the Southern California Bight (Carter et al. 1992). These survey months also corresponded to breeding, migratory, and foraging periods for many marine mammals, although marine mammal use of the study area waters varies widely throughout the year depending on the species.

Previous studies indicated that the highest densities of marine mammals and seabirds in the Bight occur near the northern Channel Islands (Bonnell et al. 1981; Briggs et al. 1981, 1987; Dohl et al. 1981) and, therefore, we concentrated our survey effort in this core area (Figure 2.2). Transect lines were arranged systematically and were designed not only to concentrate survey effort in areas near the northern Channel Islands, but also to include the wide range of habitats and bathymetry throughout the Bight. Offshore transects near the northern Channel Islands were predominantly oriented north to south and were spaced at intervals of 10' of longitude. In other areas of the study area, offshore transects oriented east to west were spaced at intervals of 15' of latitude. We flew coastline (mainland and island) transects about 300 m from shore, except in ecologically sensitive areas (e.g., marine mammal haul-out sites and seabird nesting and roosting sites), where we flew up to 400 m from shore. All at-sea and coastal transect lines were flown once per survey month except those located in the core area, which were flown twice per survey month. We conducted the second survey 5–10 days after the first survey. Weather conditions (e.g., fog or strong winds) and aircraft availability determined whether the core area was surveyed during the first or second replicate for each month.

At-Sea Subareas

We divided the at-sea study area into five subareas (Figure 2.3) to facilitate a more spatially refined statistical comparison of our data with historic data (Bonnell et al. 1981, 1983; Dohl et al. 1981, 1983). Subareas were selected to represent distinct oceanographic regions in the study area, with four subareas created within the Bight and one to the north. Because our study area was smaller than the areas surveyed during the 1975–1983 baseline studies, we placed a 13.5-km (7.5-NM) buffer around our study area and only made statistical comparisons between our data and historical data using data within this buffered area.

At the northern end of the study area, subarea one extended from just south of Point Piedras Blancas to just north of Point Conception and seaward 108 km (60 NM). The southern boundary of the subarea was located along the edge of the transition zone between colder, upwelled waters of central California and the more subtropical waters of the Bight (Chelton 1984, Lynn and Simpson 1987).

Subarea two encompassed the waters in the outer northern portion of the Bight, running almost due south from Point Conception to south of the northern Channel Islands and out 117 km (65 NM) west of San Miguel Island. A major feature of this area was the Rodriguez Seamount, approximately 55 km (30 NM) west of San Miguel Island.

Subarea three included the waters surrounding the northern Channel Islands and extending eastward from Point Conception to Point Dume and south of the islands. Main features of this area include the Santa Barbara Channel, major pinniped and seabird breeding habitat on the northern islands (particularly San Miguel Island), and significant upwelling (Harms and Winant 1998).

Subarea four encompassed the eastern Bight, which is little influenced by coastal upwelling. This subarea contained pinniped breeding and haul-out areas on Santa Barbara, Santa Catalina, and San Clemente Islands.

Subarea five included the offshore portion of the southern Bight, which contains large expanses of open, deep ocean, as well as ocean ridges and banks. The northwestern section of this subarea is influenced by the Point Conception upwelling plume. San Nicolas Island is an important pinniped rookery and hauling ground.

Coastal Subareas

The coastlines of the mainland and the Channel Islands were divided into five subareas (Figure 2.3): three subareas along the mainland coastline (northern, central, and southern) and two subareas along the island coastlines (northern Channel Islands and southern Channel Islands).

The northern mainland coastline subarea extended from Cambria to Point Arguello and included Morro Bay, Point Buchon, and Point Sal.

The central mainland coastline subarea extended from Point Arguello to just east of Point Dume and included Point Conception, the Santa Barbara Channel coastline, and Mugu Lagoon.

The southern mainland coastline subarea extended from just south of Point Dume to the U.S./Mexican border and included Santa Monica Bay, Palos Verdes, Dana Point, and Point Loma.

The northern Channel Islands coastline subarea included San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands.

The southern Channel Islands coastline subarea included Santa Barbara, San Nicolas, Santa Catalina, and San Clemente Islands.

Aerial Surveys

We conducted aerial surveys from a high-winged, twin-engine Partenavia PN 68 Observer aircraft following the methods developed for surveying marine mammals by Bonnell et al. (1981, 1983) and for surveying seabirds by Briggs et al. (1985, 1987). We flew surveys at 61 m (200 ft) above sea level at 162 km hr^{-1} (90 knots) ground speed. The primary observers sat on either side of the aircraft and scanned the sea surface through bubble windows. Each of two observers counted and identified marine mammals and seabirds sighted within a 50-m strip on their side of the aircraft, for a total strip width of 100 m when both observers were surveying. At least one observer surveyed, but observers discontinued surveying when glare covered more than 25% of their field of view. To ensure that the strip width was 50 m, we calculated sighting angles from the aircraft to the water (Appendix B). Observers rechecked the sighting angles using a clinometer several times during each survey. Observers concentrated survey effort within the 50-m strips, but also recorded animals sighted outside the strip. Animals outside the 50-m strip width were designated as off-transect and were not included in density estimates or statistical analyses.

Observers recorded marine mammal and seabird observations on audiotape using hand-held tape recorders (VSC-2002, Model No. 14-1158, Tandy Corporation, Fort Worth, TX, USA). Data recorded included time (to the nearest second), species, number of animals, behavior, age, sex, and plumage. Observers identified animals to species or nearest taxon and made exact counts for solitary animals or small groups and estimated counts for large groups (>10). They recorded marine mammal behaviors, including swimming, diving, and rafting/floating on the water, and also determined swimming direction for animals sighted.

A third observer seated next to the pilot operated a laptop computer connected to an onboard GPS unit (see below) and functioned as an additional marine mammal observer as duties permitted. This observer entered marine mammal sightings into a sighting log by hand and calculated sighting angles to observed animals using a clinometer.

Each observer transcribed their data from audiotape or sighting log to standardized data forms and entered the data in the computer program SIGHT (Micro Computer Solutions, Portland, OR, USA), which was used to help ensure more accurate data entry. Two people checked the data entry for accuracy by printing the SIGHT data, comparing it with the transcribed forms, and correcting any errors detected.

We determined the location of each observation using a Garmin® 12 Plus Global Positioning System (GPS; Garmin Ltd., Olathe, KS, USA). We connected the GPS unit to a laptop computer that was operated by the third observer in the aircraft. We synchronized observer watches with the computer clock twice each day to ensure accuracy. The computer program dLog (R.G. Ford Consulting, Inc., Portland, OR) recorded aircraft position (waypoint) from the GPS unit every 5 seconds in a log file. We chose to record the aircraft's position at this frequency to allow adequate spatial coverage of the trackline (225 m is traversed every 5 seconds at our survey speed of 162 km hr^{-1}) and to limit the size of the resulting data files.

We then interpolated the location of each sighting using the program INTERPD (R.G. Ford Consulting, Inc., Portland, OR, USA), which calculated sighting positions between waypoints for each marine mammal observation based on the time the animal was observed (we assumed the aircraft was traveling at a constant speed of 162 km hr^{-1}). We checked for errors in the waypoint log file by converting it to a text file and importing it into the Geographical Information System (GIS) program ArcView (ESRI, Redlands, CA, USA) for visual inspection. In ArcView, the waypoints appeared as a series of dots representing our trackline on a map of the study area. If a waypoint appeared to be erroneous (i.e., it was not in line with the rest of the waypoints or appeared to be over land on coastal transects), we deleted it from the original log file. Occasionally, we lost GPS satellite reception or had computer errors. To obtain locations for marine mammal observations that occurred during these errors, we interpolated locations based on the assumption of constant aircraft speed and used the time recorded for the observations to determine the sighting location.

Spatial Analysis

The track-log GPS data taken during the aerial survey were processed using SAS to create text files in Earth Science Research Institute's GIS program Arc Info (ESRI, Redlands, CA, USA) to generate a format for point and line coverages. Point and line coverages were created, and attribute data were added. The data were reprojected using the California Teale Albers projection for ease of distance and area calculations.

Track-line coverages were buffered (an area perpendicular to the transect line was added) based on the number of observers in the aircraft (one observer, buffer = 25 m; two observers, buffer = 50 m). After buffering the transect, data were split into coastal and offshore types. This was necessary because there were instances where the two transect types passed through the same grid cell. Next, both transect types were intersected with a master latitude and longitude grid containing 1' of latitude by 1' of longitude and 5' of latitude by 5' of longitude divisions. This grid system was used to calculate and display the species densities and habitat values. After intersection, the buffered transects contained the unique latitude and longitude grid-square identifier for both the 1'- and 5'- grids.

Species observations originally in dBase format were imported into Arc View as event themes. Observation data points were filtered based on transect type (coastal or offshore) and replicate number. Point and line coverages were first created in latitude and longitude formats and reprojected to Albers format to match the buffered transects. Observation points were then intersected with the buffered transects to assign grid number identifications to the points. The databases were then processed in SAS software (SAS Institute, 1999) to calculate densities.

Statistical Analysis

We divided survey data into observations from offshore and coastal transects. We analyzed offshore and coastal transect data separately to assess differences among seasons (January, May, and September) and subareas. Data from offshore transects were used to make statistical or qualitative comparisons with aerial survey data collected by Bonnell et al. (1981, 1983) and Dohl et al. (1981, 1983), who surveyed the Bight from 1975 to 1978 and surveyed central and northern California (Point Conception to the California/Oregon border) from 1980 to 1983.

From the transect data, at-sea densities were calculated for five species of marine mammals: California sea lion (*Zalophus californianus*), harbor seal (*Phoca vitulina*), long-beaked/short-beaked common dolphins (*Delphinus capensis/delphis*), Risso's dolphins (*Grampus griseus*), and bottlenose dolphins (*Tursiops truncatus*). Since long-beaked and short-beaked common dolphins could not be reliably distinguished from the air, they are treated as a single species in this report. On-transect sighting sample sizes for the remaining species were considered to be too small to support at-sea density calculations. Sightings were not corrected for availability bias, the probability that an animal of a given species would be at the surface (and thus available to be seen) when the survey aircraft passed over head.

We used generalized linear mixed models (GLMM) using SAS software (SAS Institute, 1999) to model species counts on grids as having a Poisson distribution with means that are proportional to grid size (offset variable) (McCullagh and Nelder 1989) and that vary according to subarea, season, year, and replicate. This Poisson model is equivalent to a model for species density when dividing both sides of the model equation by grid size. We estimated and tested the effects of subarea and season on densities. We controlled for variation between replicates and years by including them as random effect variables. We also estimated and tested these effects to evaluate the significance of these effects on density.

For any species in which we observed no occurrences in any of the subareas or seasons, we restricted the GLMM to estimate and test differences in densities on only those subareas and seasons in which the species was observed. For those subareas or seasons where no species was observed, the observed density and its standard error were zero. In this case, one of two possibilities occurred. The first was that the entire season or subarea contained no individuals of that species, which made that season or subarea significantly different from any other season or subarea where the species was observed at least once. The second possibility was that the species was present but too rare to be observed by the survey, in which case the standard error of zero was useless. There were not enough data for the GLMM to distinguish between these two possibilities or to compare them against the seasons and subareas that did have observations. For this reason, we also evaluated differences in subareas and seasons simply by identifying the subareas and seasons with observations from the ones with no observations.

For similar reasons, we occasionally restricted the GLMM to exclude the replicate random effect when no observations of the species occurred for one of the replicates. Conversely, for those species having sufficiently high densities, we expanded the GLMM to include a term for interaction between subarea and seasonal effects. Interaction effects were estimated for a species whenever positive densities occurred in all combinations of subarea and season.

Distribution maps for marine mammal species were created in ArcView. For the four species discussed above, densities for 5 minute latitude and longitude grids were averaged across years for each month creating three maps for each species representing January, May, and September. To facilitate simpler visual comparison among the three maps, map legends were numerically standardized for each species. The five legend categories were broken down as follows: 1) zero representing locations where animals were not observed; 2) nonzero densities to the 50th percentile; 3) densities between the 50th and 75th percentiles; 4) densities between the 75th and 90th percentiles; and 5) densities between the 90th percentile and the maximum density observed.

RESULTS AND DISCUSSION

From 1999 to 2002, we spent 102 days in the air and completed nine surveys. For all surveys combined, we flew more than 54,641 km (30,356 NM) of trackline, with about 20,079 km (11,155 NM) in the core area and about 14,435 km (8,019 NM) along coastlines. We recorded 4,795 total sightings, of which 3,118 (65%) were on transect. We estimated 68,309 marine mammals in the SCB, including 8,940 pinnipeds, 58,798 cetaceans, 409 sea otters, and 162 unidentified marine mammals. Of the total sightings, 3,118 (65%) were recorded on transect. A total of 20 species of marine mammals was sighted, including 4 pinnipeds, 1 carnivore (southern sea otter, *Enhydra lutris nereis*), and 15 cetaceans (Table 2.2).

An additional 7 species known to occur in the study area (2 pinnipeds and 5 cetaceans) were not sighted during the present study, but had been recorded in central and southern California waters during the 1975–1983 studies (Bonnell et al. 1981, 1983; Dohl et al. 1981,

1983) (Table 2.3). Of these species, the sei whale (*Balaenoptera borealis*), listed as threatened under the U.S. Endangered Species Act (ESA) (35 FR 8495); pygmy and dwarf sperm whales (*Kogia breviceps*/*K. simus*); and *Mesoplodon* spp. beaked whales are rare in southern California waters. Short-finned pilot whales (*Globicephala macrorhynchus*) were common in the SCB in the 1970s, particularly around Santa Catalina Island, but disappeared from area waters following the major El Niño event in 1982–1983 (Bonnell and Dailey 1993); they have been sighted off California in low numbers in recent years (Carretta et al. 2003).

The lack of sightings of harbor porpoises (*Phocoena phocoena*) during the present study is more difficult to understand. Although harbor porpoises have suffered mortality in commercial fisheries in recent years, the stock found in nearshore waters along the coast between Morro Bay and Point Conception is estimated to number nearly 1,000 animals (Carretta et al. 2003). However, we searched these waters on every aerial survey and did not detect harbor porpoises.

Although Steller sea lions (*Eumetopias jubatus*) were once abundant off southern California, the state population has been declining for decades (Ainley and Lewis 1974; Bonnell et al. 1981, 1983; Bonnell and Dailey 1993), and we did not observe them. Pups were last born in the SCB on San Miguel Island in 1981 (DeLong and Melin 2000), and Stellers are now quite rare in area waters. The species was listed as threatened under the ESA in 1990 (55 FR 50006).

Guadalupe fur seals (*Arctocephalus townsendi*) are also listed as threatened under the ESA (50 FR 51252), and, although a few individuals are seen on the Channel Islands each year, they are seldom sighted at sea in the SCB, and we did not detect them.

The overall mean density in the study area for the five most abundant species (California sea lion, *Zalophus californianus*; harbor seal, *Phoca vitulina*; long-beaked/short-beaked common dolphins, *Delphinus capensis/delphis*; Risso's dolphin, *Grampus griseus*; and bottlenose dolphins, *Tursiops truncatus*) was 1.66 animals km^{-2}, with seasonal densities ranging from a low of 1.13 animals km^{-2} in May to 2.02 km^{-2} in September. These densities primarily reflect the abundance of common dolphins and California sea lions—the two most common marine mammal species in the study area. Mean densities were highest in September when common dolphins were most abundant in the study area, intermediate in January when California sea lions reached peak abundance at sea, and lowest in May.

The following species accounts discuss each of the 20 species recorded during the present study.

PINNIPEDS

California Sea Lion (*Zalophus californianus*)

California sea lions range along the Pacific coast from British Columbia to Mexico. They breed in the summer on islands from the Gulf of California in Mexico to the Channel Islands in southern California (Bonnell and Dailey 1993). In southern California, California sea lions breed on four islands: San Miguel, San Nicolas, Santa Barbara, and San Clemente. San Miguel and San Nicolas are the major rookeries and together account for more than 90% of all pups born (Bonnell and Dailey 1993).

In the fall, non-lactating females, juveniles, and subadult and adult males disperse northward from the Channel Islands rookeries to overwinter along the coasts of central and northern California, Oregon, Washington, and British Columbia. Lactating females and pups, however, remain in area waters year-round (Stewart and Yochem 2000). Simultaneously, other animals, particularly adult males, move northward into the SCB from the Mexican rookery islands (Bonnell et al. 1981, 1983). Males from the Baja California rookeries may spend most of the year in U.S. waters (Carretta et al. 2003).

Although the historical data are insufficient to allow estimation of the pre-exploitation population and distribution of the California sea lion, it is known that sea lions were very abundant along the coasts of California and Baja California, Mexico, in the mid-19th century (Scammon 1874). Beginning in the last century, extensive hunting sharply reduced sea lion numbers until, by the late 1920s, less than 1,000 could be found on the southern California rookeries (Bonnot 1928, Cass 1985). Since that time, the California sea lion population has grown rapidly and recolonized much of its southern California range (Bartholomew and Boolootian 1960, Le Boeuf and Bonnell 1980, Bonnell et al. 1983). Currently, the U.S. stock, defined as that portion of the population breeding in U.S. waters, is estimated at 237,000–244,000 animals and is believed to be growing at a rate of 5.4–6.1% per year (Carretta et al. 2003).

During the baseline study of Southern California Bight marine mammals conducted from 1975 to 1978 (Bonnell et al. 1981), a minimum at-sea density for the study area of about 0.08 California sea lions km^{-2} was recorded in the spring, from April through June (equaling about 7,000 animals at sea). The maximum density of 0.53 sea lions km^{-2} was recorded in the fall, from October through December (equaling about 48,000 animals at sea).

Based on analysis of the sighting data from the 1975–1978 study, Bonnell and Ford (1987) found that California sea lions in the summer were most abundant in waters near their rookery islands and in the north and central SCB. In the fall, when many California sea lions were moving northward out of the area, a northward shift in distribution was also observed within the SCB. Sea lion use of the waters of the SCB was highest in the winter. Through the spring, as sea lions returned to the rookery islands, the areas of highest abundance shifted to the central and eastern SCB, where spawning anchovy and squid are seasonally abundant (Bonnell and Ford 1987, Bonnell and Dailey 1993).

In their 1980–1983 baseline study of central and northern California, Bonnell et al. (1983) recorded peaks in at-sea abundance during the spring and fall. In the southern sector (from about Point Conception to Point Sur, corresponding approximately to northern subarea 1 in the present study), densities of up to 1.34 animals km^{-2} were observed over the shelf in the fall. Numbers of sea lions hauled out on the central California coast peaked in mid-fall, as animals moved northward. Bonnell et al. (1983) estimated the U.S. population of California sea lions at 93,947 animals, based on counts made during the summer breeding season; this figure included 62,547 sea lions counted on land and an estimated at-sea population of 31,400.

During the 3 years of the present study, we counted 8,047 California sea lions at sea, both on and off transect, making them the most abundant pinnipeds in the study area. Sea lions were generally seen alone or in pairs (with a mean of 1.7 animals per sighting), but aggregations of up to 150 individuals were encountered.

Sea lions were generally observed in relatively shallow water: 41.5% of the sightings were recorded in waters over the continental shelf (0–200 m), and 72.7% were seen in waters shallower than 600 m. The mean water depth for California sea lions sighted on-transect on offshore surveys was 465.2 m.

California sea lions were sighted at distances of less than 0.2 to more than 117 km from land. The mean distance from shore of California sea lions sighted on-transect on offshore surveys was 17.1 km; 70.7% of the sightings were recorded less than 20 km from land.

Sighting Distribution. – California sea lions were sighted at sea throughout the study area (Figure 2.4), with concentrations in waters west of Point Conception, in the Santa Barbara Channel, over the Santa Rosa Ridge south to San Nicolas and Santa Barbara Islands, and in waters extending south from San Nicolas Island to San Clemente Island and Tanner–Cortes Banks. They were seen in greatest numbers around the Channel Islands, especially the northern chain, San Nicolas Island, and Santa Barbara Island. Sea lions were also observed near shore along the length of the mainland shoreline in the study area, particularly from Santa Monica Bay northward. Based on the 1999–2002 sighting data, at-sea population estimates (± SE) were calculated for California sea lions within the study area (Table 2.4). The estimates ranged from a low of 46,954 (± 4,618) individuals in the area in September to a high of 84,671 (± 16,934) in January.

At-Sea Densities. – Densities of California sea lions (± SE) were calculated for the entire study area using data from both the offshore and coastal surveys (Table 2.5). Although the densities of sea lions recorded on offshore surveys did not differ significantly among seasons or subareas, densities recorded on coastal surveys did differ significantly among subareas (ANOVA: $F_{4,1781} = 18.6$, $P < 0.0001$), with greatest abundance observed along the northern mainland coast and around the Channel Islands. Overall densities ranged from a low of 0.61 sea lions km^{-2} in September to a high of 1.10 in January. Highest densities (from 1.00 to 2.40) were observed in nearshore mainland and island waters on the coastal surveys. Densities recorded on offshore surveys were lower and varied less, from 0.37 km^{-2} in May to 0.50 in January. Further detail on sea lions densities recorded in mainland and island nearshore waters is presented in Tables 2.7 and 2.8.

Overall, at-sea densities were highest in the Santa Barbara Channel and the waters surrounding the northern Channel Islands (subarea 3; Figure 2.3), ranging from 0.60 sea lions km^{-2} in May to 0.78 in January (Table 2.6). Although the highest seasonal density, 0.81 km^{-2}, was observed in the eastern SCB (subarea 4) in January, at-sea densities in this subarea during the other survey months were low, 0.18 to 0.19. Densities in the waters west of San Miguel Island and Point Conception (subarea 2) ranged from 0.05 km^{-2} in January (the lowest subarea density recorded during the study) to 0.52 in May. In the waters around and west of San Nicolas Island (subarea 5), densities varied from 0.20 to 0.48 animals km^{-2}; north of Point Conception, in the Santa Maria Basin and along the adjoining coastline, they ranged from 0.21 to 0.35.

Seasonal Patterns. – In January (Figure 2.5a), lactating females and their pups were present on and near the rookery islands, and many animals from the Mexican rookeries were in the SCB. Highest densities (1.5 or more km^{-2}) were recorded in nearshore waters at San Miguel, Santa Rosa, San Nicolas, and San Clemente Islands; at Tanner Bank; over the San Pedro Basin; and along the southern mainland shore off San Diego and Orange Counties.

Lower densities were observed in the Santa Barbara Channel, around the northern Channel Islands and Santa Barbara Island, nearshore in various areas along the mainland, offshore over the slope in the Santa Maria Basin, over the Santa Rosa Ridge, and west of San Nicolas Island.

In May (Figure 2.5b), the pupping and breeding season was under way, and sea lions were still returning to the rookery islands from waters to the north. Highest densities were recorded in nearshore waters along the central coast; in upper slope waters northwest of San Miguel Island; and in nearshore waters at San Miguel, Santa Rosa, and San Nicolas islands. Lower densities were observed nearshore and offshore over the slope off the central coast, west of San Miguel Island, in the Santa Barbara Channel and near the northern Channel Islands east into Santa Monica Bay, nearshore at the southern Channel Islands, and near Tanner Bank.

In September (Figure 2.5c), many animals were moving northward out of the SCB, while females and pups remain around the rookery islands. Highest densities were recorded in nearshore waters along the central coast, around the northern Channel Islands and Santa Barbara Island, and over the Santa Rosa Ridge. Lower densities were observed over the shelf in the Santa Maria Basin, in the Santa Barbara Channel and near the northern Channel Islands eastward toward Santa Monica Bay, and in the waters between San Nicolas and San Clemente islands.

Summary. – California sea lions are present year-round in southern California waters and are found throughout the study area. We found sea lions to be most abundant in waters over the continental shelf and upper slope (less than 600 m deep) and nearshore (within about 20 km of land).

The U.S. population has more than doubled since the earlier baseline studies ended in 1983 and is still growing. Correspondingly, recorded at-sea densities of sea lions have risen by a factor of two or more since the 1975–1983 baseline studies.

However, overall seasonal patterns of sea lion distribution in the study area have remained relatively constant in the decades since the 1975–1983 studies. California sea lion abundance at sea was consistently highest in the northern and central waters of the SCB, from the Santa Barbara Channel and northern Channel Islands south through the other rookery islands to Tanner-Cortes Banks. A seasonal shift in distribution toward the southern half of the SCB was observed in winter, when thousands of animals from the Mexican rookeries enter the area.

In shelf waters north of Point Conception, California sea lion abundance increased in the fall as animals moved northward along the coast. A lower peak in abundance was observed during the southward return in the spring.

Harbor Seal (*Phoca vitulina*)

In the eastern North Pacific, the harbor seal ranges along the coastline from Baja California to the Aleutian Islands (Green et al. 1989). Currently, the California population is estimated at 27,863 animals (Carretta et al. 2003). The observed growth rate of the California population has slowed in recent years on both the mainland and the Channel Islands, and the stock may be near its environmental carrying capacity (Carretta et al. 2003).

Harbor seals haul out on all the islands in the Southern California Bight, although nearly 90% of total island counts are recorded on the northern island chain, and there is a distinct seasonal pattern of abundance on land (Bonnell and Dailey 1993). The numbers of harbor seals observed on land increase rapidly through the spring and summer, as animals haul out to pup, breed, and molt. Pups are born in southern California from mid-February through mid-April, with a peak in March (Bartholomew and Boolootian 1960, Stewart 1988, Green et al. 1989). In mid-July, numbers hauled out begin declining to less than one-third of the summer level as animals disperse following the breeding season and molt; the population observed on land remains at this lower level through the fall and winter (Bonnell et al. 1981, Stewart and Yochem 1984, Bonnell and Dailey 1993). Harbor seals may make week-long trips to sea, or possibly move to and from other haul-out sites (Hanan 1996, Koski et al. 1998).

Based on their census data from the 1975–1978 baseline study, Bonnell et al. (1981) concluded that the Southern California Bight harbor seal population was growing and estimated that it numbered about 3,000 animals. On at-sea surveys, harbor seals were generally seen close to shore: 71% were recorded within 10 km of land. They were sighted around all the Channel Islands (over 50% of all sightings were within 10 km of the northern chain). Low numbers of harbor seals were also recorded throughout the SCB, in waters over the Santa Rosa–Cortes Ridge, in the San Pedro Basin, and off the Palos Verde Peninsula. Greatest numbers were recorded during the summer, from July through September, but the numbers were too low for seasonal patterns to be discerned (Bonnell et al. 1981, Bonnell and Dailey 1993).

During their 1980–1983 study of central and northern California waters, Bonnell et al. (1983) sighted a few harbor seals as far as 50 km from shore, but most (91%) were recorded within 20 km of the coastline. About 80% of the sightings were made in waters less than 200 m deep. Bonnell et al. (1983) recorded highest at-sea densities north of the current study area, from about Point Sur northward. Greatest numbers of harbor seals were sighted during the winter, from December through February.

During the 3 years of the present study, we counted 497 harbor seals at sea, both on and off transect. Sightings of harbor seals were almost always of individual animals, although groups of up to 6 were occasionally observed.

Harbor seals were found primarily in shallow, nearshore waters: more than 88% of the sightings were recorded on coastal surveys within 0.5 km of shore. On offshore surveys, 79.4% of the sightings were recorded in waters over the continental shelf, and 91.2% were in waters shallower than 400 m. The mean water depth for harbor seals sighted on-transect on offshore surveys was 181.8 m.

Harbor seals were sighted on transect on offshore surveys at a mean distance of 6.9 km from shore; 52.9% of the sightings were recorded less than 5 km from land, and 79.4% were within 10 km. Only one harbor seal was seen more than 20 km from shore.

Sighting Distribution. – Unsurprisingly, relatively few harbor seals were observed on offshore surveys (Figure 2.6). Most sightings were recorded in waters over the shelf north of Point Conception and throughout the Santa Barbara Channel. Several were also seen in the south-central SCB near the southern Channel Islands. On coastal surveys, harbor seals were sighted along the length of the mainland shoreline, with highest concentrations observed on the Santa Barbara and San Luis Obispo County coasts. At the islands, greatest numbers were recorded around the northern chain and at San Nicolas and San Clemente Islands. At-sea population estimates (± SE) within the study area (Table 2.4) ranged from a low of 5,388 (± 770) harbor seals for both the May and September survey months to a high of 8,467 (± 1,539) animals in January.

At-Sea Densities. – Densities of harbor seals (± SE) were calculated for the entire study area using data from both the offshore and coastal surveys (Table 2.5). As was the case for California sea lions, the densities of harbor seals recorded on offshore surveys did not differ significantly among seasons or subareas, but differed significantly among subareas on coastal surveys, with greatest abundance observed along the central mainland coast (ANOVA: $F_{4,1781} = 12.1$, $P < 0.0001$). Overall densities were low throughout the year, ranging from 0.07 animals km^{-2} in May and September to 0.11 in January. Most of this reflected the very low densities recorded on offshore surveys, 0 to 0.01 km^{-2}. Densities recorded in nearshore mainland and island waters on coastal surveys ranged from 0.11 seals km^{-2} in May to 0.21 in September and 0.33 in January.

At-sea densities within the study area subareas were very low (Table 2.6). The highest monthly density, 0.04 km^{-2}, was recorded in September in central subarea 3 (Figure 2.3), which encompassed the Santa Barbara Channel and waters surrounding the northern Channel Islands.

Densities recorded on coastal surveys were substantially higher. Harbor seal densities for the entire mainland coast ranged from lows of 0.20 and 0.23 km^{-2} in May and September, respectively, to a high of 0.41 in January (Table 2.7). Overall, densities along the island coastlines ranged from a low of 0.16 km^{-2} in May to 0.20 in September and 0.23 in January (Table 2.8).

Seasonal Patterns. – As shown in Figure 2.7, the seasonal patterns of harbor seal distribution did not vary greatly. Highest densities were consistently recorded along the coast north of Point Conception, along the northern shore of the Santa Barbara Channel, and around the northern Channel Islands. Elevated densities were also observed near Santa Barbara and San Clemente Islands in some months.

Summary. – Harbor seals are year-round residents in coastal California waters. We found harbor seals to be most abundant in shallow waters (less than 200 m deep) and very close to shore (generally less than 1 km from land).

The population in the study area has grown since the earlier baseline studies, but may have stabilized in recent years. As Bonnell et al. (1983) also observed in central California during the 1980–1983 baseline study, highest densities in the present study were recorded in the winter (January), when harbor seals spend more time at sea.

No coastal surveys were conducted during the 1975–1978 study of the Southern California Bight, and, subsequently, substantially fewer harbor seals were sighted than during the present study. As a result, it is difficult to compare the sighting data from the two studies. At present, harbor seals are most abundant in nearshore waters around the northern Channel Islands and along the mainland from about Ventura County northward.

Northern Elephant Seal (*Mirounga angustirostris*)

The breeding range of the northern elephant seal presently extends from Baja California to Oregon, and elephant seals range at sea from Mexico to the Gulf of Alaska (Bonnell et al. 1983, Bonnell and Dailey 1993, Le Boeuf and Laws 1994, Le Boeuf et al. 2000). In southern California, they breed in large numbers on San Miguel and San Nicolas Islands, in increasing numbers on Santa Rosa Island, and in relatively small numbers on Santa Barbara and San Clemente Islands (Stewart et al. 1994, Stewart and Yochem 2000).

Northern elephant seals typically haul out on land only to breed and molt (Le Boeuf 1981), alternating these stays with two extended foraging trips, or migrations, per year (Le Boeuf and Laws 1994). The breeding season is in the winter, from approximately December to March.

Stewart et al. (1994) estimated the 1991 U.S./Mexican population at 127,000 animals and concluded that the population appeared to be growing in California, but was stable or decreasing slowly in Mexico. Based on pup counts, the California breeding stock of northern elephant seals was estimated at approximately 101,000 animals in 2001 (Carretta et al. 2002).

The 1975–1978 and 1980–1983 baseline studies found elephant seals at sea off southern California to be widespread in inshore waters; sightings were only occasionally recorded beyond the continental slope (Bonnell et al. 1981, 1983; Bonnell and Dailey 1993). In the winter and spring, most sightings were recorded in the eastern SCB, from the Santa Monica Basin and eastern rim of the Santa Cruz Basin south to the Catalina and Coronado Escarpments. Sightings were more widely scattered in the summer and fall, with a few occurring offshore over the Patton Escarpment (Bonnell et al. 1981, 1983; Bonnell and Dailey 1993). Bonnell et al. (1983) estimated the 1982 elephant seal breeding population in the SCB at 27,500 animals.

North of Point Conception, Bonnell et al. (1983) sighted northern elephant seals at distances of less than 1 to 140 km from shore; most of these sightings (80%) were recorded over the slope and shelf. Seasonally, the greatest number of sightings (38%) was recorded in winter, during the elephant seal breeding season.

Elephant seals tend to be undersampled by at-sea surveys, because they forage during part of the year in North Pacific waters far from the study area and spend most of their time under water. Thus, despite their large southern California breeding population, only 186 northern elephant seals were sighted at sea in the study area during the 3 years of the present study. The mean water depth for elephant seals sighted on standard offshore surveys was 311.0 m; 65.5% of these were recorded in waters less than 400 m deep.

Northern elephant seals were sighted at distances ranging from about 200 m to about 58 km offshore. The mean distance from land of elephant seals sighted on standard offshore surveys was 10.6 km; 63.7% of these were recorded less than 20 km from land.

Sighting Distribution. – Nearly all of the northern elephant seals sighted at sea during the present study were in the western half of the SCB (Figure 2.8), spread between and around the two major rookeries at San Miguel and San Nicolas Islands. Elephant seals were also seen throughout the Santa Barbara Channel and in low numbers in waters north of Point Conception.

At-Sea Densities. – Because of the limited sighting sample size, at-sea densities were not calculated for the northern elephant seal in the present study.

Summary. – Northern elephant seals are present year-round in southern California waters. We found elephant seals primarily in waters over the continental shelf and slope (less than 400 m deep) and relatively nearshore (within 20 km of land).

The U.S. breeding population of northern elephant seals is growing and has increased approximately fourfold since the end of the 1975–1983 baseline studies. The sparcity of at-sea sighting data for this species makes comparisons between the present and earlier studies difficult.

Northern Fur Seal (*Callorhinus ursinus*)

In the eastern North Pacific, northern fur seals range southward from the Bering Sea to California. Two stocks of northern fur seals are present seasonally in California waters, the eastern North Pacific stock and San Miguel Island stock (Bonnell and Dailey 1993, Koski et al. 1998). The eastern North Pacific stock is now estimated to number approximately 940,000 animals, of which about 99% are associated with the Pribilof Islands rookeries in the eastern Bering Sea (Angliss and Lodge 2002). In the fall following the June–July breeding season, females and many juveniles leave the Bering Sea and migrate southward along the west coast as far as California.

Fur seals from the Bering Sea arrive offshore California in late November (Bonnell and Dailey 1993). Some animals move southward into continental slope and shelf waters, with maximum numbers offshore between 34–42°N from February through April. Nearly 270,000 have been estimated to be present at this time (Antonelis and Perez 1984). Most of these animals are gone by early June (Bonnell and Dailey 1993, Koski et al. 1998).

Northern fur seals established a breeding colony on San Miguel Island in the late 1950s or early 1960s (Peterson et al. 1968). Since that time, the colony has increased steadily, except for steep declines in 1983 and 1998 associated with El Niño events in 1982–1983 and 1997–1998 (DeLong and Antonelis 1991, Forney et al. 2000). The most recent estimate of the San Miguel Island stock is approximately 7,800 fur seals (Forney et al. 2000), down sharply from the (pre-El Niño) 1997 estimate of 12,000 (DeLong and Melin 2000). Recovery from the 1998 decline has been slowed by adult female mortality that occurred along with high pup mortality during the 1997–1998 event (Melin and DeLong 1994, Carretta et al. 2003).

The San Miguel Island stock probably remains within the general vicinity of the rookery during most of the year. Lactating females appear to forage primarily in upwelling areas west of Point Conception in summer (Antonelis et al. 1990, Stewart and Yochem 2000), and most sightings in the fall and winter have been recorded in offshore waters west of San Miguel Island (Bonnell et al. 1981, 1983; Koski et al. 1998).

About 80% of the fur seal sightings recorded in or near the Southern California Bight by Bonnell et al. (1981) during the 1975–1978 baseline study were offshore over the continental slope, particularly west of San Miguel Island. Most were observed in waters over the Santa Rosa–Cortes Ridge, in the San Nicolas Basin, and near Tanner–Cortes Banks. About 97% of the sightings were recorded in the winter and spring; Bonnell et al. (1981) estimated mean fur seal abundance in the SCB and offshore to 122°30'W during those seasons at about 5,000 animals.

Most of the fur seal sightings made from June through November (presumably animals from the San Miguel Island rookery) were recorded in areas west of San Miguel Island, over the Rodriguez Seamount, and northward at distances of 25–70 km offshore to about the latitude of Point Sal (Bonnell et al. 1981, 1983).

We sighted only 15 northern fur seals in the study area. The distributions of sighting depths and distances from land were somewhat bimodal. Although the mean depth for all fur seal sightings was 979.9 m, 60.1% were recorded in waters shallower than 800 m, and 33.3% were in waters deeper than 2,000 m.

Northern fur seals were sighted at distances of less than 1 to more than 114 km from land. The mean distance from land for all northern fur seal sightings was 44. 4 km; 46.7% of these were 10–30 km from land and another 46.7% were greater than 50 km offshore. Although the sample size is small, this pattern of sighting distribution may reflect the presence in the study area of animals from the San Miguel Island rookery in relatively nearshore waters and Bering Sea migrants farther offshore.

Sighting Distribution. – Although a single fur seal was seen in the eastern SCB (Figure 2.9), between Santa Barbara and Santa Catalina Islands, the remaining animals sighted during the present study were in the western half of the SCB (west of about 120°00'W longitude) or north of Point Conception. About half of the sightings were recorded offshore over the continental slope.

At-Sea Densities. – Because of the limited sighting sample size, at-sea densities were not calculated for the northern fur seal.

Summary. – Despite the severe mortality suffered during recent El Niño events, the northern fur seal colony on San Miguel Island has been growing since the 1975–1983 baseline studies. In contrast, the large Pribilof Islands' population in the Bering Sea has been declining for decades. Female fur seals from the Bering rookeries migrate south into California waters following the summer breeding season, becoming the most abundant pinnipeds offshore during the winter months (January–March).

Bonnell et al. (1981, 1983) sighted many more northern fur seals in study area waters during the 1975–1983 baseline studies than were seen during the present study. This difference may have been due to several factors: 1) the continuing decline of the Bering Sea population, indicating that fewer fur seals are wintering offshore California than in previous decades; 2) the lack of surveys in the present study during the peak months of fur seal presence offshore California (February–March); and 3) the survey methods employed in the present study, which limited potential fur seal sightings to the narrow, 50-m corridors searched by the primary observers.

CARNIVORES

Southern Sea Otter (*Enhydra lutris nereis*)

Southern sea otters currently range along the California coast in nearshore waters from near Año Nuevo Island south to approximately Point Conception (Riedman and Estes 1990, FWS 2003). Since 1998, 100–150 sea otters have moved south and east of Point Conception along the Channel in the early spring, with most returning to waters north of the point by mid-summer (FWS 2003). A small, translocated population of less than 30 otters is also present at San Nicolas Island (FWS 2003).

The southern sea otter population is estimated to have numbered approximately 14,000 animals before the onset of commercial hunting (FWS 1995). The remnant California population began recovering from a low of about 50 animals around 1914 (Bryant 1915, Riedman 1987). The California sea otter population grew steadily at a rate of about 5% per year until the mid-1970s, when it was estimated to contain nearly 1,800 animals (Riedman 1987, Riedman and Estes 1990). In 1977, the southern sea otter was listed as a federal threatened species (42 FR 2968); the main reasons for listing were 1) its small population size and limited distribution; and 2) the threat of oil spills, pollution, and competition with humans.

Although there have been serious declines in numbers since the late 1970s, which were attributed to incidental mortality in commercial fisheries, disease, and possibly food resource limitation, the southern sea otter population has increased overall since the end of the 1975–1983 baseline studies (Wendell et al. 1985; FWS 2000, 2003). During the most recent spring census in May 2003, 2,505 sea otters were counted; this is the highest total recorded since surveys began (USGS 2003). Based on 3-year averages, the California sea otter population appears to be roughly stable at present (USGS 2003).

No sea otters were sighted during the 1975–1978 baseline study of the Southern California Bight (Bonnell et al. 1981).

During the 1980–1983 baseline study of central and northern California, Bonnell et al. (1983) conducted 16 aerial surveys of the entire California sea otter range. During that period, the southernmost large groups of sea otters were located in the vicinity of Point San Luis/Shell Beach. Bonnell et al. (1983) also sighted a few otters south of that area, between the Santa Maria River and Point Conception. In 1983, 1,277 southern sea otters were counted during the spring census (FWS 2003).

During the 3 years of the present study, we counted 409 sea otters in the study area. The mean water depth of all sightings was 28.2 m, and 96.6% of all sightings were recorded in waters less than 200 m deep.

Although a few sea otters were seen as far as 38 km from shore, the mean distance from land of all sightings was 1.2 km, and 96.3% of the animals sighted were less than 5 km from land.

Sighting Distribution. – Sea otters were recorded in greatest numbers along the mainland shoreline from Cambria south to Point Conception (Figure 2.10). Otters were also seen along the mainland shore east of Point Conception during all three survey months. During January and September surveys, otters were sighted as far east as Pitas Point in Ventura County; on May surveys, they were observed as far east as Goleta Point in Santa Barbara County.

Sea otters were sighted during all three survey months at San Nicolas Island, where the translocated population resides, and at San Miguel Island, the closest island to Point Conception. One sighting of a pair of sea otters was also recorded near the southeast end of Santa Cruz Island in September 2001.

Sightings recorded at sea on offshore surveys included two groups of otters seen 6–33 km from shore off the San Luis Obispo County coast and several individual animals encountered in waters between San Nicolas Island and the northern chain during a supplemental survey in July 2000.

At-Sea Densities. – Because of the relatively limited sighting sample size, no at-sea densities were calculated for the southern sea otter.

Summary. – Despite setbacks due to fisheries-related mortality, disease, and possible food resource limitation, the southern sea otter population has grown overall since the 1975–1983 baseline studies.

Since the earlier baseline studies, the sea otter population has extended its range southward. Otters are now found, at least seasonally, along the Santa Barbara Channel shoreline as far east as Ventura County and are occasionally seen around the northern Channel Islands. A small population of translocated sea otters, established in the late 1980s, is still present at San Nicolas Island.

CETACEANS

Gray Whale (*Eschrichtius robustus*)

Gray whales migrate through southern California waters twice a year on their way between Mexican breeding lagoons and feeding grounds in the Bering Sea. The southbound migration of gray whales through the Southern California Bight begins in December and lasts through February; the northbound migration is more prolonged, lasting from February through May with a peak in March (Leatherwood 1974, Bonnell and Dailey 1993). Females and their calves are the last component of the population to move northward (Herzing and Mate 1984, Poole 1984). Gray whales are generally absent from southern California waters from August through November.

The California, or eastern Pacific, stock of the gray whale was estimated to contain approximately 30,000 animals in the 1850s (Scammon 1874), but was reduced to about 4,000 animals by commercial whaling by 1874 (Henderson 1984) and was hunted offshore the Mexican breeding lagoons again in this century (Reeves 1984). Since receiving protection in 1946, however, the population has recovered significantly. The eastern North Pacific stock was removed from the List of Endangered and Threatened Wildlife in 1994. Between 1967 and 1996, the eastern North Pacific gray whale population increased at a rate of 2.5% per year and was estimated at 26,635 animals in 1997–1998 (Rugh et al. 1999, Angliss and Lodge 2003).

Migrating gray whales generally travel within 3 km of the shoreline over most of the route (Braham 1984b, Herzing and Mate 1984, Brueggeman et al. 1987), except when crossing mouths of rivers and straits (Pike 1962) or crossing between mainland Alaska and Kodiak Island (Braham 1984b). However, Green et al. (1992) found evidence that the width of the gray whale migration corridor changes in concert with varying widths of the 0–40-m depth zone; off Washington, where the shelf is broad, they recorded a mean offshore sighting distance of 18.5 km.

Off California north of Point Conception, gray whale migration patterns also appear to be influenced by coastal physiography and bathymetry (MBC 1989). Data from aerial surveys indicated that the gray whale migratory corridor off Point Sal was at least 33 km wide, but that

73% of the whales passed within 24 km of shore in water depths of less than 200 m (MBC 1989).

Based on sighting data from the 1975–1983 baseline studies (Dohl et al. 1981, 1983; Bonnell and Dailey 1993), the gray whale migration pathway through the Southern California Bight has been described as broad and diffuse, following three general routes and extending up to 200 km offshore. More than 50% of the 300 sightings made by Dohl et al. (1981) in the SCB occurred within 15 km from the mainland shore. Southbound and northbound migration pathways in the SCB were not found to be notably different (Bonnell and Dailey 1993).

During the 3 years of the present study, we counted 265 gray whales at sea in the study area. Groups of up to nine animals were observed.

The mean water depth for gray whales sighted on standard surveys was 161.8 m, and 61.9% of the animals were sighted in waters less than 200 m deep. Although gray whales were sighted as far as 50.2 km from shore, the mean distance from land for gray whales sighted on standard surveys was 4.4 km; 60.4% of these were within 5 km of land.

Sighting Distribution. – Figure 2.11 presents gray whale sightings recorded during the January and May survey months. This information is summarized below.

The May surveys were flown near the end of the gray whale's northbound migration through the Southern California Bight. A few sightings were recorded along the shoreline between Point Conception and Shell Beach and at the northern Channel Islands; one sighting was made off the San Diego County coast.

Gray whales are generally absent from the SCB in September. Only one sighting—a pair of gray whales (reported as a cow and calf) in the Anacapa Passage—was recorded in this month during the 3 years of the present study.

January is near the peak of the gray whale's southbound migration through the SCB. Surveys in January recorded a stream of sightings that extended along the mainland shoreline from about Cambria south to Point Conception, then across the western end of the Santa Barbara Channel to the northern Channel Islands. Sightings occurred all along the north shoreline of the northern island chain. South of the islands, sightings of gray whales were dispersed in a broad band down the eastern slope of the Santa Rosa–Cortes Ridge and over the Santa Cruz Basin between San Nicolas and Santa Catalina Islands. South of that area, sightings were scattered through the San Diego Basin, as animals apparently moved back toward the mainland shore.

At-Sea Densities. – Because of the limited sighting sample size, no densities were calculated for the gray whale.

Summary. – Gray whales migrate through southern California nearshore waters every winter on their way to and from the calving and breeding lagoons in Baja California. The eastern North Pacific gray whale population has increased since the 1975–1983 studies and may now be near its carrying capacity.

As far as can be ascertained from the surveys conducted during the present study, the patterns of gray whale use of southern California waters has not changed substantially in recent decades.

Fin Whale (*Balaenoptera physalus*)

The second largest cetaceans, fin whales are distributed worldwide. NOAA Fisheries recognizes three stocks in U.S. Pacific waters: Alaska; California, Oregon, and Washington; and Hawaii (Mizroch et al. 1984, Hill et al. 1997, Reeves et al. 1998b). Fin whale migratory behavior in the eastern North Pacific appears to be complex, with either inshore–offshore or north–south movements depending on an individual's age, reproductive status, or "stock" affinity (Reeves et al. 1998b).

The world population of fin whales before exploitation may have been as high as 500,000 animals (Gambrell 1985). Due to their strength and speed, fin whales were not effectively harvested by early whalers, but came to be intensively hunted with the development of modern whaling equipment and techniques in the late 1800s (Tønnesson and Johnson 1982, Webb 1988). By 1976, when fin whales were protected from commercial harvest, the world population had been reduced to an estimated 103,000–122,000 animals (Gambrell 1985). In response to this severe population decline, the fin whale was listed as a federal endangered species in 1970 (35 FR 8495).

A recent population estimate for the entire North Pacific is approximately 14,600–18,600 animals (Perry et al. 1999). Based on ship surveys conducted in 1996 and 2001, 3,279 fin whales are estimated to occur off California, Oregon, and Washington (Carretta et al. 2003). There is some evidence that recent increases in fin whale abundance have occurred in California waters, but these have not been significant (Barlow 1994, Barlow and Gerrodette 1996). In recent years, fin whales have occurred year-round off central and southern California, with peak numbers in summer and fall (Dohl et al. 1981, 1983; Barlow 1995; Forney et al. 1995). Since fin whale abundance decreases in the winter off California and Oregon (Dohl et al. 1981, 1983; Green et al. 1992; Forney et al. 1995), it is believed that the distribution of this stock probably extends outside these waters seasonally.

During the 1975–1978 baseline study of the Southern California Bight (Dohl et al. 1981), highest fin whale numbers were recorded in the spring, although individuals were sighted in the SCB in all seasons. In the spring, from April through June, fin whales were seen in the Santa Barbara Channel, in waters over the Santa Rosa–Cortes Ridge, and in the southern part of the SCB east to about 118°W. They were sighted in waters north of San Nicolas Island and over Tanner and Cortes Banks in the summer (from July through September) and in waters west of San Nicolas Island, off San Clemente Island, and west of Tanner Bank in the winter (from January through March).

North of Point Conception, fin whales were observed predominantly over the slope and shelf during the 1980–1983 baseline study (Dohl et al. 1983). About 97% of the sightings were recorded in the southern half of the study area, although mostly from about Point Buchon north to the Gulf of the Farallones.

Based on the 1975–1983 data, Bonnell and Dailey (1993) estimated that about 70 fin whales were present in the SCB in June, as migrants moved northward through the area, with a summer population of about 30 animals.

During the 3 years of the present study, we counted 106 fin whales in the study area. Fin whales were found in deeper waters than blue whales; none were sighted on the continental shelf (less than 200 m), and 81.1% were seen in waters with depths between 400 and 1,200 m. The mean water depth for all fin whale sightings was 979.7 m.

Fin whales were also sighted farther offshore than blue whales, at distances between about 7 and 82 km from land. The mean distance from land for all sightings was 41.5 km, and 92.3% were recorded more than 20 km from shore; 41.2% were more than 50 km offshore.

Sighting Distribution. – Figure 2.12 presents fin whale sightings recorded during the May and September survey months. This information is summarized below.

Although several fin whales were seen in waters west of the Santa Barbara Channel during May surveys, most sightings were recorded south of the northern Channel Islands, particularly west and southwest of San Nicolas Island. Sightings were also scattered through the southeastern quadrant of the SCB as far east as the San Diego Basin.

All the fin whale sightings recorded on September surveys were offshore, primarily over the continental slope, in an arc extending from about Point Piedras Blancas in the north to Tanner–Cortes Banks; fin whales were concentrated in waters over the slope to the west and northwest of San Nicolas Island.

Two sightings of fin whales were recorded on January surveys: one sighting was over the slope west-southwest of San Nicolas Island, and the other was a few kilometers east of the northern tip of San Clemente Island.

At-Sea Densities. – Because of the limited sighting sample size, no at-sea densities were calculated for the fin whale.

Summary. – Fin whales are seen in study area waters throughout the year, but are much less common during the winter months. Although a quantitative comparison cannot be made with the data collected during the present study, use of southern California waters by fin whales appears to be increasing.

Compared to blue and humpback whales, fin whales were generally found in relatively deep, slope (between 400 and 1,200 m deep) and offshore waters (more than 20 km from land). They entered the Santa Barbara Channel and the eastern half of the SCB less frequently. During the 1975–1978 baseline study, Dohl et al. (1981) recorded a broader distribution of fin whale sightings in the SCB than was observed during the present study.

Blue Whale (*Balaenoptera musculus*)

The largest of all animals, blue whales are distributed worldwide in circumpolar and temperate waters and inhabit both coastal and pelagic environments (Leatherwood et al. 1982, Reeves et al. 1998a). Like most baleen whales, they migrate between warmer waters used for breeding and calving in winter and high-latitude feeding grounds where food is plentiful in the summer. In the eastern North Pacific, blue whales are found from the Gulf of Alaska south to at least Costa Rica (Reeves et al. 1998a, Mate et al. 1999). Rice (1992) concluded that the California population is separate from that in the Gulf of Alaska and the eastern Aleutians, and this view is supported by other recent work (Barlow 1995, Calambokidis and Steiger 1995, Calambokidis et al. 1995).

Blue whales were heavily exploited by commercial whalers following the introduction of modern whaling equipment and techniques in the late 19th century. Worldwide, the blue whale population was reduced from a pre-exploitation estimate of 228,000 animals to less than 10,000 (Brownell et al. 1989). The pre-exploitation population of blue whales in the North Pacific has been estimated at 4,500–5,000 animals (Braham 1984a, Leatherwood et al. 1987). In response to this severe population decline, the blue whale was listed as a federal endangered species in 1970 (35 FR 8495).

No reliable population estimate exists for the North Pacific, except for the population that summers off California (Reeves et al. 1998a). More than 700 individual blue whales had been photo-identified in California and Mexican coastal waters through 1993 (Calambokidis 1995), and this stock has recently been estimated at 2,134 animals (Reeves et al. 1998a). Although the population appears to be growing, the observed increase in blue whale abundance off California during the past two decades is thought to be too large to be explained by population growth alone and may at least partially be due to a shift in distribution (Reeves et al. 1998a).

Blue whales occur along the west coast of Baja California from March through July (Gendron and Zavala-Hernández 1995). They are first observed around the Channel Islands, in Monterey Bay, and in the Gulf of the Farallones in June or July, and are present on the continental shelf in these areas from August to November (Calambokidis et al. 1990, Calambokidis 1995, Larkman and Veit 1998, Mate et al. 1999). Sighting data collected off southern California from 1992 through 1999 by Cascadia Research Collective (Cascadia Research, unpubl. data) indicate that blue whales in the Santa Barbara Channel tend to aggregate along the shelf break (seaward of the 200-m isobath). Sighting frequencies were highest west of San Miguel Island, along the north sides of San Miguel and Santa Rosa Islands, and along the western half of Santa Cruz Island. In some years, summer feeding concentrations of up to 100 blue whales have been recorded in these waters (Koski et al. 1998).

During the 1975–1978 baseline study of the Southern California Bight (Dohl et al. 1981), no blue whales were seen in the winter, from January through March; about 84% were sighted in the spring and summer. In the spring, from April through June, blue whales were sighted in the western Santa Barbara Channel and in waters 40–45 km east of San Clemente Island. In the summer, from July through September, they were seen in the Santa Barbara Channel and near San Clemente Island.

North of Point Conception, Dohl et al. (1983) sighted blue whales during their 1980–1983 baseline study mainly over the shelf and slope, especially from about Point Piedras Blancas south. Blue whales were seen from May through November in these waters, with 80% recorded during the months of September through November.

Line transect analysis of aerial survey data from the 1975–1983 baseline studies indicated the presence of about 50 blue whales in the SCB in June (and about half that in October) (Bonnell and Dailey 1993). The summer population of blue whales in the SCB was estimated to number at least 20 animals, which were concentrated during July through September in waters from the western Santa Barbara Channel offshore to about Rodriguez Seamount.

During the 3 years of the present study, we counted 102 blue whales in the study area. They were sighted mainly on the continental shelf and upper slope—41.4% were sighted in waters less than 200 m deep and 75.8% in waters shallower than 400 m. The mean water depth for all blue whale sightings was 610.4 m.

Blue whales were sighted at distances of less than 2 to 69 km from land. The mean distance from land for all blue whale sightings was 21.8 km. Only 1.7% were sighted within 5 km of land, but 75.8% were seen between 10 and 20 km from shore.

Sighting Distribution. – Figure 2.13 presents blue whale sightings recorded during the May and September survey months. This information is summarized below.

During May surveys, blue whale sightings were relatively restricted in area, with the majority being observed in the western Santa Barbara Channel, particularly near the northern Channel Islands. A blue whale sighting was also recorded south of San Nicolas Island. Although not depicted in Figure 2.13, several blue whales were also seen in the Santa Barbara Channel and north of San Nicolas Island during a supplemental survey in June 1999.

Blue whales were much more broadly distributed during September surveys. Sightings were recorded over the shelf and slope from about Point Piedras Blancas in the north to near San Clemente Island. Sightings were concentrated in waters to the west of the Santa Barbara Channel and northern Channel Islands, from about Point Arguello south to the western slope of the Santa Rosa–Cortes Ridge.

No blue whales were sighted on January surveys.

At-Sea Densities. – Because of the limited sighting sample size, no at-sea densities were calculated for the blue whale.

Summary. – A portion of the California, Oregon, and Washington stock of blue whales forages each summer in waters in and near the Santa Barbara Channel and northern Channel Islands. During the present study, we generally found blue whales in waters over the continental slope and upper shelf (less than 400 m deep) and relative close to shore (within 20 km of land).

Blue whales have increased in abundance in the study area since the 1975–1983 baseline studies, probably due to a combination of population growth and shifts in distribution.

Humpback Whale (*Megaptera novaeangliae*)

Humpback whales are distributed worldwide and undertake extensive migrations in parts of their range (Leatherwood et al. 1982). They aggregate from late spring through the fall to feed in productive temperate and high-latitude waters and migrate in the winter months to lower latitudes for breeding and calving. In the eastern North Pacific, humpbacks range from arctic waters south to central California in the summer. On their feeding grounds, humpbacks are found primarily on the continental shelf near shallow banks and nearshore marine waters (Rice 1974, Wolman 1986). Humpback whales winter in three areas: waters off Mexico (Rice 1974); Hawaii (Baker et al. 1986); and the Marianas, Bonin, and Ryukyu Islands and Taiwan in the western Pacific (Nishiwaki 1959).

The pre-exploitation world population of humpback whales has been estimated at about 115,000 animals (Brownell et al. 1989). Made vulnerable by their coastal distribution and gregariousness, humpback whale populations were greatly depleted throughout the world in this century by both land-based and pelagic whaling operations (Rice 1974, 1978; Tønnessen and Johnson 1982; Brownell et al. 1989). Between 1905 and 1960, 23,000 humpbacks were taken by modern whaling operations in the North Pacific (Johnson and Wolman 1984), and at least 5,000 more were taken from 1960 to 1965 (Rice 1978). In response to this severe population decline, the humpback whale was listed as a federal endangered species in 1970 (35 FR 8495).

Population estimates for the entire North Pacific increased from 1,200 in 1966 to 6,000–8,000 in about 1992 (Forney et al. 2000). A recent estimate for the eastern North Pacific stock of humpback whales is 1,314 animals (Carretta et al. 2003).

Based on photo-identification work, Calambokidis et al. (1996) concluded that humpback whales off California, Oregon, and Washington form a single, intermixing population, with very little interchange with populations farther north. Whales from this west coast population feed off California through summer and fall (Dohl et al. 1983, Calambokidis et al. 1996). Based on sighting data collected off southern California from 1992 through 1999 by Cascadia Research Collective (Cascadia Research, unpubl. data), humpback whales occur throughout the western two-thirds of the Santa Barbara Channel and, to a lesser extent, in the Santa Maria Basin. As is the case for blue whales, there appears to be a tendency for humpbacks to concentrate along the shelfbreak north of the Channel Islands.

Dohl et al. (1981) recorded only 18 sightings of humpback whales in the Southern California Bight during their 1975–1978 baseline study. Highest numbers were seen in the summer and fall; no sightings were recorded during the months of December through February. From these data, Bonnell and Dailey (1993) estimated the migrant population of humpbacks at 25–35 animals, but concluded that there was no summer resident population in the SCB.

During their 1980–1983 baseline study, Dohl et al. (1983) found humpback whales off central and northern California from April through December. Humpbacks were sighted throughout the Santa Maria Basin, but greatest numbers were concentrated in the Gulf of the Farallones during the months of August through November.

During the 3 years of the present study, we counted 68 humpback whales at sea in the study area. On average, humpbacks were seen in slightly deeper waters than blue whales. The mean sighting depth was 643.3 m; 30.8% of the sightings were recorded in waters less than 200 m deep, and 57.6% were in waters 400–1,200 m deep.

Humpback whales were sighted at distances of less than 0.5 km to about 82 km from land. Although sightings of humpback whales tended to be farther offshore than blue whale sightings, with a mean distance from land of 31.0 km, a higher percentage of humpbacks (9.6%) were seen within 5 km of shore; 34.2% of the sightings were recorded 10–20 km from shore.

Sighting Distribution. – Figure 2.14 shows humpback whale sightings recorded during the May and September survey months. This information is summarized below.

Except for a single sighting near Tanner–Cortes Banks, all sightings of humpback whales made on May surveys were recorded in the Santa Barbara Channel (particularly near the northern island chain) and in slope waters to the immediate west.

On September surveys, sightings of humpback whales were distributed from the western end of the Santa Barbara Channel north to about the latitude of Morro Bay. Sightings recorded north of Point Conception were offshore over the continental slope.

No humpback whales were sighted on January surveys.

At-Sea Densities. – Because of the limited sighting sample size, no at-sea densities were calculated for the humpback whale.

Summary. – Although there is some evidence of a decline in abundance between 1996 and 2001, the Eastern Pacific stock of humpbacks appears to be increasing in abundance (Carretta et al. 2003). Humpback whales have increased substantially in southern California waters since the earlier baseline studies and now forage regularly each summer–early fall in waters in and near the Santa Barbara Channel and southern Santa Maria Basin.

We found humpback whales predominantly in waters over the mid-slope (400–1,200 m deep), although nearly one-third were sighted over the continental shelf. On average, humpbacks were seen somewhat farther from shore than blue whales, with a mean sighting distance of 31.0 km from land.

Minke Whale (*Balaenoptera acutorostrata*)

Minke whales, the smallest of the baleen whales, range worldwide in waters along the continental margins. In the eastern North Pacific, minke whales are a coastal species and are widely distributed on the continental shelf (Green et al. 1989). In the summer, minke whales appear to be broadly distributed between Baja California and the Bering and Chukchi Seas; in the winter, their range is more restricted, extending from Islas De Revillagigedo, Mexico, to at least northern Washington (Rice 1974, Leatherwood et al. 1982).

Brownell et al. (1989) estimated the world population of minke whales at about 725,000 animals, of which 600,000 were in the southern hemisphere. Although no reliable estimates exist for the North Pacific population, the minke whale population in California, Oregon, and Washington waters is currently estimated at 1,015 animals (Carretta et al. 2003).

Using sighting data collected during the 1975–1983 baseline studies (Dohl et al. 1981, 1983), Bonnell and Dailey (1993) described a cycle of abundance for minke whales in the Southern California Bight with small, but distinct peaks in June and November, suggesting that a few whales probably migrated through the area in the spring and returned in the fall. They estimated a migrant population of about 30 to 70 animals in spring and fall and a summer resident population in the SCB of 20 to 40 whales. The summer population of minke whales was distributed in the Santa Barbara Channel, over the Santa Rosa–Cortes Ridge, and in waters from the northern island chain south to San Nicolas Island.

We sighted only three minke whales during the 3 years of the present study (Figure 2.15): 1) in September 2000, a minke was observed about 72 km southwest of San Clemente Island near Tanner-Cortes Banks in 222 m of water; 2) in May 2001, a minke was seen about 53 km west of San Miguel Island near Rodriguez Seamount in 1,250 m of water; and 3) in September 2001, a minke whale was sighted about 8 km southwest of Santa Barbara in the northern Santa Barbara Channel in 115 m of water.

No minke whales were sighted on January surveys.

Summary. – We recorded only three sightings of minke whales during the present study. In contrast, Dohl et al. (1981) found minke whales to be the second most prevalent baleen whales (after gray whales) in the SCB during their 1975–1983 study. They did record the fewest sightings of minke whales during the winter (none were seen in January). North of Point Conception, Dohl et al. (1983) observed minke whales during most months of the year, although only two sightings were recorded south of Point Sur.

Common Dolphin (*Delphinus capensis/delphis*)

Common dolphins inhabit tropical to temperate waters worldwide. In the eastern North Pacific, they range from the equator to at least central Oregon (Forney et al. 2000), although their occurrence north of the Southern California Bight has generally been associated with warm-water years (Bonnell and Dailey 1993). Common dolphins are very gregarious and are frequently encountered in herds of 1,000 or more (Leatherwood et al. 1982).

Two species of common dolphin have recently been recognized in California waters (Heyning and Perrin 1994, Forney et al. 2000). A coastal form, the long-beaked common dolphin (*Delphinus capensis*), is commonly found within about 100 km of the coast from Baja north to about central California (Heyning and Perrin 1994, Rosel et al. 1994). Its relative abundance changes both seasonally and interannually, with the highest densities observed during warm-water events (Heyning and Perrin 1994, Forney et al. 2000). A recent abundance estimate for this stock is 43,360 animals (Carretta et al. 2003).

The short-beaked common dolphin (*D. delphis*) is the most abundant cetacean off California, ranging from the coast to more than 550 km offshore (Forney et al. 2000). On recent fall and summer surveys conducted by NOAA Fisheries, *D. delphis* have been sighted as far north as Oregon (42°N) (Forney et al. 2000). A recent abundance estimate for the California, Oregon, and Washington population of the short-beaked common dolphin is 449,846 animals (Carretta et al. 2003).

During their 1975–1978 study of the Southern California Bight, Dohl et al. (1981) found common dolphins to be by far the most abundant cetacean species in the SCB, accounting for 57–84% of the total seasonal cetacean population in the area. Dohl et al. (1986) conducted an analysis of these data and concluded that the species exhibited a strongly seasonal pattern of occupation in the SCB, being most abundant in the summer and fall and retreating southward during the winter.

In the winter and spring, common dolphins were found almost exclusively in the eastern parts of the SCB. Total abundance from January through June was estimated to average 15,400 animals.

Through the summer, the numbers of common dolphins in waters east of Santa Catalina and San Clemente Islands remained high, but the species' distribution expanded to include the central SCB. Total estimated abundance for the period from July through December averaged 57,300 animals. The summer–fall distribution included most of the SCB inshore of the Patton Escarpment.

Dohl et al. (1983) sighted common dolphins north of Point Conception only once during their 1980–1983 baseline study of central and northern California: a small group of five was seen about 50 km west of Año Nuevo Island in March 1980.

During the 3 years of the present study, we sighted an estimated 50,366 common dolphins at sea, making them the most abundant marine mammals in the study area. Because they could not be reliably distinguished from the air, no distinction was made between the two species. Although a few individual animals were sighted, group sizes of up to 4,500 were estimated. Because most sightings of common dolphins were recorded by the primary observers, who searched a 50-m corridor, total group sizes could not always be estimated. As a result, no mean group size was calculated for common dolphins.

Common dolphins generally were sighted in waters over the continental shelf and upper slope. The mean water depth for sightings recorded on transect on offshore surveys was 516.7 m; 54.4% were seen in waters less than 400 m deep, and 89.5% were seen in waters less than 1,000 m deep.

Although sighted as far as 75 km from land, common dolphins were also found relatively near shore—the mean distance from land of common dolphin sightings recorded on transect on offshore surveys was 20.1 km, and 71.9% were seen within 20 km of land.

Sighting Distribution. – Figure 2.16 shows common dolphin sightings recorded during each of the three primary survey months. This information is summarized below.

On May surveys, common dolphins were sighted mainly in relatively nearshore waters from the Santa Barbara Channel east into Santa Monica Bay. South of the Palos Verde Peninsula, sightings were scattered throughout the southeastern SCB as far south as the Mexican border. Two sightings were also recorded north of Point Conception over the slope west of Purisima Point.

On September surveys, common dolphin sightings were distributed much more broadly throughout the SCB, east of a line extending roughly from Point Conception to Tanner–Banks, with concentrations in the eastern Santa Barbara Channel and outer Santa Monica Bay. Several sightings were also recorded over the shelf and slope north of Point Conception to about Cambria.

Sightings of common dolphins made on January surveys also were generally restricted to the eastern half of the SCB, with some concentration in the eastern Santa Barbara Channel. Several sightings were recorded over the shelf north of Point Conception to about Cambria.

Based on the 1999–2002 sighting data, at-sea population estimates (± SE) were calculated for common dolphins within the study area (Table 2.4). The estimates ranged from a low of 8,467 (± 5,388) individuals in the area in May to a high of 93,138 (± 36,947) in September.

At-Sea Densities. – Densities of common dolphins (± SE) were calculated for the entire study area using data from both the offshore and coastal surveys (Table 2.5). On offshore surveys, densities of common dolphins differed among seasons (ANOVA: $F_{2,4487} = 8.5$, $P < 0.001$) and subareas (ANOVA: $F_{3,4487} = 3.5$, $P = 0.01$). Overall densities ranged from a low of 0.11 dolphins km^{-2} in May to a high of 1.21 in September. Densities recorded on offshore surveys varied from 0.16 km^{-2} in May to 1.70 in September. Very low densities were observed in nearshore mainland and island waters—only one sighting of common dolphins was recorded on coastal surveys during the present study.

Recorded at-sea densities of common dolphins were generally highest in subarea 4, the eastern SCB (Figure 2.3), where they ranged from a low of 0.50 animals km^{-2} in May to a high of 1.11 in September (Table 2.6). However, the single highest seasonal density (4.49 km^{-2}) was recorded in September in central subarea 3, which encompassed the Santa Barbara Channel and northern Channel Islands. Densities during the other survey months were much lower, varying from 0.07 in January to 0.11 in May.

Seasonal Patterns. – In January (Figure 2.17a), the highest densities of common dolphins (30–156 animals km^{-2}) were recorded in one nearshore block at the Ventura/Los Angeles County line. Lower densities were observed southeast of San Clemente Island near the Mexican border, in the eastern Santa Barbara Channel, and over the northern San Diego Basin.

In May (Figure 2.17b), as in January, highest densities were observed in a block in outer Santa Monica Bay near the Ventura/Los Angeles County line. Lower densities were recorded in a block north of Santa Cruz Island.

In September (Figure 2.17c), highest densities were recorded in blocks in the western and north-central Santa Barbara Channel, over the Santa Rosa–Cortes Ridge, and in the southern San Diego Basin near the Mexican border. Lower densities were observed over the slope west of Point Buchon north of Point Conception, in the eastern Santa Barbara Channel, and in the San Pedro Basin.

Summary. – Two species of common dolphins, an offshore and a coastal form, have been recognized in California waters since the 1975–1983 studies, although they were not distinguished during the present study. Common dolphin populations off California have increased since the initial baseline studies, probably due to a combination of population growth and movement of animals into the area from waters farther south and west. Since the major El Niño event in 1982–1983, common dolphins have expanded their range over shelf and slope waters far north of Point Conception.

We generally found common dolphins in waters over the continental shelf and slope (less than 1,000 m deep) and relatively close to land (less than 20 km from shore). Sightings of common dolphins indicated a seasonal pattern of distribution within the Southern California Bight similar to that described by Dohl et al. (1981), with a southward shift in abundance during the cold-water months.

Risso’s Dolphin (*Grampus griseus*)

Risso's dolphins are distributed worldwide in pelagic tropical and warm-temperate waters (Watson 1981). In the eastern North Pacific, they range from the equator to British Columbia (56°N) (Guiguet and Pike 1965, Braham 1983). Although Risso's dolphins historically have been seen predominantly in waters over the continental slope, sightings over the shelf have increased since 1971 (Leatherwood et al. 1982, Carretta et al. 1995, Koski et al. 1998). The Risso's dolphins found off California during the colder winter months are thought to shift northward to Oregon and Washington in the late spring and summer, and there seems to be a distributional gap between California animals and Risso’s dolphins sighted in the tropical Pacific and Gulf of California (Forney et al. 2000).

No population estimates are available for Risso's dolphins in the North Pacific (NMFS 1987). A recent abundance estimate for the California, Oregon, and Washington stock is 16,066 animals (Carretta et al. 2003).

During the 1975–1978 baseline study, Dohl et al. (1981) observed Risso's dolphins in the Southern California Bight year-round. Based on these data, Bonnell and Dailey (1993) estimated mean abundance throughout the year at about 1,400 animals, although generally fewer than 1,000 were present outside the months of September through November, when numbers increased to about 4,000.

In summer and fall, Risso's dolphins were mainly distributed inshore of the Santa Rosa–Cortes Ridge; in winter and spring, the population shifted offshore and was predominantly found over and beyond the Santa Rosa–Cortes Ridge, San Clemente Escarpment, and nearby offshore banks (Dohl et al. 1981, Bonnell and Dailey 1993).

Off central California, Dohl et al. (1983) recorded the highest incidence of sightings between Point Conception and Monterey Bay during their 1980–1983 study; the majority of sightings were over the continental slope in waters 200–2,000 m deep.

During the 3 years of the present study, we counted 1,980 Risso’s dolphins at sea in the study area. Observed group size ranged from 1 to 125 animals. Because most sightings of Risso’s dolphins were recorded by the primary observers, who searched a 50-m corridor, total group sizes could not always be estimated. As a result, no mean group size was calculated for Risso’s dolphins.

Risso’s dolphins were sighted most frequently over the upper continental slope—45.4% of the animals sighted on standard surveys were seen in waters 200–600 m deep. The mean water depth for Risso’s dolphins sighted on standard surveys was 647.1 m.

Although seen as far as 70 km offshore, Risso’s dolphins were also sighted relatively near shore on standard surveys; 65.5% of the sightings were recorded less than 20 km from land.

Sighting Distribution. – Figure 2.18 presents Risso’s dolphin sightings recorded during each of the three primary survey months. This information is summarized below.

The distributions of sightings of Risso’s dolphins were fairly similar during all three survey months. In May, most sightings were recorded in the northern half of the SCB, from the western Santa Barbara Channel over the Santa Rosa–Cortes Ridge and Santa Cruz Basin to Santa Monica Bay. Several sightings were made over the slope north of Point Conception to about Point Sal.

Sightings of Risso’s dolphins on September surveys were scattered through the SCB from the Santa Barbara Channel and over the Santa Cruz Basin to San Nicolas Island, with several sightings farther east in the San Pedro and San Diego Basins. North of Point Conception, Risso’s dolphins were sighted over the slope to about Cayucos.

January sightings of Risso’s dolphins were concentrated along the north shoreline of Santa Cruz Island, south of the northern chain through the Santa Cruz Basin, and near Santa Barbara Island. A few sightings were recorded over the slope north of Point Conception between Point Buchon and Point Piedras Blancas.

Based on the 1999–2002 sighting data, at-sea population estimates were calculated for Risso’s dolphins within the study area (Table 2.4). The estimates ranged from a low of 4,618 (± 2,309) individuals in the area in September to a high of 10,007 (± 3,849) in January.

At-Sea Densities. – Densities of Risso's dolphins (± SE) were calculated for the entire study area using data from both the offshore and coastal surveys (Table 2.5). On offshore surveys, densities differed among subareas (ANOVA: $F_{4.4940} = 2.6$, $P = 0.03$). Overall densities remained relatively low throughout the year with minor variation among seasons, ranging from 0.06 animals km^{-2} on September to 0.13 in January. Very low densities were observed in nearshore mainland and island waters in May and September, but a density of 0.23 animals km^{-2} was recorded for the January surveys. All these animals were sighted along the shorelines of the northern Channel Island chain, where a January peak of 0.74 dolphins km^{-2} was observed.

Recorded at-sea densities of Risso's dolphins were consistently highest in central subarea 3, which encompassed the Santa Barbara Channel and northern Channel Islands (Figure 2.3), where they ranged from a low of 0.13 animals km^{-2} in September to a high of 0.27 in May (Table 2.6). Somewhat lower densities (0.05 to 0.12 animals km^{-2}) were observed in subarea 4, the eastern SCB.

Seasonal Patterns. – In January (Figure 2.19a), the highest densities of Risso's dolphins (up to 5 animals km^{-2}) were observed along the northern shoreline of Santa Cruz Island and south of the northern island chain, over the Santa Rosa–Cortes Ridge and north of Santa Barbara Island.

In May (Figure 2.19b), Risso's dolphins were recorded in highest densities in nearshore waters south and west of the northern Channel Islands and in the western Santa Barbara Channel.

In September (Figure 2.19c), highest densities of Risso's dolphins were again observed in the western Santa Barbara Channel. Lower densities were recorded in waters around the northern Channel Islands.

Summary. – Risso's dolphins are believed to have increased in abundance off southern California during recent decades. Based on comparison with the 1975–1983 baseline studies, Risso's dolphins have apparently expanded their range in southern California waters in recent decades.

We generally found Risso's dolphins in waters over the upper continental slope (200–600 m deep) and relatively close to shore (less than 20 km from land).

Pacific Bottlenose Dolphin (*Tursiops truncatus*)

Bottlenose dolphins are more widely distributed than any other species of small cetacean in the tropical and temperate eastern North Pacific (Leatherwood et al. 1982). Off the American coastline, they range from the equator north to at least California (Leatherwood and Reeves 1986, Bonnell and Dailey 1993).

Bottlenose dolphins are present in the Southern California Bight year-round (Bonnell and Dailey 1993). Norris and Prescott (1961) identified distinct coastal and offshore populations in the SCB. Although no information is available on intermixing, studies of parasites indicate that some degree of isolation does exist (Walker 1975). The coastal bottlenose dolphin population in southern California has recently been estimated at 206 animals and is considered to be stable (Dudzik 1999, Carretta et al. 2003). A recent estimate for the offshore population is 5,065 animals (Carretta et al. 2003).

Coastal bottlenose dolphins usually inhabit waters within 1 km of the mainland shore, primarily from Point Conception south to Mexico, although animals from this population have been sighted as far north as San Francisco since the 1982–1983 El Niño event (Dohl et al. 1981, Hansen 1990, Wells et al. 1990, Carretta et al. 1998, Defran and Weller 1999, Forney et al. 2000). These dolphins appear to form small resident groups that occupy relatively stable home ranges (Shane et al. 1986), although movements of small groups outside the population's home range have been recorded (Dohl et al. 1983, Wells et al. 1990).

Offshore bottlenose dolphins have been sighted as far north as 41°N along the northern California coast and may reach Oregon and Washington waters during warm-water periods (Forney et al. 2000). No seasonal patterns in their distribution have been detected (Forney and Barlow 1998, Forney et al. 2000). In the Southern California Bight, the offshore population moves between nearshore waters around several southern California islands and is apparently centered around Santa Catalina Island for most of the year (Dohl et al. 1981, Bonnell and Dailey 1993).

No coastal surveys were flown during the 1975–1978 baseline study of the Southern California Bight. On offshore transects, Dohl et al. (1981) recorded highest numbers of bottlenose dolphins during the fall and winter, coincident with the peak of market squid spawning in the SCB (Bonnell and Dailey 1993). Sightings were concentrated in waters around Santa Catalina Island. The summer population was more widely distributed, occupying waters near Santa Catalina, San Clemente, Santa Barbara, Anacapa, and San Nicolas Islands and along the mainland shore. This offshore population was estimated to range between 200 and about 550 animals (Dohl et al. 1981, Bonnell and Dailey 1993).

No bottlenose dolphins were recorded off central or northern California during the 1980–1983 study (Dohl et al. 1983).

During the 3 years of the present study, we counted 844 bottlenose dolphins at sea in the study area. Observed group size ranged from 1 to 25 animals. Because most sightings of bottlenose dolphins were recorded by the primary observers, who searched a 50-m corridor, total group sizes could not always be estimated. As a result, no mean group size was calculated for bottlenose dolphins.

Most sightings were of animals from the coastal population. The mean water depth for all bottlenose dolphin sightings was only 33.3 m, and 92.5% of the sightings were recorded in waters less than 200 m deep.

The mean sighting distance from land was 1.0 km; 92.5% were recorded within 5 km of the shoreline, and the farthest was 47.5 km offshore.

Sighting Distribution. – Figure 2.20 presents the sightings of bottlenose dolphins recorded during each of the three primary survey months. This information is summarized below.

On May surveys, bottlenose dolphins were sighted nearshore along the mainland coast from Point Conception to the Mexican border, with concentrations along the Santa Barbara and Ventura County coasts; several sightings north of Point Conception were clustered in the vicinity of Point Buchon and Morro Bay. The few sightings recorded offshore were scattered in the western Santa Barbara Channel, along the shorelines of Santa Rosa, Santa Cruz, and Santa Barbara Islands, in the San Pedro Basin, and southwest of San Nicolas Island.

Sightings of bottlenose dolphins in nearshore waters in September ranged from near Cambria in the north to the Mexican border, with concentrations along the Ventura County coast. Offshore, bottlenose dolphins were sighted in the Santa Barbara Channel and east of Santa Catalina Island.

In January, nearshore sightings of bottlenose dolphins were recorded along the mainland from Morro Bay to the Mexican border, with heaviest concentrations along the Santa Barbara and Ventura County shorelines. Offshore, bottlenose dolphins were seen in the Santa Barbara Channel, near Santa Barbara Island, and southeast of San Clemente Island.

At-Sea Densities. – Densities of bottlenose dolphins (± SE) were calculated for the entire study area, using data from both the offshore and coastal surveys (Table 2.5). Although the densities of bottlenose dolphins recorded on offshore surveys did not differ significantly among seasons or subareas, densities recorded on coastal surveys differed significantly among both seasons (ANOVA: $F_{2,1521} = 5.9$, $P < 0.01$) and subareas (ANOVA: $F_{3,1521} = 5.8$, $P = 0.001$). Overall densities ranged from a low of 0.06 dolphins km^{-2} in January to a high of 0.17 in May. Higher densities (from 0.19 km^{-2} in January to 0.47 in May) were observed in nearshore mainland and island waters on the coastal surveys. Densities recorded on offshore surveys were very low, varying from 0.00 dolphins km^{-2} in January to 0.03 in May.

Recorded at-sea densities of bottlenose dolphins were very low throughout the study area (Table 2.6). They reached a peak of 0.08 animals km^{-2} in central subarea 3 (Figure 2.3), which encompassed the Santa Barbara Channel and northern Channel Islands. Densities in the other four subareas were calculated at 0.03 dolphins km^{-2} or less.

Mainland coastal densities of bottlenose dolphins for the entire study area ranged from a low of 0.36 dolphins km^{-2} in January to a high of 0.85 in May (Table 2.7). Measured densities were highest along the central coastline, from Point Arguello east to near Point Dume, where they ranged from a low of 0.43 km^{-2} in September to a high of 1.12 in May. Densities along the southern mainland coastline, from Point Dume south to the Mexican border, also showed a May peak of 0.85 animals km^{-2}, and a January low of 0.09. Densities along the northern mainland coastline, from Point Arguello north to Point Piedras Blancas, were highest during the warm-water month of September (0.67 km^{-2}) and reached a low of 0.00 in January. Island coastline densities of bottlenose dolphins were extremely low, only reaching as high as 0.01 km^{-2} around the northern Channel Islands in May (Table 2.8).

Seasonal Patterns. – Overall densities of bottlenose dolphins in the Southern California Bight were low during January surveys (Figure 2.21). Densities of 0–1 animal km^{-2} were recorded in only two blocks—along the southern Santa Barbara County coast and on the north side of Santa Barbara Island.

The highest densities were recorded in May. Densities of 5–17 animals km^{-2} were observed along the mainland coast near the Santa Barbara/Ventura County line and east of Point Dume, and densities of 0–5 dolphins km^{-2} were recorded at several locations along the coast between Santa Barbara and San Diego Counties.

In September, recorded densities of bottlenose dolphins were also somewhat lower than in May. Densities of 5–17 dolphins km^{-2} were observed in one block along the mainland coast in northern San Diego County; densities of 0–1 km^{-2} were recorded along the mainland from eastern Santa Barbara County to about the Los Angeles County line and in the north-central Santa Barbara Channel.

Summary. – Although no information on population trends is available for the offshore population of bottlenose dolphins, the California coastal population is thought to have remained stable over a decade or more.

During the present study, most of the sightings of bottlenose dolphins were of coastal dolphins; more than 90% were in waters less than 200 m deep and less than 5 km from shore.

The lack of coastal surveys during the 1975–1978 baseline study makes comparisons of sighting data with the present study difficult. However, since the earlier baseline studies (following the 1982–1983 El Niño event), bottlenose dolphins have ranged north of Point Conception during warm-water periods; we recorded them in this area during all survey months.

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

Pacific white-sided dolphins are found in temperate waters of the North Pacific. They are widely distributed in the eastern North Pacific from Baja California to the Gulf of Alaska (Nishiwaki 1972; Leatherwood et al. 1982, 1984). Southern California (between 33° and 36°N) appears to be an area of mixing of two genetically distinct forms (Lux et al. 1997, Forney et al. 2000). Pacific white-sided dolphins range widely in offshore, slope, and continental shelf waters, but may be more common over the continental shelf at the northern and southern extremes of their range (Leatherwood et al. 1984).

Recent population estimates for the species in the eastern North Pacific range from 30,000 to 50,000 animals (NMFS 1987), although Dohl et al. (1983) estimated a peak fall population of 86,000 Pacific white-sided dolphins off central and northern California. Carretta et al. (2003) estimated the average abundance for the stock off California, Oregon, and Washington at 59,274 animals for 1996–2001.

During the 1975–1983 baseline studies (Dohl et al. 1981, 1983; Bonnell and Dailey 1993), Pacific white-sided dolphins were found year-round in California waters, reaching a peak in the fall when most schools were seen south of Monterey Bay. In the SCB, white-sided dolphins moved south in the fall and north in the spring, peaking from about September through November when they were found in the western Santa Barbara Channel, over the San Miguel Island shelf, and along the Santa Rosa–Cortes Ridge. The SCB population during this season was estimated at more than 10,000 animals. Numbers increased in the central and eastern SCB as animals moved southward during the latter part of this period. Numbers also increased in Mexican waters at this time (Leatherwood et al. 1984).

In the winter, Pacific white-sided dolphins were apparently present in low numbers throughout California and Mexican waters, and there was evidence of an offshore shift in their seasonal distribution (Dohl et al. 1981, Bonnell and Dailey 1993). In January in the SCB, Dohl et al. (1981) recorded sightings of white-sided dolphins only in offshore waters over the Santa Rosa–Cortes Ridge.

A reverse movement toward inshore waters apparently occurred in the spring; sightings in March and April were concentrated within 30 km of shore, and a few sightings were recorded close to shore through June–July (Dohl et al. 1981, Bonnell and Dailey 1993).

During the 3 years of the present study, we counted 503 Pacific white-sided dolphins at sea on standard surveys of the study area. Observed group size ranged from 1 to 50 animals. Because most sightings of Pacific white-sided dolphins were recorded by the primary observers, who searched a 50-m corridor, total group sizes could not always be estimated. As a result, no mean group size was calculated for Pacific white-sided dolphins.

Sightings of white-sided dolphins were widely distributed across depths—30.7% were recorded in waters less than 200 m deep, 61.4% in waters less than 600 m deep, and another 23.4% were in waters deeper than 1,600 m. The mean depth of all sightings was 827.8 m.

Pacific white-sided dolphins were sighted at distances of less than 0.5 to nearly 85 km from shore. The mean distance from land on standard surveys was 23.8 km; only 6.0% were recorded within 5 km of land, but 46.3% were within 20 km, and 81.2% within 40 km.

Sighting Distribution. – Figure 2.22 presents sightings of Pacific white-sided dolphins recorded during each of the three primary survey months. This information is summarized below.

In May, a few sightings of Pacific white-sided dolphins were recorded in the western Santa Barbara Channel, but the majority of sightings were in the eastern half of the Southern California Bight, from the Santa Rosa–Cortes Ridge and San Nicolas Island eastward.

There were relatively few sightings of Pacific white-sided dolphins on September surveys. Sightings were scattered from off Point Sal in the Santa Maria Basin to the San Pedro Basin; two sightings were also recorded in deep water west of San Nicolas Island in the vicinity of the San Juan Seamount.

Low numbers of Pacific white-sided dolphins were also sighted during January surveys. Most were in the southeastern SCB, from the Santa Rosa–Cortes Ridge/Santa Cruz Basin to waters south and east of San Clemente Island (where the majority of sightings were made). A few sightings were recorded north of Point Conception, nearshore near Point Arguello, and offshore over the slope west-southwest of Point Buchon.

At-Sea Densities. – Because of the limited sighting sample size, no at-sea densities were calculated for the Pacific white-sided dolphin.

Summary. – No long-term trends in abundance have been identified for the California, Oregon, and Washington stock of Pacific white-sided dolphins.

We found Pacific white-sided dolphins to be widely distributed in relation to water depth, but generally less than about 40 km from land.

The earlier baseline studies recorded the highest numbers of Pacific white-sided dolphins in the fall. In contrast, the majority of sightings of white-sided dolphins during the present survey were made during the May surveys.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found only in the North Pacific. Although Scammon (1874) reported that northern right whale dolphins occurred as far north as the Bering Sea, Leatherwood and Walker (1979) concluded that the species has a more restricted range in the temperate eastern North Pacific from about San Diego to British Columbia (30–50°N). The majority of sightings and strandings have occurred off California (Leatherwood and Walker 1979), and the northernmost sighting records are from waters off Vancouver Island (Pike and MacAskie 1969, Guiguet and Schick 1970).

The population appears to undergo a general southward and inshore movement in the fall and winter as water temperatures cool and a return to more northern and offshore waters as temperatures increase in the late spring and summer (Leatherwood and Walker 1979).

Leatherwood and Walker (1979) estimated that 17,800 northern right whale dolphins were present off southern California during peak abundance, while Dohl et al. (1981) calculated the mean population in the SCB from January through May to be about 6,500 animals, with numbers increasing as animals enter the SCB from the north. Dohl et al. (1983) estimated the population off central and northern California to range from 27,000 in the spring to 61,500 in the winter. More recently, however, Carretta et al. (2003) estimated the size of the California, Oregon, and Washington stock at 20,362 animals.

In their 1975–1978 baseline study, Dohl et al. (1981) found northern right whale dolphins to be common in the Southern California Bight from winter through spring, but rare after June. During these months, right whale dolphins remained in the vicinity of the Santa Rosa–Cortes Ridge, but there was also a pronounced inshore trend, with sightings concentrated near Santa Catalina Island and the waters around the Santa Cruz Basin and Anacapa Island.

By May, *Lissodelphis* sightings were concentrated around the northern Channel Islands, along the Santa Rosa–Cortes Ridge, and over the Catalina and Clemente Escarpments. During the warmer months of July through November, most of the population was farther north, and no right whale dolphins were sighted during the warm-water months of July through October.

In their 1980–1983 baseline study, Dohl et al. (1983) found the mean sighting depth for this species off central and northern California to be greater than for any other small cetacean, recording seasonal depth averages of about 900–1,500 m; sighting depths were shallowest in the winter and spring. More than one-half of all sightings were recorded in the southern sector of the study area, between Point Conception and Point Sur. Numbers of northern right whale dolphins peaked in these waters in mid-winter. Dohl et al. (1983) believed that these seasonal changes in distribution were due to influxes of animals from farther offshore, rather than to north-to-south migration.

During the 3 years of the present study, we counted 503 northern right whale dolphins at sea in the study area. Observed group size ranged from 1 to 250 animals. Because most sightings of northern right whale dolphins were recorded by the primary observers, who searched a 50-m corridor, total group sizes could not always be estimated. As a result, no mean group size was calculated for northern right whale dolphins.

Right whale dolphins were found in relatively deep water—only one sighting was recorded in waters less than 200 m deep, and 78.4% of the sightings were recorded in waters deeper than 1,000 m.

Northern right whale dolphins were sighted between 4 and 75 km from land. The mean distance from land of northern right whale dolphin sightings was 26.4 km; only 16.9% of the sightings were recorded within 20 km of land, but 77.2% were between 20 and 35 km of mainland and island shorelines.

Sighting Distribution. – Figure 2.23 presents northern right whale dolphin sightings recorded during each of the three primary survey months. This information is summarized below.

On May surveys, northern right whale dolphins were generally seen offshore and in the western half of the Southern California Bight. Sightings were recorded over the slope from Point Sal south to San Miguel Island, north of San Nicolas Island over the Santa Rosa–Cortes Ridge and Santa Cruz Basin, and south and southwest of San Nicolas Island toward Tanner–Cortes Banks.

Northern right whale dolphins were only sighted twice, at opposite ends of the SCB, during September surveys: once about 20 km offshore in the San Diego Basin, and once offshore over the slope north of Rodriguez Seamount.

The distribution of sightings recorded on January surveys was again somewhat limited. Northern right whale dolphins were sighted mainly along the Santa Rosa–Cortes Ridge from the northern island chain south to San Nicolas Island; a few sightings were scattered north of Point Conception to about the latitude of Shell Beach.

Summary. – No information is available regarding trends in abundance of northern right whale dolphins off California, Oregon, and Washington.

We generally found northern right whale dolphins in relatively deep water over the continental slope (more than 1,000 m deep) at distances of 20 to 35 km from land. Dohl et al. (1983) also found the mean sighting depth of *Lissodelphis* to be the greatest of any dolphin species off central California.

The few sightings of northern right whale dolphins recorded on September surveys during the present study compared well with findings from the 1975–1978 baseline study; seasonal patterns of distribution were also consistent with those described in the earlier study.

Dall’s Porpoise (*Phocoenoides dalli*)

Dall's porpoises inhabit temperate and subarctic waters of the North Pacific (Leatherwood and Reeves 1986) and are rarely found in waters warmer than 17°C (Morejohn 1979, Leatherwood et al. 1982). In the eastern North Pacific, Dall's porpoises range from the Bering Sea and Gulf of Alaska south to Baja California (Leatherwood and Fielding 1974, Leatherwood et al. 1982). Sighting patterns suggest north-south movement as oceanographic conditions change (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney et al. 1995, 2000).

Although total population estimates for Dall's porpoise in the North Pacific (including the Bering Sea) have varied widely, from 840,000 to 10 million (Bouchet 1981), the most recent estimate places the population at 1.4 to 2.8 million animals (Jones et al. 1987). Carretta et al. (2003) estimated a total abundance at 99,517 animals for California, Oregon, and Washington (including inland Washington waters).

During the 1975–1978 baseline study, Dohl et al. (1981) observed low numbers of Dall's porpoises (50–150 animals) in the Southern California Bight in the spring and summer, when they were found in the western Santa Barbara Channel, around the northern Channel Islands, and over the Santa Rosa–Cortes Ridge (Dohl et al. 1981, Bonnell and Dailey 1993).

The population apparently expanded southward in the fall, as Dall's porpoises entered the SCB (Dohl et al. 1981, Bonnell and Dailey 1993). By January–February, when the population was estimated to increase to more than 1,000 animals, Dall's porpoises were observed in most of the inshore waters of the SCB, including the shelves of Santa Catalina, San Clemente, and Santa Barbara Islands (probably in association with squid spawning in these areas) (Dohl et al. 1981, Bonnell and Dailey 1993).

North of Point Conception, Dohl et al. (1983) sighted Dall’s porpoises over the shelf and slope in all seasons of the year during their 1980–1983 baseline study, although twice as many were seen from September through November than during the rest of the year.

During the 3 years of the present study, we counted 56 Dall’s porpoises at sea in the study area. Observed group size ranged from 1 to 7 animals. Because most sightings of Dall’s porpoises were recorded by the primary observers, who searched a 50-m corridor, total group sizes could not always be estimated. As a result, no mean group size was calculated for Dall’s porpoises.

Dall’s porpoises were sighted predominantly in waters over the upper continental slope—only 1.8% were recorded in waters shallower than 200 m, and 67.8% were in waters 200–800 m deep.

Dall’s porpoises were sighted at distances of less than 5 km out to about 68 km from land. The mean distance from land of Dall’s porpoises sighted on standard surveys was 28.9 km; 50.0% of these were recorded less than 20 km from land, but there was also an offshore component—33.9% of the sightings were more than 50 km offshore.

Sighting Distribution. – Figure 2.24 presents the sightings of Dall’s porpoises recorded during each of the three primary survey months. All but four of the Dall’s porpoise sightings recorded during the study were north of the northern Channel Islands—in the western Santa Barbara Channel and offshore over the continental slope from the Channel north to about Morro Bay. The remaining sightings included two just south of the Anacapa Passage, one offshore over the slope south of San Miguel Island, and one near the southeastern tip of Santa Catalina Island.

At-Sea Densities. – Because of the limited sighting sample size, no at-sea densities were calculated for the Dall’s porpoise.

Summary. – There are insufficient data to evaluate potential trends in abundance for the California, Oregon, and Washington stock of Dall’s porpoises.

We generally found Dall’s porpoises in waters over the upper continental shelf (200–800 m deep). Although half of the animals sighted were within 20 km of land, about one-third were more than 50 km offshore.

The 1975–1983 baseline studies found Dall’s porpoises to be most abundant and distributed throughout the SCB during the winter. In contrast, we rarely sighted Dall’s porpoises south of the Santa Barbara Channel. Although the sighting sample size was small, the fewest sightings were recorded in September.

Killer Whale (*Orcinus orca*)

Killer whales are distributed worldwide, but generally occur in cold waters within about 800 km of land (Heyning and Dahlheim 1988). In the eastern North Pacific, they are found from the Bering, Chukchi, and Beaufort Seas south to the equator (Braham and Dahlheim 1982, Dahlheim et al. 1982, Leatherwood et al. 1982, Brueggeman et al. 1984). Killer whales travel and feed in social groups known as pods, which may vary in number from a few to, occasionally, hundreds of animals (Bigg et al. 1987). In some areas, such as Puget Sound, killer whale populations are resident year-round; in others, they may make seasonal movements in response to changes in prey availability (Watson 1981, Leatherwood et al. 1982).

Since killer whales prey on large, very mobile prey species, their distribution does not necessarily correlate with physical oceanographic features. Transient groups of killer whales occur occasionally near pinniped haulouts, rookeries, and feeding areas (Green et al. 1989).

Killer whales occur year-round in California waters (Bonnell and Dailey 1993). Whales from two stocks, the eastern North Pacific transient stock and the eastern North Pacific offshore stock, are thought to occur regularly in California waters (Forney et al. 2000, Carretta et al. 2001). In addition, individuals from the Washington-British Columbia resident stock have been sighted in coastal waters as far south as Monterey Bay (Carretta et al. 2001).

Most killer whales seen in coastal southern California waters are likely to be transients. Although whales of the offshore stock have been identified off California, they apparently do not mix with transient and resident stocks, but are most similar (genetically, morphologically, and behaviorally) to resident whales (Ford et al. 1994, Black et al. 1997, Dahlheim et al. 1997, Forney et al. 2000).

No current estimates exist for the world population of killer whales (Brownell et al. 1989). The total number of killer whales off the California, Oregon, and Washington coasts has recently been estimated at 1,340, with the offshore population accounting for 466 of these animals (Carretta et al. 2003).

Dohl et al. (1981) recorded only three sightings of 35 killer whales in the Southern California Bight during their 1975–1978 baseline study. These sightings were made offshore near Rodriguez Seamount, in the Santa Cruz Passage between Santa Rosa and Santa Cruz Islands, and in the northern Santa Barbara Channel.

During their 1980–1983 baseline study, Dohl et al. (1983) recorded sightings of killer whales in coastal waters north of Point Conception during every season and month; more than 90% of the animals were seen from Monterey Bay northward. Discounting a single sighting of 55 individuals in October 1981, no significant difference in total numbers was noted between seasons in this area (Dohl et al. 1983), although Bonnell and Dailey (1993) felt this pattern of sightings suggested that the observed killer whales were in transit to or from the large pinniped rookeries in southern California or Mexico. Most (86%) of the killer whale sightings recorded by Dohl et al. (1983) were over the continental slope in waters ranging from 110 to 3,200 m.

During the 3 years of the present study, we sighted 36 killer whales at sea in the study area. The observed group sizes ranged from 1 to 7 animals. The mean depth for all killer whale sightings was 545.m; although only one sighting (2.8%) was recorded over the shelf (in waters less than 200 m deep), 94.4% were over the slope in waters less than 800 m deep.

Killer whales were sighted at distances of less than 3 to almost 50 km from land. The mean distance from land for all sightings was 25.5 km; 19.4% of these were less than 5 km from shore, and 66.7% were within 25 km.

Sighting Distribution. – Figure 2.25 shows the killer whale sightings recorded during all three survey years. The relatively few sightings were scattered through the Southern California Bight from waters west of the Santa Barbara Channel eastward to Santa Monica Bay and southward to the vicinity of Tanner–Cortes Banks.

At-Sea Densities. – Because of the limited sighting sample size, no at-sea densities were calculated for the killer whale.

Summary. – Although killer whales may be observed off southern California at any time of the year, their appearance in this area cannot be predicted, probably because these animals are part of the eastern North Pacific transient stock and are merely passing through area waters. As was true for the earlier baseline studies, we recorded relatively few sightings of killer whales.

Sperm Whale (*Physeter macrocephalus*)

The largest of the toothed whales, sperm whales are found predominantly in temperate to tropical waters in both hemispheres (Gosho et al. 1984). In the North Pacific, females and juveniles generally remain south of about 45°N year-round, while adult males range northward as far as the Bering Sea in the summer (Gosho et al. 1984). During the winter, most of the population is distributed south of 40°N (Gosho et al. 1984). Off California, sperm whales are present in offshore waters year-round, with peak abundance first from April to mid-June and again from late August through November as they pass by during migration (Dohl et al. 1981, 1983; Gosho et al. 1984).

Sperm whales are primarily a pelagic species and are generally found in water depths greater than 1,000 m (Watkins 1977), although their distribution does suggest a preference for continental shelf margins and seamounts, areas of upwelling and high productivity (Leatherwood and Reeves 1986). Sperm whales occasionally have been seen within the SCB, particularly near the northern Channel Islands (Leatherwood et al. 1987).

Sperm whales were subjected to two major phases of commercial whaling: during the mid-18th to mid-19th centuries; and in the modern whaling era, particularly between 1946 and 1980 (Gosho et al. 1984, Brownell et al. 1989). The current world population of sperm whales has been estimated at 1,950,000 animals, down from an estimated pre-exploitation population of 2,400,000 (Brownell et al. 1989). The initial population size for the eastern North Pacific was estimated at 311,000 animals (Braham 1984a). In response to this severe population decline, the sperm whale was listed as a federal endangered species in 1970 (35 FR 8495).

Using acoustic methods, Barlow and Taylor (1998) estimated 39,200 sperm whales in a 7.8 million-km^2 study area encompassing waters between the U.S. west coast and Hawaii.

Based on ship surveys conducted in the mid-1990s, Barlow and Taylor (2001) estimated a summer–fall population of 1,407 sperm whales along the California, Oregon, and Washington coasts. They also estimated 1,640 sperm whales off Baja, but there is no evidence of mixing between the two stocks (Carretta et al. 2001). More recently, the California, Oregon, and Washington stock of sperm whales has been estimated at 1,233 animals (Carretta et al. 2003).

During the 1975–1978 baseline study of the Southern California Bight, Dohl et al. (1981) recorded only a single sighting of sperm whales, well offshore to the west-southwest of San Nicolas Island. They also reported three sightings outside of their study area, including one group only 6 km offshore near Point Arguello and two sightings west of the San Juan Seamount.

North of Point Conception, Dohl et al. (1983) sighted sperm whales throughout the study area in all seasons during their 1980–1983 baseline study of central and northern California. The majority of sightings were in waters deeper than 1,800 m, but near the shelf edge.

We sighted only 10 sperm whales at sea in the study area during the 3 years of the present study. All sightings were recorded in deep waters well offshore. The mean water depth of all sightings was 2,286 m, and the shallowest sighting depth was 1,024 m. The mean distance from land was 69.9 km, with no sightings closer than 53.5 km from shore.

As shown in Figure 2.26, all sperm whale sightings recorded during the present study were well offshore from about Point Conception north to the latitude of Morro Bay.

Summary. – Off California, sperm whales are generally found in deep waters well offshore. Few sightings of sperm whales were recorded in the Southern California Bight during either the 1975-1978 baseline study or the present study.

Cuvier’s Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale, or the goosebeak whale, is the most widely distributed and most frequently sighted beaked whale in the North Pacific (Rice 1986). In the eastern North Pacific, Cuvier's beaked whales range from Baja California north to the Aleutian Islands, but do not appear to inhabit the Bering or Arctic Seas (Mitchell 1968, Rice 1986). There is evidence for a single eastern North Pacific population extending from Alaska to Baja (Forney et al. 2000). The species is generally found seaward of the 1,000-m isobath and is seldom sighted in waters colder than 10°C (Watson 1981). Carretta et al. (2003) reported an estimate of 1,884 Cuvier’s beaked whales for the California, Oregon, and Washington stock.

Cuvier's beaked whales constitute nearly 80% of all identified beaked whale sightings off southern California (Barlow and Gerrodette 1996) and appear to be the most abundant beaked whale in the area (Koski et al. 1998). No clear seasonal trends in abundance or distribution have been identified in this area (Koski et al. 1998).

In the 1975–1978 baseline study, Dohl et al. (1981) sighted small groups of Cuvier's beaked whales in the Southern California Bight on three occasions: 2 groups totaling 6 animals over Tanner–Cortes Banks in April and November 1977, and a group of 4 near Santa Barbara Island in June 1977.

Dohl et al. (1983) sighted Cuvier's beaked whales off central and northern California from June through January during their 1980–1983 baseline study. The majority of sightings were recorded in waters deeper than 2,000 m, and all but one were recorded in the southern sector of the study area, between Point Conception and Point Sur.

We recorded only three sightings of 7 Cuvier’s beaked whales during the 3 years of the present study (Figure 2.27): 1) in September 1999, 2 Cuvier’s beaked whales were sighted about 45 km west-southwest of San Clemente Island in 1,420 m of water; 2) in January 2001, 2 animals were seen about 22 km south-southwest of Santa Barbara Island in 1,087 m of water; 3) in May 2001, 3 whales were observed about 64 km south of San Nicolas Island in the vicinity of Tanner and Cortes Banks in 1,315 m of water.

Summary. – Cuvier’s beaked whales are uncommon in southern California waters. We recorded them in deep waters (greater than 1,000 m in depth) in the southern half of the SCB.

Baird’s Beaked Whale (*Berardius bairdii*)

In the eastern North Pacific, Baird's beaked whales, or giant bottlenose whales, are distributed from Baja California north to the Bering Sea (Leatherwood et al. 1982, Rice 1986). Baird’s beaked whales are sighted infrequently along the continental slopes and throughout the deep waters of the eastern North Pacific (Balcomb 1989). Although the species' migratory movements are unclear, peaks in abundance have been observed off British Columbia and California during the warm-water months of June to November (Watson 1981, Leatherwood et al. 1982, Dohl et al. 1983). Carretta et al. (2003) estimated the population in U.S. coastal waters from California to Washington at approximately 228 animals.

The Southern California Bight is near the southern limit of the species' range in the eastern North Pacific, and Baird's beaked whales may typically remain over or beyond the continental slope in this region (Leatherwood et al. 1982).

No Baird's beaked whales were sighted during the baseline study of the Southern California Bight conducted in 1975–1978 by Dohl et al. (1981), and no stranding records have been reported for the SCB (Bonnell and Dailey 1993).

North of Point Conception, Dohl et al. (1983) recorded several sightings of Baird’s beaked whales in waters over the continental slope south of Point Piedras Blancas during their 1980–1983 baseline study.

We recorded one possible sighting of Baird’s beaked whales during the 3 years of the present study. In January 2000, a group of 4 large beaked whales, thought to be Baird’s, was sighted about 77 km south of San Nicolas Island near Tanner–Cortes Banks in 1,315 m of water.

Summary. – Given the rarity of Baird’s beaked whales in southern California waters and their offshore distribution, it is not surprising that we recorded only one possible sighting during the 3 years of the present study.

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LITERATURE CITED

AINLEY, D. G., and T. J. Lewis. 1974. History of Farallon-island marine bird populations, 1854-1972. Condor 76:432-446.

ANGLISS, R. P., and K. L. Lodge (eds.). 2002. Alaska marine mammal stock assessments, 2002. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-133. 224 pp.

ANGLISS, R. P., and K. L. Lodge (eds.). 2003. Draft Alaska marine mammal stock assessments, 2003. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-XXX.

ANTONELIS, G. A., B. S. Stewart, and W. F. Perryman. 1990. Foraging characteristics of female northern fur seals (*Callorhinus ursinus*) and California sea lions (*Zalophus californianus*). Canadian Journal of Zoology 68:150-158.

ANTONELIS, G. A., Jr., and M. A. Perez. 1984. Estimated annual food consumption by northern fur seals in the California Current. California Cooperative Oceanic Fisheries Investigations Report, Vol. XXV:135-145.

BAKER, C. S., L. M. Herman, A. Perry, W. S. Lawton, J. M. Straley, A. A. Wolman, G. D. Kaufman, H. E. Winn, J. D. Hall, J. M. Reineke, and J. Ostman. 1986. Migratory movement and population structure of humpback whales (*Megaptera novaeangliae*) in the central and eastern North Pacific. Marine Ecology Progress Series Vol. 31:105-119.

BALCOMB, K. C., III. 1989. Baird’s beaked whale *Berardius bairdii* Stejneger, 1883: Arnoux’s beaked whale *Berardius arnuxii* Duvernoy, 1851. Pp. 261-288 *in*: S. H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 4. Academic Press Limited.

BARLOW, J. 1994. Recent information on the status of large whales in California waters. NOAA Technical Memorandum NMFS-SWFSC-203. 27 pp.

BARLOW, J. 1995. The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall of 1991. Fishery Bulletin 93:1-14.

BARLOW, J., and B. L. Taylor. 1998. Preliminary abundance of sperm whales in the northeastern temperate Pacific estimated from a combined visual and acoustic survey. International Whaling Commission. Working Paper SC/50/CAWS20. 19 pp.

BARLOW, J., and B. L. Taylor. 2001. Estimates of large whale abundance off California, Oregon, Washington, and Baja California based on 1993 and 1996 ship surveys. Administrative Report LJ-01-03 available from Southwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, CA 92038. 12 pp.

BARLOW, J., and T. Gerrodette. 1996. Abundance of cetaceans in California waters based on 1991 and 1993 ship surveys. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-233.

BARLOW, J., K. A. Forney, P. S. Hill, R. L. Brownell, Jr., J. V. Carretta, D. P. DeMaster, F. Julian, M. S. Lowry, T. Ragen, and R. R. Reeves. 1997. U.S. Pacific Marine Mammal Stock Assessments: 1996. NOAA Technical Memorandum NMFS-SWFSC-248.

BARLOW, J., R. L. Brownell, Jr., D. P. DeMaster, K. A. Forney, M. S. Lowry, S. Osmek, T. J. Ragen, R. R. Reeves, and R. J. Small. 1995. U.S. Pacific Marine Mammal Stock Assessments. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-219. 162 pp.

BARTHOLOMEW, G. A., and R. A. Boolootian. 1960. Population structure of the pinnipeds of the Channel Islands, California. Journal of Mammalogy 41:366-375.

BLACK, N. A., A. Schulman-Janiger, R. L. Ternullo, and M. Guerrero-Ruiz. 1997. Killer whales of California and western Mexico: A catalog of photo-identified individuals. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-247. 174 pp.

BONNELL, M. L., and M. D. Dailey. 1993. Marine mammals. Pp. 604-681 *in*: M. D. Dailey, D. J. Reish, and J. W. Anderson (eds.), Ecology of the Southern California Bight: A Synthesis and Interpretation. Berkeley, CA: University of California Press.

BONNELL, M. L., and R. G. Ford. 1987. California sea lion distribution: A statistical analysis of aerial transect data. Journal of Wildlife Management 51(1):13-19.

BONNELL, M. L., and R. G. Ford. 2001. Marine mammal and seabird computer database analysis system (CDAS). Prepared by Ecological Consulting, Inc., Portland, OR, for the Pacific OCS Region, Minerals Management Service. Contract No. 1435-01-97-PO-14206.

BONNELL, M. L., B. J. Le Boeuf, M. O. Pierson, D. H. Dettman, G. D. Farrens, and C. B. Heath. 1981. Pinnipeds of the Southern California Bight. Summary Report, 1975-1978, Part I, *In*: Vol. III, Principal Investigator's reports, marine mammal and seabird survey of the Southern California Bight area. NTIS No. PB 81-248-71. 535 pp.

BONNELL, M. L., M. O. Pierson, and G. D. Farrens. 1983. Pinnipeds and sea otters of central and northern California, 1980-1983: status, abundance, and distribution. Final Report to U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region under Contract 14-12-0001-29090. OCS Study MMS 84-0044. 220 pp.

BONNOT, P. 1928. The sea lions of California. California Fish and Game 14:1-16.

BOUCHET, G. C. 1981. Estimation of the abundance of Dall's porpoise (*Phocoenoides dalli*) in the North Pacific Ocean and Bering Sea. U.S. Department of Commerce, NOAA, NMFS, NWAFC Processed Report 81-1. 25 pp.

BRAHAM, H. W. 1983. Northern records of Risso's dolphin, *Grampus griseus*, in the northeast Pacific. Canadian Field-Naturalist 97:89-90.

BRAHAM, H. W. 1984a. The status of endangered whales: An overview. Marine Fisheries Review 46:2-6.

BRAHAM, H. W. 1984b. Distribution and migration of gray whales in Alaska. Pp. 249-266 *in*: M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, New York.

BRAHAM, H. W., and M. E. Dahlheim. 1982. Killer whales in Alaska documented in the Platform of Opportunity Program. Report of the International Whaling Commission. 32:643-646.

BRIGGS, K. T., E. W. Chu, D. B. Lewis, W. B. Tyler, R. L. Pittman, and G. L. Hunt. 1981a. Final Report: Summary of marine mammal and seabird surveys of the Southern California Bight area 1975–1978. Volume III: Investigator’s Reports. Part III. Seabirds Book, Chapter I. Distribution, numbers, and seasonal status of seabirds of the Southern California Bight, Unpublished Report, University of California, Institute of Marine Sciences, Santa Cruz, California.

BRIGGS, K. T., W. B. Tyler, D. B. Lewis. 1985. Aerial surveys for seabirds – methodological experiments. Journal of Wildlife Management 49:412-417.

BRIGGS, K. T., W. G. Tyler, D. B. Lewis, and D. R. Carlson. 1987. Bird communities at sea off California, 1975–1983. Studies in Avian Biology 11:1–74.

BROWNELL, R. L., Jr., K. Ralls, and W. F. Perrin. 1989. The plight of the 'forgotten' whales. Oceanus 32(1):5-13.

BRUEGGEMAN, J. J., G. A. Green, R. A. Grotefendt, and D. G. Chapman. 1987. Aerial surveys of endangered cetaceans and other marine mammals in the northwestern Gulf of Alaska and southeastern Bering Sea. Final Report prepared for MMS/NOAA/OCSEAP, Anchorage. Contract No. 85-ABC-00093, Res. Unit 673. 139 pp. + app.

BRUEGGEMAN, J. J., R. A. Grotefendt, and A. W. Erickson. 1984. Endangered whale abundance and distribution in the Navarin Basin of the Bering Sea during the ice-free period. Alaska Sea Grant Report 84:201-236.

BRYANT, H. C. 1915. Sea otters near Point Sur. California Department of Fish and Game 1(3):134-135.

CALAMBOKIDIS, J. 1995. Blue whales off California. Whalewatcher 29(1):3-7.

CALAMBOKIDIS, J., and G. H. Steiger. 1995. Population assessment of humpback and blue whales using photo-identification from 1993 surveys off California. Final contract report to Southwest Fisheries Center, La Jolla, CA. 31 pp.

CALAMBOKIDIS, J., G. H. Steiger, J. C. Cubbage, K. C. Balcomb, C. Ewald, S. Kruse, R. Wells, and R. Sears. 1990. Sightings and movements of blue whales off central California 1986-88 from photo-identification of individuals. Report of the International Whaling Commission. Special Issue 12:343-348.

CALAMBOKIDIS, J., G. H. Steiger, J. R. Evenson, K. R. Flynn, K. C. Balcomb, D. E. Claridge, P. Bloedel, J. M. Straley, C. S. Baker, O. von Ziegesar, M. E. Dahlheim, J. M. Waite, J. D. Darling, G. Ellis, and G. A. Green. 1996. Interchange and isolation of humpback whales off California and other North Pacific feeding grounds. Marine Mammal Science 12(2):215-226.

CALAMBOKIDIS, J., R. Sears, G. H. Steiger, and J. Evenson. 1995. Movement and block structure of blue whales in the eastern North Pacific. Abstracts Proceedings 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL, 14-18 December 1995.

CARRETTA, J. V., J. Barlow, J., K. A. Forney, M. M. Muto, and J. Baker. 2001. U.S. Pacific Marine Mammal Stock Assessments: 2001. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Technical Memorandum NOAA-TM-NMFS-SWFSC-317. 280 pp.

CARRETTA, J. V., K. A. Forney, and J. Barlow. 1995. Report of 1993-1994 marine mammal aerial surveys conducted within the U.S. Navy Outer Sea Test Range off southern California. NOAA-TM-NMFS-SWFSC-217. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA. 90 pp.

CARRETTA, J. V., K. A. Forney, and J. L. Laake. 1998. Abundance of southern California coastal bottlenose dolphins estimated from tandem aerial surveys. Marine Mammal Science 14(4):655-675.

CARRETTA, J. V., K. A. Forney, M. M. Muto, J. Barlow, J. Baker, and M. Lowry. 2003. Draft U.S. Pacific Marine Mammal Stock Assessments: 2002. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA-TM-NMFS-SWFSC Technical Memorandum. 311 pp.

CARRETTA, J. V., M. M. Muto, J. Barlow, J. Baker, K. A. Forney, and M. Lowry. 2002. U.S. Pacific Marine Mammal Stock Assessments: 2002. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. NOAA-TM-NMFS-SWFSC-346. 286 pp.

CARTER, H. R., G. J. McChesney, D. L. Jaques, C. S. Strong, M. W. Parker, J. E. Takekawa, D. L. Jory and D. L. Whitworth. 1992. Breeding populations of seabirds in California, 1989–1991. Volume 1. Population estimates. U.S. Fish and Wildlife Service, Davis, CA.

CASS, V. L. 1985. Exploitation of California sea lions, *Zalophus californianus*, prior to 1972. Marine Fisheries Review 47(1):36-38.

CHELTON, D. B. 1984. Seasonal variability of alongshore geostrophic velocity off Central California. Journal of Geophysical Research-Oceans 89 (NC3):3473-3486.

DAHLHEIM, M. E., D. Ellifit, and J. Swenson. 1997. Killer whales of Southeast Alaska: A catalog of photo-identified individuals. Day Moon Press, Seattle, WA. 82 pp. + app.

DAHLHEIM, M. E., S. Leatherwood, and W. F. Perrin. 1982. Distribution of killer whales in the warm temperate and tropical eastern Pacific. Report of the International Whaling Commission. 32:647-653.

DAILEY, M. D., J. W. Anderson, D. J. Reish, and D. S. Gorsline. 1993. The Southern California Bight: background and setting. Pp. 1-18 *in* M. D. Dailey, D. J. Reish, and J. W. Anderson (eds.), Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles.

DEFRAN, R. H., and D. W. Weller. 1999. Occurrence, distribution, site fidelity, and school size of bottlenose dolphins (*Tursiops truncatus*) off San Diego, California. Marine Mammal Science 15(2):366-380.

DELONG, R. L., and G. A. Antonelis. 1991. Impact of the 1982-1983 El Niño on the northern fur seal population at San Miguel Island, California. Pp. 75-83 *in*: F. Trillmich and K. Ono (eds.), Pinnipeds and El Niño: Responses to environmental stress. Springer-Verlag, Berlin.

DELONG, R. L., and S. R. Melin. 2000. Thirty Years of Pinniped Research at San Miguel Island. Pp. 401-406 *in*: D. R. Browne, K. L. Mitchell, and H. W. Chaney (eds.), Proceedings of the Fifth California Islands Symposium, 29 March–1 April 1999, Santa Barbara Museum of Natural History, Santa Barbara, CA. Sponsored by the U.S. Minerals Management Service, Pacific OCS Region, Camarillo, CA. OCS Study No. 99-0038.

DOHL, T. P., K. S. Norris, R. C. Guess, J. D. Bryant, and M. W. Honig. 1981. Cetacea of the Southern California Bight. Part II of Investigator's Reports: Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975–1978. Available from NTIS, Springfield, VA, PB81-248-189. 414 pp.

DOHL, T. P., M. L. Bonnel, and R. G. Ford. 1986. Distribution and abundance of common dolphin, *Delphinus delphis*, in the Southern-California Bight – a quantitative assessment based upon aerial transect data. Fishery Bulletin 84:333-343.

DOHL, T. P., R. C. Guess, M. L. Duman, and R. C. Helm. 1983. Cetaceans of central and northern California, 1980–1983: Status, abundance, and distribution. U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region, Los Angeles, CA. OCS Study 84-005. 248 pp.

DUDZIK, K. J. 1999. Population dynamics of the Pacific coast bottlenose dolphin (*Tursiops truncatus*). M.S. thesis, San Diego State University, San Diego, CA. 63 pp.

FISH AND WILDLIFE SERVICE (FWS). 1995. Draft Southern Sea Otter Recovery Plan. U.S. Fish and Wildlife Service, Ventura, CA.

FISH AND WILDLIFE SERVICE (FWS). 2000. Draft Revised Recovery Plan for the Southern Sea Otter (*Enhydra lutris*). U.S. Fish and Wildlife Service, Region 1, Portland, Oregon. 64 pp. + app.

FISH AND WILDLIFE SERVICE (FWS). 2003. Final Revised Recovery Plan for the Southern Sea Otter (*Enhydra lutris nereis*). U.S. Fish and Wildlife Service, Region 1, Portland, OR. 165 pp.

FORD, J. K. B., G. M. Ellis, and K. C. Balcomb. 1994. Killer whales: The natural history and genealogy of *Orcinus orca* in British Columbia and Washington State. UBC Press, Vancouver, Canada.

FORNEY, K. A., and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991-1992. Marine Mammal Science 14:460-489.

FORNEY, K. A., J. Barlow, and J. V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. Fishery Bulletin 93:15-26.

FORNEY, K. A., J. Barlow, M. M. Muto, M. Lowry, J. Baker, G. Cameron, J. Mobley, C. Stinchcomb, and J. V. Carretta. 2000. U.S. Pacific marine mammal stock assessments: 2000. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-300. 276 pp.

GAMBRELL, R. 1985. Fin whale *Balaenoptera physalus* (Linnaeus, 1758). Pp. 171-192 *in*: S. H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3, The sirenians and baleen whales. Academic Press, London.

GENDRON, D., and V. Zavala-Hernàndez. 1995. Blue whales of Baja California: A summary of their distribution and preliminary reproductive data based on photo-identification. Abstracts Proceedings 11th Biennial Conference on the Biology of Marine Mammals, Orlando, FL, 14-18 December 1995.

GOSHO, M. E., D. W. Rice, and J. M. Breiwick. 1984. The sperm whale, *Physeter macrocephalus*. *In*: J. M. Breiwick and H. W. Braham (eds.), The status of endangered whales. Marine Fisheries Review 46:54-64.

GREEN, G. A., J. J. Brueggeman, C. E. Bowlby, R. A. Grotefendt, M. L. Bonnell, and K. C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. *In*: Oregon and Washington marine mammal and seabird surveys, J. J. Brueggeman (ed.). Final Report prepared for the U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region, Camarillo, CA. Bellevue, WA: Ebasco Environmental, and Portland, OR: Ecological Consulting, Inc. OCS Study MMS 91-093. 100 pp.

GREEN, G. A., M. L. Bonnell, K. C. Balcomb, D. E. Bowlby, R. A. Grotefendt, and D. G. Chapman. 1989. Synthesis of information on marine mammals of the eastern North Pacific, with emphasis on the Oregon and Washington OCS area. *In*: Information synthesis and hypothesis formulation for Oregon and Washington marine mammal and seabird surveys, J. J. Brueggeman (ed.). Final Report prepared for U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region. Bellevue, WA: Envirosphere Company, and Portland, OR: Ecological Consulting, Inc. OCS Study MMS 89-0030. pp. 1-116.

GREEN, G. A., R. A. Grotefendt, M. A. Smultea, C. E. Bowlby, and R. A. Rowlet. 1993. Delphinid aerial surveys in Oregon and Washington offshore waters. Final Report prepared for National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, Washington. Ebasco Environmental, Bellevue, Washington. 35 pp. plus app.

GUIGUET, C. J., and G. C. Pike. 1965. First specimen record of the gray grampus or Risso dolphin, *Grampus griseus* (Cuvier) from British Columbia. Murrelet 46:16.

GUIGUET, C. J., and W. J. Schick. 1970. First record of a right whale dolphin from British Columbia. Syesis 3:188.

HANAN, D. A. 1996. Dynamics of abundance and distribution for harbor seals, *Phoca vitulina richardsi*, on the coast of California. Ph.D. dissertation, University of California, Los Angeles. 158 pp.

HANSEN, L. J. 1990. California coastal bottlenose dolphins. Pp. 403-420 *in*: S. Leatherwood and R. R. Reeves (eds.), The bottlenose dolphin. Academic Press, San Diego, CA.

HARMS, S. and C. D. Winant. 1998. Characteristic patterns of the circulation in the Santa Barbara Channel. Journal of Geophysical Research 103(C2):3041–3065.

HENDERSON, D. A. 1984. Nineteenth century gray whaling: grounds, catches and kills, practices, and depletion of the whale population. Pp. 159-186, *in*: M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, New York.

HERZING, D. L., and B. R. Mate. 1984. Gray whale migrations along the Oregon coast, 1978-1981. Pp. 289-307, *in*: M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, New York.

HEYNING, J. E., and M. E. Dahlheim. 1988. *Orcinus orca*. Mammalian Species No. 304, The American Society of Mammalogists. 9 pp.

HEYNING, J. E., and W. F. Perrin. 1994. Evidence for two species of common dolphins (genus *Delphinus*) from the eastern North Pacific. Natural History Museum of Los Angeles County, Contributions in Science Number 442. 35 pp.

HICKEY, B. M. 1993. Physical oceanography. Pages 19-70 *in* M. D. Dailey, D. J. Reish, and J. W. Anderson (eds.), Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles.

HILL, P. S., D. P. DeMaster, and R. J. Small. 1997. Alaska marine mammal stock assessments, 1996. NOAA Technical Memorandum NMFS-AFDC-78. 150 pp.

HUNT, G. L., R. L. Pitman, and H. L. Jones. 1980. Distribution and abundance of seabirds breeding on the California Channel Islands. Pp. 443–459 *in* The California Islands: proceedings of a multidisciplinary symposium (D. M. Power ed.). Santa Barbara Museum Natural History, Santa Barbara, CA.

JOHNSON, J. H., and A. A. Wolman. 1984. The humpback whale, *Megaptera novaeangliae*. *In*: J. M. Breiwick and H. W. Braham (eds.), The status of endangered whales. Marine Fisheries Review 46:30-37.

JONES, L. L., G. C. Bouchet, and B. J. Turnock. 1987. Comprehensive report on the incidental take, biology, and status of Dall's porpoise. Submitted to the Ad Hoc Committee on Marine Mammals, International North Pacific Fisheries Commission. 79 pp.

KOSKI, W. R., J. W. Lawson, D. H. Thomson, and W. J. Richardson. 1998. Point Mugu Sea Range marine mammal technical report. LGL Limited, environmental research associates, King City, Ontario, Canada, in association with Ogden Environmental and Energy Services, Santa Barbara, CA, for Naval Air Warfare Center, Weapons Division, Point Mugu, CA, and Southwest Division, Naval Facilities Engineering Command, San Diego, CA. 281 pp. + app.

LARKMAN, V. E., and R. R. Veit. 1998. Seasonality and abundance of blue whales off southern California. California Cooperative Oceanic Fisheries Investigations Report 39:236-239.

LE BOEUF, B. J. 1981. Elephant seals. Pp. 326-374, *in*: B. J. Le Boeuf and S. Kaza (eds.), The Natural History of Año Nuevo. The Boxwood Press, Pacific Grove, California.

LE BOEUF, B. J., and M. L. Bonnell. 1980. Pinnipeds of the California Islands: abundance and distribution. Pp. 475-493 *in*: D. M. Power (ed.), The California islands: Proceedings of a multidisciplinary symposium. Santa Barbara, CA: Santa Barbara Museum of Natural History.

LE BOEUF, B. J., and R. M. Laws (eds.). 1994. Elephant seals: Population, ecology, behavior, and physiology. University of California Press, Berkeley, CA.

LE BOEUF, B. J., D. E. Crocker, D. P. Costa, S. B. Blackwell, P. M. Webb, and D. S. Houser. 2000. Foraging ecology of northern elephant seals. Ecological Monographs 70(3):353-382.

LEATHERWOOD, S. 1974. Aerial observations of migrating gray whales, *Eschrichtius robustus,* off southern California, 1969-1972. Marine Fisheries Review 36:45-49.

LEATHERWOOD, S., and M. Fielding. 1974. A summary of distribution and movements of Dall's porpoises, *Phocoenoides dalli,* off southern California and Baja California. Food and Agriculture Organization, United Nations, ACMRR/42.

LEATHERWOOD, S., and R. R. Reeves. 1986. Porpoises and dolphins. Pp. 110-131 *in*: D. Haley (ed.), Marine mammals of the eastern North Pacific and Arctic waters. Second Edition, Revised. Pacific Search Press.

LEATHERWOOD, S., and W. A. Walker. 1979. The northern right whale dolphin *Lissodelphis borealis* Peale in the eastern North Pacific. Pp. 85-141 *in*: H. W. Winn and B. L. Olla (eds.), Behavior of marine animals. Plenum Publishing Company, NY.

LEATHERWOOD, S., B. S. Stewart, and P. A. Folkins. 1987. Cetaceans of the Channel Islands National Marine Sanctuary. U.S. Department of Commerce, NOAA, Channel Islands National Marine Sanctuary and NMFS. 66 pp.

LEATHERWOOD, S., R. R. Reeves, A. E. Bowles, B. S. Stewart, and K. G. Goodrich. 1984. Distribution, seasonal movements and abundance of Pacific white-sided dolphins in the eastern North Pacific. Scientific Report of the Whale Research Institute 35:129-157.

LEATHERWOOD, S., R. R. Reeves, W. F. Perrin, and W. E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters. A guide to their identification. NOAA Technical Report, NMFS Circular 444. 245 pp.

LUX, C. A., A. S. Costa, and A. E. Dixon. 1997. Mitochondrial DNA population structure of the Pacific white-sided dolphin. Report of the International Whaling Commission. 47:645-652.

LYNN, R. J. and J. J. Simpson. 1987. The California Current system: The seasonal variability of its physical characteristics. Journal of Geophysical Research 92(C12):12947–12966.

MANGELS, K. F., and T. Gerrodette. 1994. Report of cetacean sightings during a marine mammal survey in the eastern Pacific Ocean and the Gulf of California aboard the NOAA ships *McArthur* and *David Starr Jordan* July 28–November 6, 1993. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-221. 88pp.

MATE, B. R., B. A. Lagerquist, and J. Calambokidis. 1999. Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. Marine Mammal Science 15(4):1246-1257.

MBC APPLIED ENVIRONMENTAL SCIENCES. 1989. Gray Whale Monitoring Study. Final Report. Prepared for U.S. Department of the Interior, Minerals Management Service, Pacific OCS Office. OCS Study MMS 88-0075. 99 pp. + app.

MCCULLAGH, P. and J.A. Nelder. 1989. Generalized Linear Models, 2nd Edition. Chapman and Hall, London. 532 pp.

MELIN, S. R., and R. L. DeLong. 2000. Population monitoring studies of northern fur seals at San Miguel Island, California. Pp. 41-51 *in*: E. H. Sinclair (ed.), Fur seal investigations, 1998. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-113. 101 pp.

MITCHELL, E. D. 1968. Northeast Pacific stranding distribution and seasonality of Cuvier's beaked whale *Ziphius cavirostris*. Canadian Journal of Zoology 46:265-279.

MIZROCH, S. A., D. W. Rice, and J. M. Breiwick. 1984. The fin whale, *Balaenoptera physalus*. Marine Fisheries Review 46(4):20-24.

MOREJOHN, G. V. 1979. The natural history of Dall's porpoise in the North Pacific Ocean. Pp. 45-83 *in*: H. E. Winn and B. L. Olla (eds.), Behavior of marine mammals: Current perspectives in research. Volume 3: Cetaceans. Plenum Press, New York, NY.

NATIONAL MARINE FISHERIES SERVICE (NMFS). 1987. Marine Mammal Protection Act of 1972, Annual Report 1986/1987. U.S. Department of Commerce, NOAA, National Marine Fisheries Service.

NISHIWAKI, M. 1959. Humpback whales in Ryukyuan waters. Scientific Report of the Whales Research Institute, Tokyo 15:1-15.

NISHIWAKI, M. 1972. General biology. Pp. 3-203 *in*: S.H. Ridgway (ed.), Mammals of the sea: Biology and medicine. Charles C. Thomas, Springfield, IL.

NORRIS, K. S., and J. H. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. University of California Publications in Zoology 63:291-402.

PERRY, S. L., D. P. DeMaster, and G. K. Silber. 1999. The great whales: History and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. Marine Fisheries Review, Special Issue 61(1):1-74.

PETERSON, R. S., B. J. Le Boeuf, and R. L. DeLong. 1968. Fur seals from the Bering Sea breeding in California. Nature (London) 219:899-901.

PIKE, G. C. 1962. Migration and feeding of the gray whale (*Eschrichtius gibbosus*). Journal of the Fisheries Research Board of Canada 19:815-838.

PIKE, G. C., and I. B. MacAskie. 1969. Marine mammals of British Columbia. Bulletin of the Fisheries Research Board of Canada, No. 171. 54 pp.

POOLE, M. M. 1984. Migration corridors of gray whales along the central California coast, 1980-1982. Pp. 389-407, *in*: M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, New York.

REEVES, R. R. 1984. Modern commercial pelagic whaling for gray whales. Pp. 187-200, *in*: M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.), The gray whale. Academic Press, New York.

REEVES, R. R., G. K. Silber, and P. M. Payne. 1998b. Draft recovery plan for the fin whale *Balaenoptera physalus* and sei whale *Balaenoptera borealis*. Office of Protected Resources, National Marine Fisheries Service, NOAA, Silver Spring, MD. 65 pp.

REEVES, R. R., P. J. Clapham, R. L. Brownell, Jr., and G. K. Silber. 1998a. Recovery plan for the blue whale (*Balaenoptera musculus*). Office of Protected Resources, National Marine Fisheries Service, NOAA, Silver Spring, MD. 42 pp.

RICE, D. W. 1974. Whales and whale research in the eastern North Pacific. *In*: W. E. Schevill (ed.), The whale problem: A status report. Cambridge, MA: Harvard University Press. pp. 170-195.

RICE, D. W. 1978. The humpback whale in the North Pacific: Distribution, exploitation, and numbers. Pp. 29-44 *in*: K. S. Norris and R. R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. Contract Report, Marine Mammal Commission, NTIS PB-280-794.

RICE, D. W. 1986. Beaked whales. Pp. 103-109 *in*: D. Haley (ed.), Marine mammals of eastern North Pacific and Arctic waters. 2nd edition. Pacific Search Press, Seattle, WA.

RICE, D. W. 1992. The blue whales of the southeastern North Pacific Ocean. Alaska Fisheries Science Center, Quarterly Report, Oct.-Dec., pp. 1-3.

RIEDMAN, M. L. 1987. Summary of information on the biology of the southern sea otter. Technical Support Document 1. Vol. II, Final environmental impact statement: Translocation of southern sea otters. Sacramento, CA: U.S. Fish and Wildlife Service. 69 pp.

RIEDMAN, M. L., and J. A. Estes. 1990. The sea otter (*Enhydra lutris*): behavior, ecology, and natural history. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service. Biological Report 90(14). 126 pp.

ROSEL, P. E., A. E. Dizon, and J. E. Heyning. 1994. Population genetic analysis of two forms of the common dolphin (genus *Delphinus*) using mitochondrial DNA control region sequences. Marine Biology 119:159-167.

RUGH, D. J., M. M. Muto, S. E. Moore, and D. P. DeMaster. 1999. Status review of the eastern North Pacific stock of gray whales. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-103. 96 pp.

SAS INSTITUTE INC. 1999. SAS OnlineDoc®, Version 8, Cary, North Carolina: SAS Institute Inc. http://v8doc.sas.com/sashtml/

SCAMMON, C. M. 1874. The marine mammals of the northwestern coast of North America. John H. Carmany and Co., San Francisco. 320 pp.

SHANE, S. H., R. S. Wells, and B. Würsig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. Marine Mammal Science 2:34-63.

STEWART, B. S. 1988. Abundance of harbor seals on San Miguel Island, California, 1927 through 1986. Bulletin of the Southern California Academy of Sciences 87(1):39-43.

STEWART, B. S., and P. K. Yochem. 1984. Seasonal abundance of pinnipeds at San Nicolas Island, California, 1980-1982. Bulletin of the Southern California Academy of Sciences 83:121-132.

STEWART, B. S., and P. K. Yochem. 2000. Community ecology of California Channel Islands pinnipeds. Pp. 413-420 *in*: D. R. Browne, K. L. Mitchell, and H. W. Chaney (eds.), Proceedings of the Fifth California Islands Symposium, 29 March–1 April 1999, Santa Barbara Museum of Natural History, Santa Barbara, CA. Sponsored by the U.S. Minerals Management Service, Pacific OCS Region, Camarillo, CA. OCS Study No. 99-0038.

STEWART, B. S., P. K. Yochem, H. R. Huber, R. L. DeLong, R. J. Jameson, W. J. Sydeman, S. G. Allen, and B. J. Le Boeuf. 1994. History and present status of the northern elephant seal population. Pp. 29-48 *in*: B. J. Le Boeuf and R. M. Laws (eds.), Elephant seals: Population, ecology, behavior, and physiology. University of California Press, Berkeley, CA.

TØNNESSEN, J. N., and A. O. Johnson. 1982. The history of modern whaling. University of California Press, Berkeley. 798 pp.

U. S. GEOLOGICAL SURVEY (USGS). 2003. California sea otter surveys. U.S. Geological Survey, Western Ecological Research Center. http://www.werc.usgs.gov/otters/ca-surveys.html.

WALKER, W. A. 1975. Review of the live-capture fishery for smaller cetaceans taken in Southern California waters for public display, 1966-19977. Journal of the Fisheries Research Board of Canada 32:1197-1211.

WATKINS, W. A. 1977. Acoustic behavior of sperm whales. Oceanus 20:50-58.

WATSON, L. 1981. Sea guide to whales of the world. E. P. Dutton, NY. 302 pp.

WEBB, R. L. 1988. On the Northwest: Commercial whaling in the Pacific Northwest, 1790-1967. University of British Columbia Press, Vancouver. 425 pp.

WELLS, R. S., T. P. Dohl, L. J. Hansen, D. L. Kelly, A. Baldridge, and R. H. Defran. 1990. Northward extension of the range of bottlenose dolphins along the California coast. Pp. 421-431 *in*: S. Leatherwood and R. R. Reeves (eds.), The bottlenose dolphin. Academic Press, San Diego, CA.

WENDELL, F. E., R. A. Hardy, and J. A. Ames. 1985. Assessment of the accidental take of sea otters, *Enhydra lutris,* in gill and trammel nets. Unpubl. Report, Marine Resources Branch, California Department of Fish and Game. 30 pp.

WOLMAN, A. A. 1986. Humpback whale. Pp. 57-63 *in*: D. Haley (ed.), Marine mammals of eastern North Pacific and Arctic waters. Second Edition, Revised. Pacific Search Press.

Table 2.1. Dates of aerial survey flights in southern California from 1999-2002.

1999	2000	2001	2002
	7-Jan-2000	6-Jan-2001	7-Jan-2002
	8-Jan-2000	7-Jan-2001	8-Jan-2002
	9-Jan-2000	10-Jan-2001	9-Jan-2002
	13-Jan-2000	12-Jan-2001	10-Jan-2002
	14-Jan-2000	13-Jan-2001	11-Jan-2002
	18-Jan-2000	14-Jan-2001	12-Jan-2002
	19-Jan-2000	15-Jan-2001	17-Jan-2002
	21-Jan-2000	22-Jan-2001	18-Jan-2002
	22-Jan-2000	23-Jan-2001	19-Jan-2002
	23-Jan-2000	24-Jan-2001	20-Jan-2002
	20-Apr-2000	25-Jan-2001	
8-May-1999	6-May-2000	6-May-2001	
9-May-1999	7-May-2000	7-May-2001	
10-May-1999	8-May-2000	8-May-2001	
11-May-1999	9-May-2000	9-May-2001	
13-May-1999	10-May-2000	10-May-2001	
14-May-1999	12-May-2000	11-May-2001	
15-May-1999	13-May-2000	12-May-2001	
23-May-1999	14-May-2000	13-May-2001	
24-May-1999	15-May-2000	15-May-2001	
25-May-1999	16-May-2000	16-May-2001	
	17-May-2000	17-May-2001	
		18-May-2001	
10-Sep-1999	6-Sep-2000	5-Sep-2001	
11-Sep-1999	7-Sep-2000	6-Sep-2001	
12-Sep-1999	8-Sep-2000	7-Sep-2001	
20-Sep-1999	9-Sep-2000	8-Sep-2001	
21-Sep-1999	10-Sep-2000	17-Sep-2001	
22-Sep-1999	14-Sep-2000	18-Sep-2001	
23-Sep-1999	15-Sep-2000	22-Sep-2001	
28-Sep-1999	20-Sep-2000	23-Sep-2001	
29-Sep-1999	21-Sep-2000	24-Sep-2001	
30-Sep-1999	22-Sep-2000	25-Sep-2001	
	28-Sep-2000		

Table 2.2. Marine mammals sighted on USGS/MMS marine mammal/seabird surveys, May 1999-January 2002.

Pinnipeds
California sea lion (*Zalophus californianus*)
Harbor seal (*Phoca vitulina*)
Northern elephant seal (*Mirounga angustirostris*)
Northern fur seal (*Callorhinus ursinus*)

Carnivores
Southern sea otter (*Enhydra lutris nereis*)

Cetaceans
Mysticetes
Gray whale (*Eschrichtius robustus*)
Fin whale (*Balaenoptera physalus*)
Blue whale (*Balaenoptera musculus*)
Humpback whale (*Megaptera novaeangliae*)
Minke whale (*Balaenoptera acutorostrata*)

Odontocetes
Long-beaked/short-beaked common dolphin (*Delphinus capensis*/*D. delphis*)
Risso's dolphin (*Grampus griseus*)
Bottlenose dolphin (*Tursiops truncatus*)
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)
Northern right whale dolphin (*Lissodelphis borealis*)
Dall's porpoise (*Phocoenoides dalli*)
Killer whale (*Orcinus orca*)
Sperm whale (*Physeter macrocephalus*)
Cuvier's beaked whale (*Ziphius cavirostris*)
Baird's beaked whale (*Berardius bairdi*) [one probable sighting]

Table 2.3. Marine mammals not sighted on USGS/MMS marine mammal/seabird surveys, May 1999-January 2002, but identified during the 1975–1983 baseline studies.

Pinnipeds
Steller sea lion (*Eumetopias jubatus*)[1,2]
Guadalupe fur seal (*Arctocephalus townsendi*)[1]

Cetaceans
Mysticetes
Sei whale (*Balaenoptera borealis*)[1,2]

Odontocetes
Harbor porpoise (*Phocoena phocoena*)[2]
Short-finned pilot whales (*Globicephala macrorhynchus*)[1,2]
Pygmy/dwarf sperm whale (*Kogia breviceps*/*K. simus*)[2]
Mesoplodon spp. beaked whales (*M. carlhubbsi*/*ginkgodens*/*densirostris*/*hectori*/ *stejnegeri*)[1]

[1] Sighted during the Southern California Bight study, 1975–1977 (Bonnell et al., 1981; Dohl et al., 1981).
[2] Sighted during the Central and Northern California study, 1980–1982 (Bonnell et al., 1983; Dohl et al., 1983).

Table 2.4. Population size estimates (±SE) of selected marine mammals within the entire Southern California Bight from 1999-2002 during September, January, and May.

Species	Population Size Estimate		
	January	May	September
California Sea Lion	88520 ± 16934	54651 ± 5388	46954 ± 4618
Harbor Seal	8467 ± 1539	5388 ± 770	5388 ± 770
Common Dolphin	28480 ± 8467	8467 ± 5388	93138 ± 36947
Risso's Dolphin	10007 ± 3849	5388 ± 1539	4618 ± 2309
Bottlenose Dolphin	4618 ± 1539	13085 ± 3079	5388 ± 1539

Table 2.5. At-sea, coastline, and combined densities (±SE) km^2 of selected marine mammals within the entire Southern California Bight from 1999-2002 during September, January, and May.

Species	Entire Southern California Bight			Entire At-sea			Entire Coastline		
	January	May	September	January	May	September	January	May	September
California Sea Lion	1.15±0.22	0.71±0.07	0.61±0.06	0.57±0.19	0.37±0.04	0.45±0.05	2.40±0.55	1.46±0.20	1.00±0.15
Harbor Seal	0.11±0.02	0.07±0.01	0.07±0.01	0.01±0.00	0.01±0.00	0.01±0.00	0.33±0.05	0.18±0.02	0.21±0.03
Common Dolphin	0.37±0.11	0.11±0.07	1.21±0.48	0.53±0.17	0.16±0.11	1.70±0.67	0.02±0.02	0.00±0.00	0.00±0.00
Risso's Dolphin	0.13±0.05	0.07±0.02	0.06±0.03	0.08±0.03	0.10±0.03	0.07±0.03	0.23±0.16	0.00±0.00	0.02±0.02
Bottlenose Dolphin	0.06±0.02	0.17±0.04	0.07±0.02	0.00±0.00	0.03±0.02	0.02±0.02	0.19±0.05	0.47±0.11	0.20±0.05

Table 2.6. At-sea densities (±SE) km^2 of selected marine mammals within subareas of the Southern California Bight from 1999-2002 during September, January, and May.

Species	At-Sea Subareas within the Southern California Bight														
	1 (North)			2 (West-Center)			3 (Center)			4 (South-East)			5 (South)		
	January	May	September	January	May	September	January	May	September	January	May	September	January	May	September
California Sea Lion	0.23±0.05	0.22±0.05	0.35±0.08	0.05±0.03	0.52±0.13	0.16±0.06	0.88±0.38	0.60±0.11	0.78±0.14	0.92±0.66	0.18±0.03	0.19±0.04	0.20±0.05	0.32±0.06	0.48±0.13
Harbor Seal	0.02±0.01	0.02±0.01	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.03±0.01	0.04±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00
Common Dolphin	0.75±0.62	0.00±0.00	0.44±0.26	0.00±0.00	0.00±0.00	0.00±0.00	0.58±0.27	0.11±0.06	4.49±2.40	1.08±0.50	0.50±0.40	1.11±0.58	0.00±0.00	0.00±0.00	0.57±0.31
Risso's Dolphin	0.00±0.00	0.07±0.07	0.07±0.07	0.00±0.00	0.02±0.02	0.00±0.00	0.14±0.08	0.27±0.11	0.13±0.07	0.11±0.07	0.05±0.04	0.12±0.11	0.05±0.03	0.02±0.01	0.00±0.00
Bottlenose Dolphin	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.08±0.08	0.07±0.06	0.02±0.01	0.03±0.02	0.00±0.00	0.00±0.00	0.02±0.02	0.00±0.00

Table 2.7. Mainland coastline densities (±SE) km^2 of selected marine mammals within subareas of the Southern California Bight from 1999-2002 during September, January, and May.

Species				Mainland Coastal Subareas								
	Entire Mainland Coastline			Northern Mainland Coastline			Center Mainland Coastline			Southern Mainland Coastline		
	January	May	September	January	May	September	January	May	September	January	May	September
California Sea Lion	0.36±0.12	0.53±0.13	0.53±0.21	0.18±0.12	1.19±0.44	2.03±1.01	0.25±0.10	0.41±0.19	0.10±0.03	0.62±0.34	0.34±0.16	0.24±0.18
Harbor Seal	0.41±0.10	0.20±0.03	0.23±0.04	0.25±0.11	0.23±0.07	0.35±0.09	0.73±0.19	0.30±0.06	0.31±0.06	0.04±0.02	0.05±0.02	0.06±0.04
Common Dolphin	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Risso's Dolphin	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Bottlenose Dolphin	0.36±0.10	0.85±0.20	0.40±0.10	0.00±0.00	0.16±0.16	0.67±0.28	0.68±0.20	1.12±0.34	0.43±0.16	0.09±0.04	0.85±0.32	0.21±0.11

Table 2.8. Island coastline densities (±SE) km^2 of selected marine mammals within subareas of the Southern California Bight from 1999-2002 during September, January, and May.

Species				Island Coastal Subareas					
	Island Coastlines			Northern Channel Is. Coastline			Southern Channel Is. Coastline		
	January	May	September	January	May	September	January	May	September
California Sea Lion	4.70±1.15	2.56±0.40	1.45±0.21	1.66±0.30	2.14±0.35	1.38±0.28	11.11±3.47	3.48±1.01	1.58±0.34
Harbor Seal	0.23±0.04	0.16±0.03	0.20±0.04	0.26±0.06	0.23±0.05	0.22±0.04	0.17±0.05	0.03±0.02	0.16±0.06
Common Dolphin	0.03±0.03	0.00±0.00	0.00±0.00	0.05±0.05	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Risso's Dolphin	0.50±0.34	0.00±0.00	0.05±0.05	0.74±0.50	0.00±0.00	0.07±0.07	0.00±0.00	0.00±0.00	0.00±0.00
Bottlenose Dolphin	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.01±0.01	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

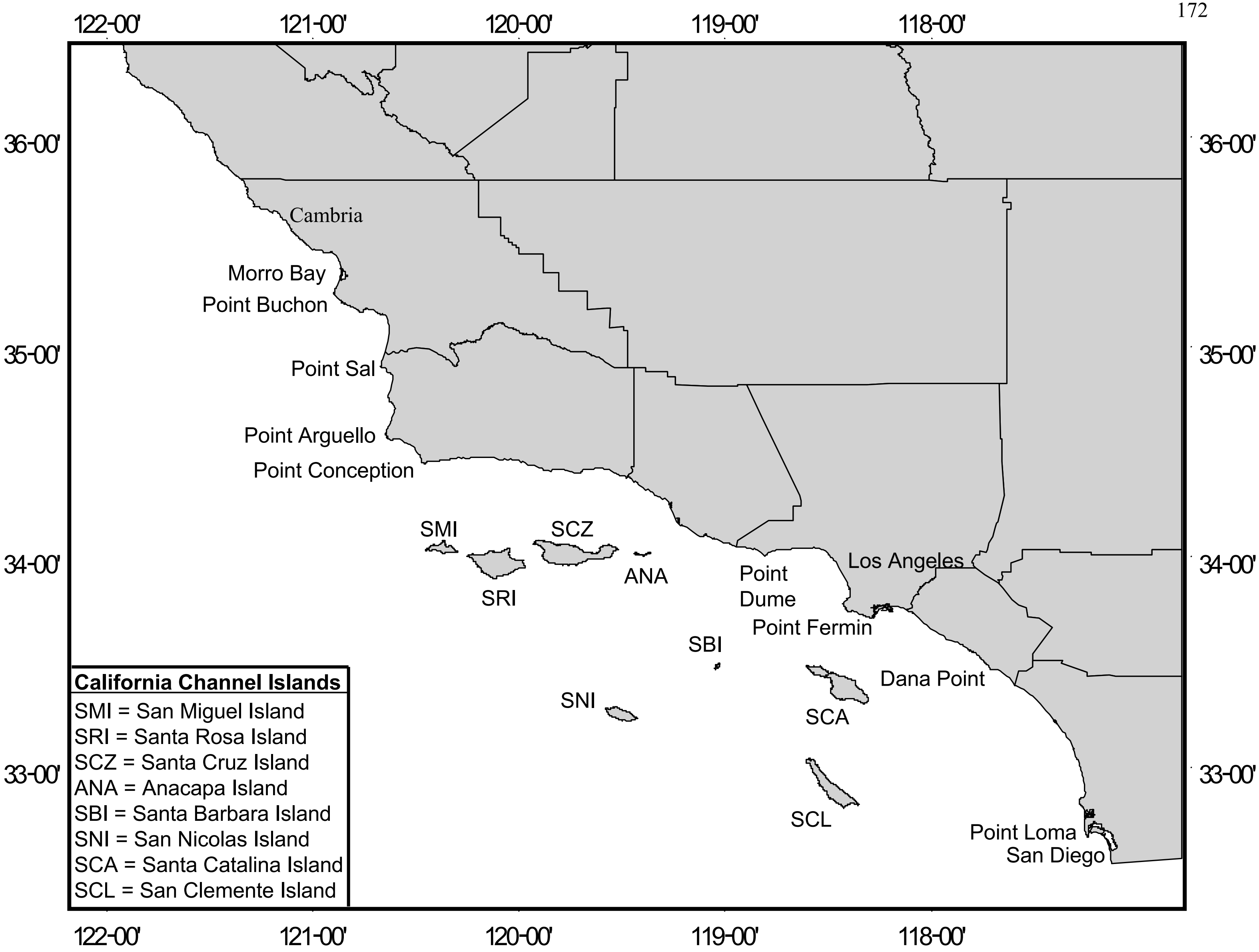


FIGURE 2.1. Map of central and southern California showing locations of county boundaries, major cities, coastal points, and islands.

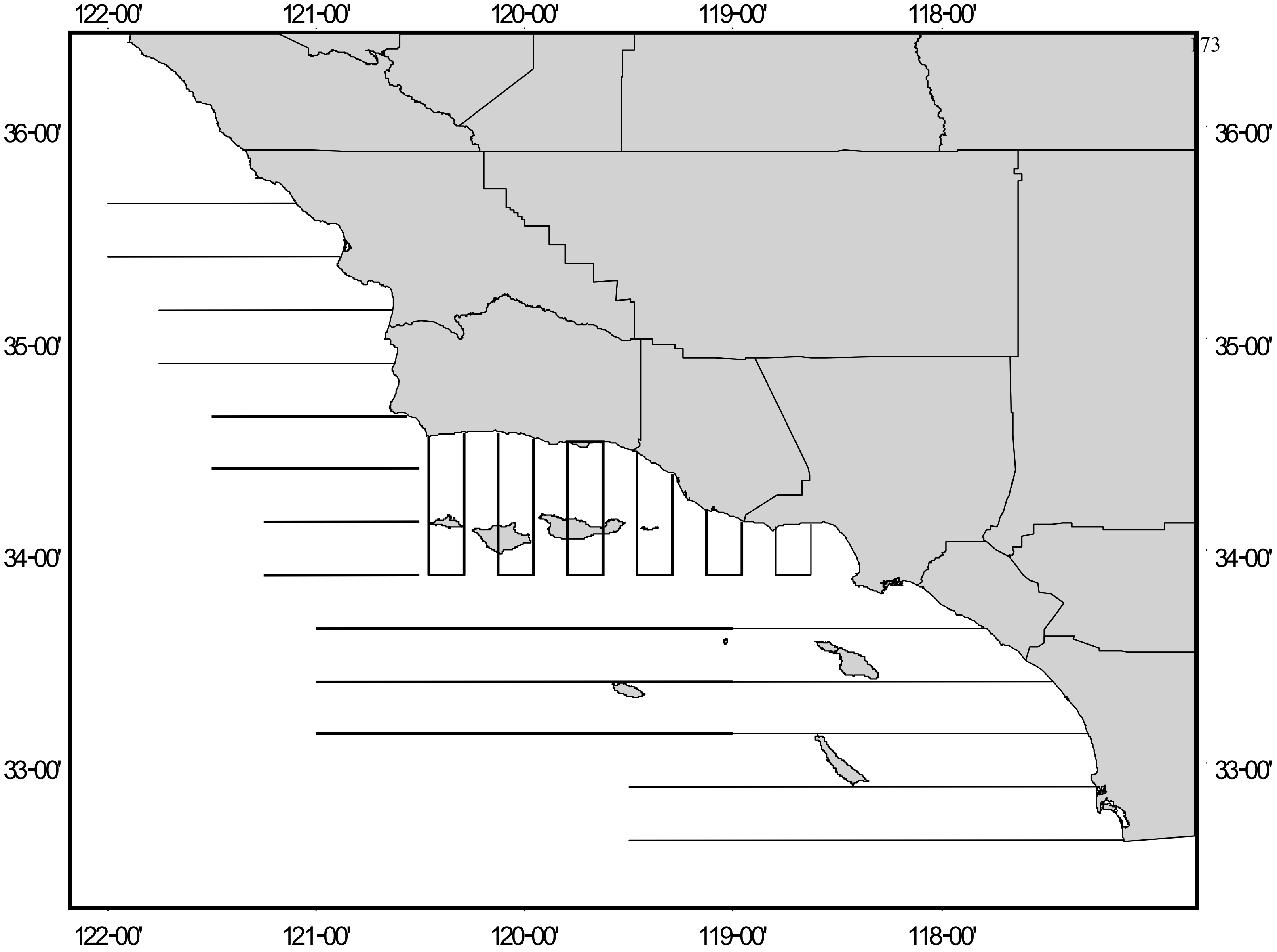


FIGURE 2.2. Map of central and southern California showing locations of core area and non-core area transect lines. Core area transect lines are represented by thicker lines. Non-core area transect lines are represented by thinner lines. The core area was surveyed twice each survey month from 1999–2002.

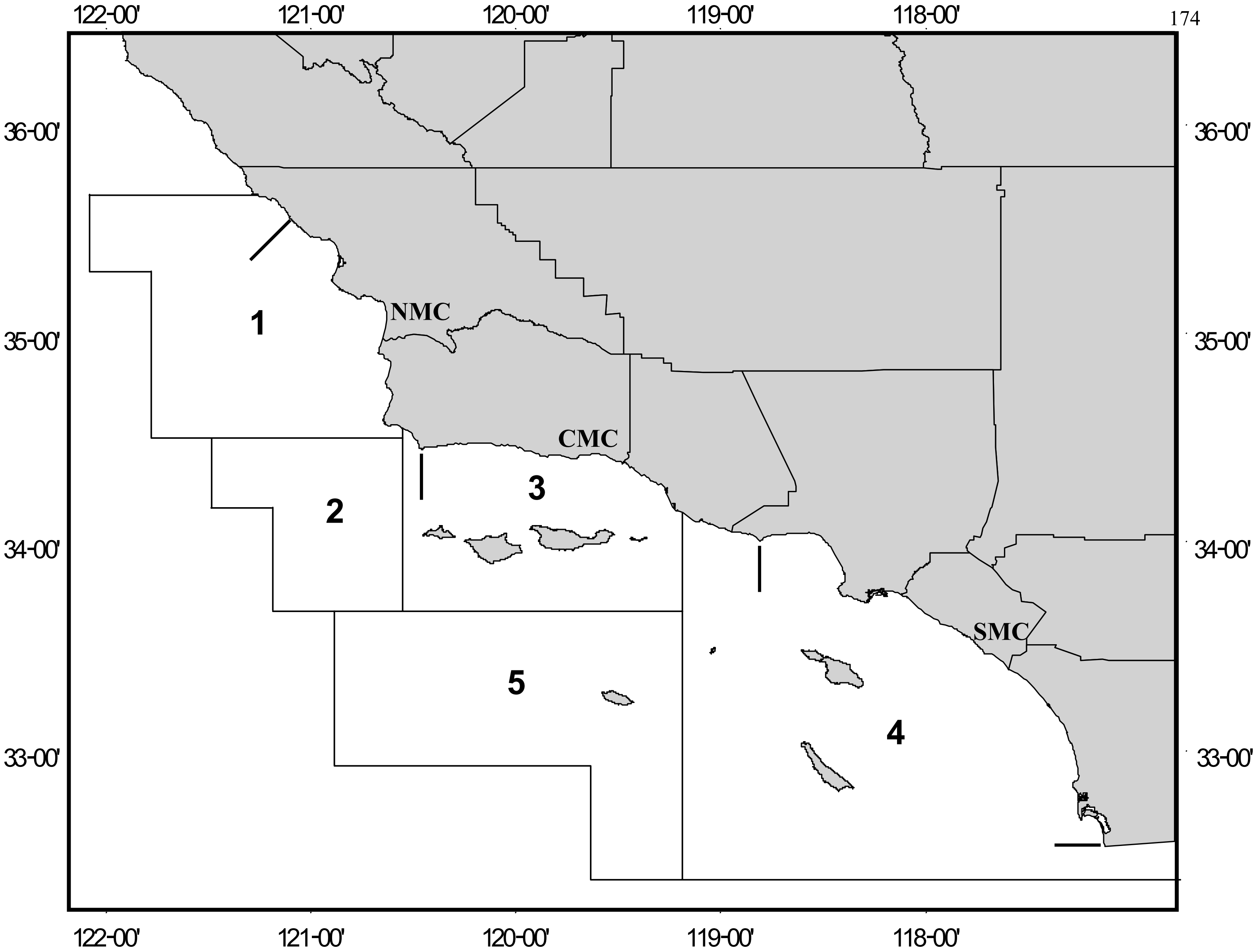


FIGURE 2.3. Map of central and southern California showing locations of at-sea and coastal subareas. At-sea subareas are numbered 1–5. Coastal subarea boundaries are denoted by bars. NMC = northern mainland coast. CMC = central mainland coast. SMC = southern mainland coast.

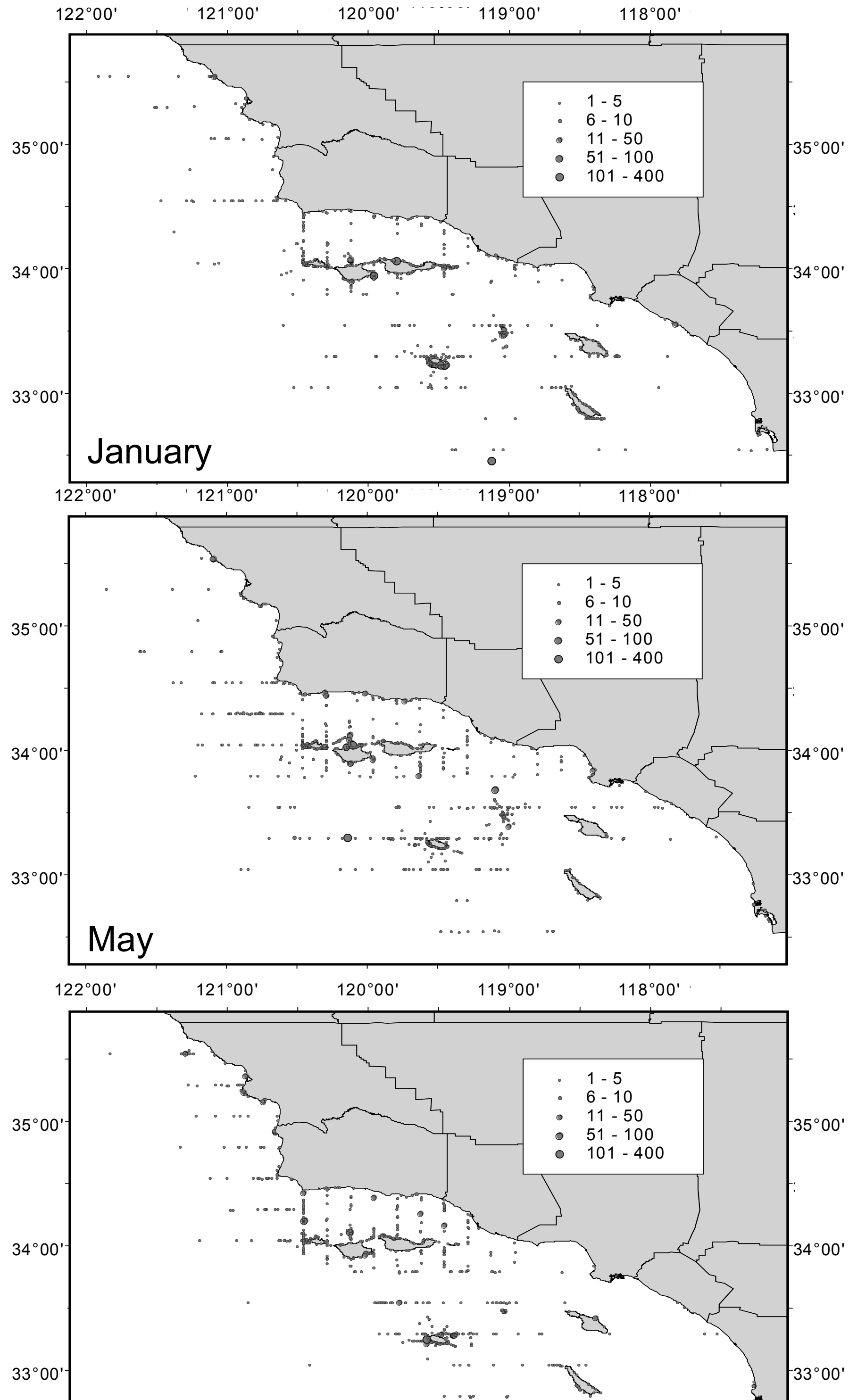


FIGURE 2.4. Sightings of California sea lions (*Zalophus californianus*) in the study area from 1999-2002 by survey month.

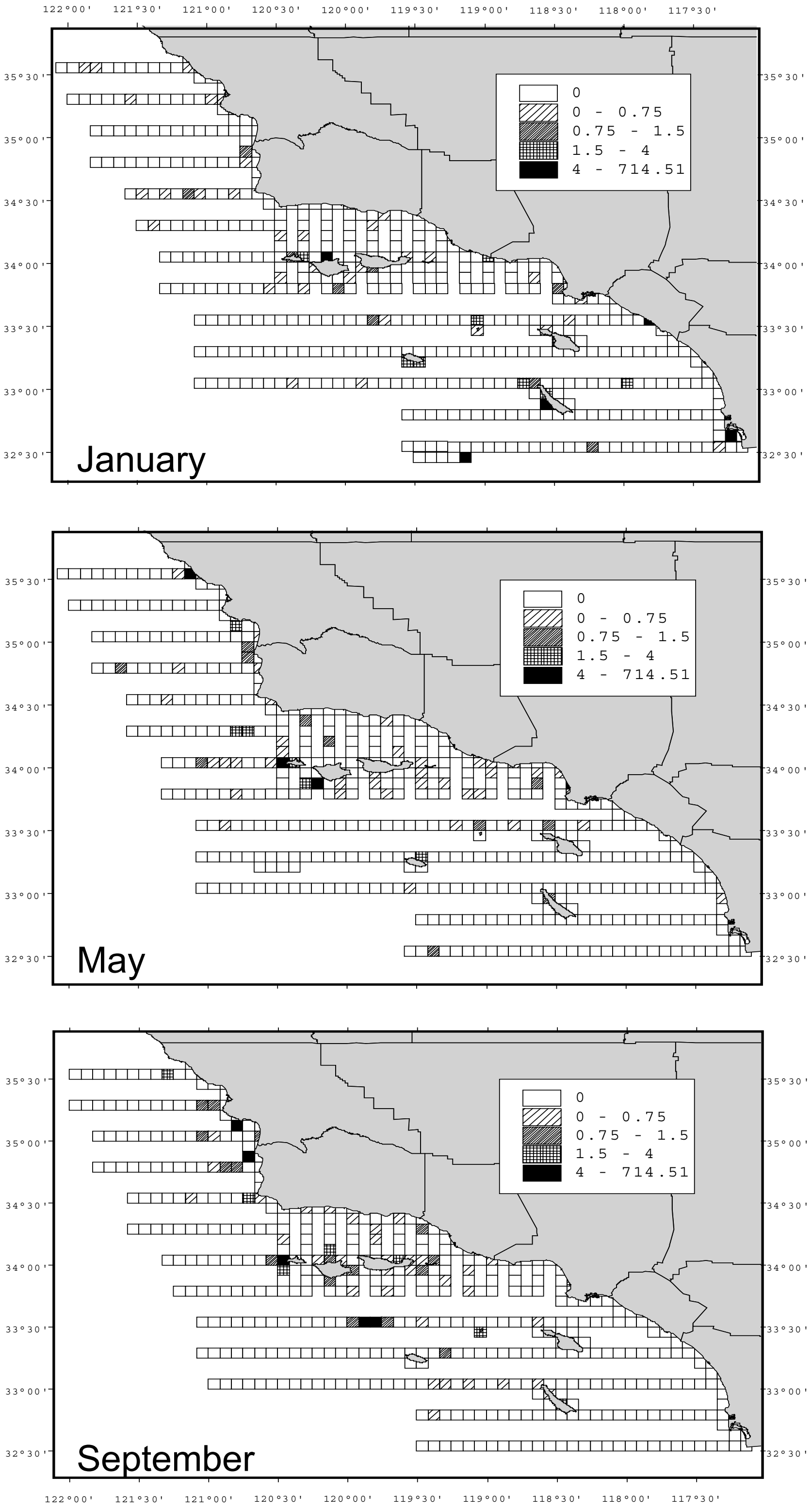


FIGURE 2.5. Observed densities of California sea lions (*Zalophus californianus*) in the study area from 1999-2002 by survey month.

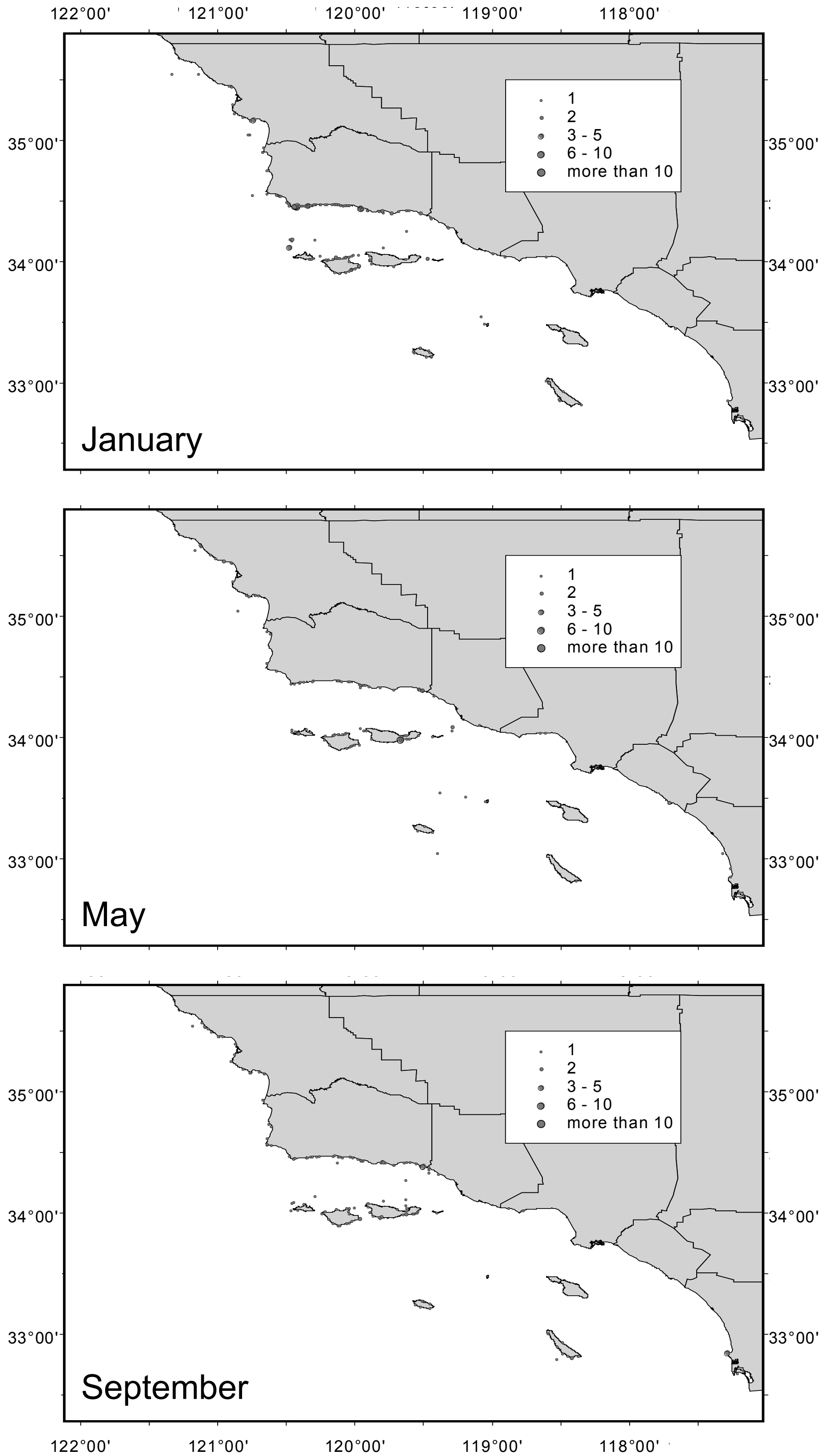


FIGURE 2.6. Sightings of harbor seals (*Phoca vitulina*) in the study area from 1999-2002 by survey month.

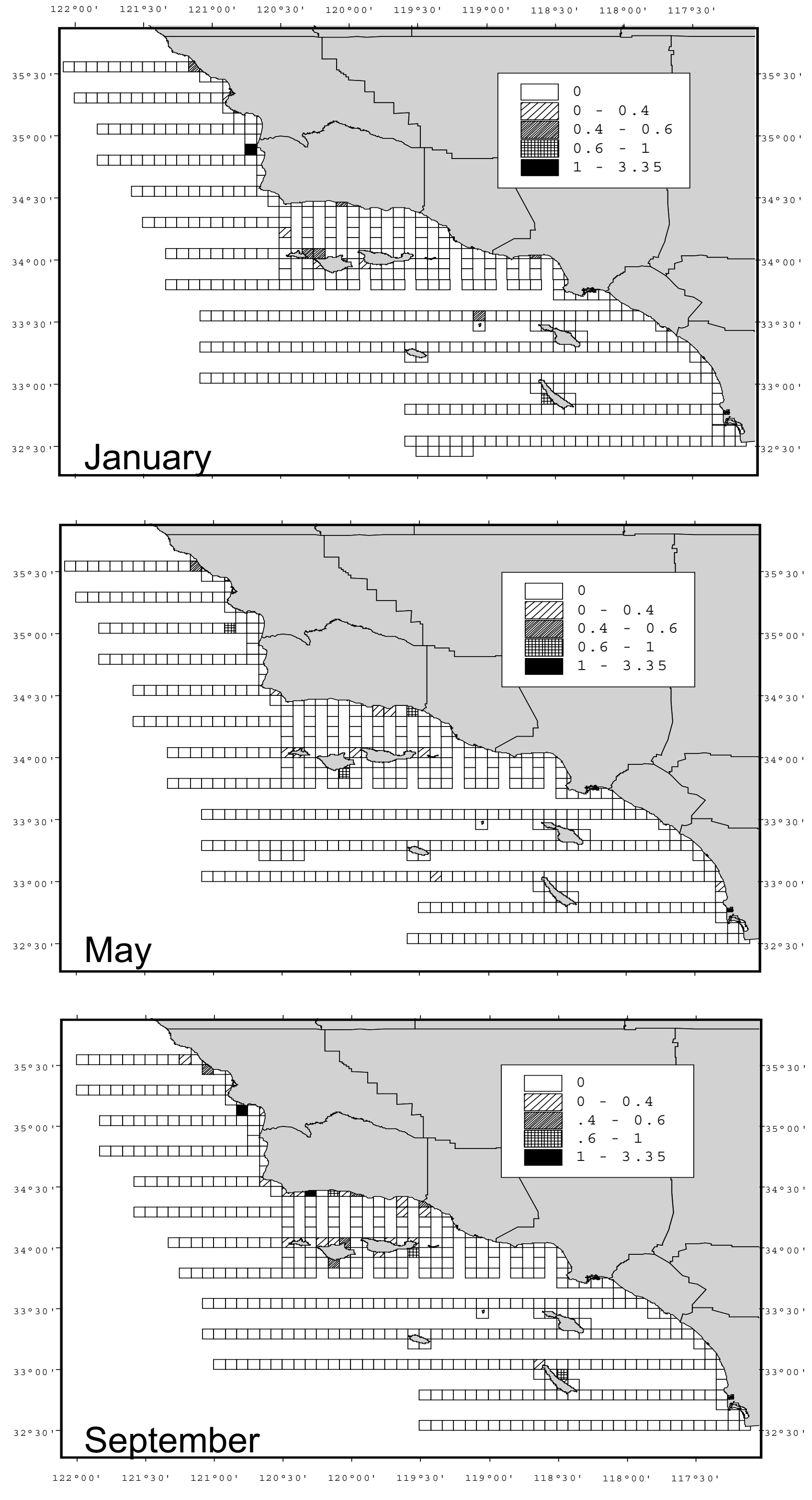


FIGURE 2.7. Observed densities of harbor seals (*Phoca vitulina*) in the study area from 1999-2002 by survey month.

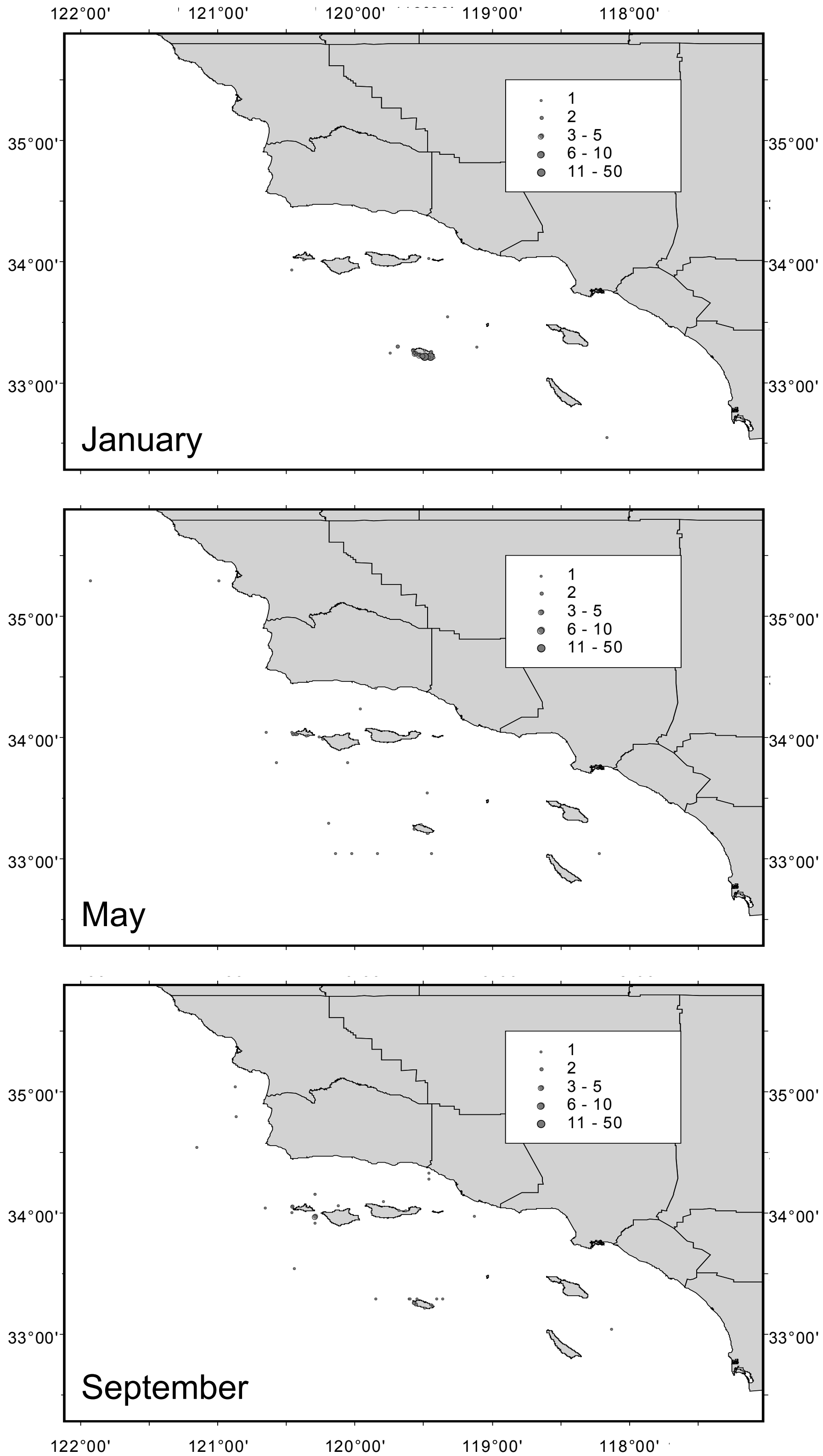


FIGURE 2.8. Sightings of northern elephant seals (*Mirounga angustirostris*) in the study area from 1999-2002 by survey month.

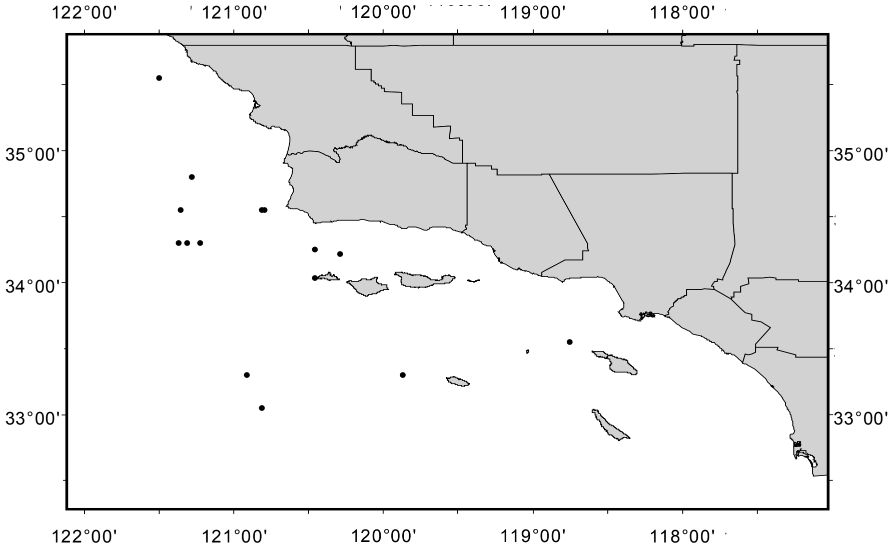


FIGURE 2.9. Sightings of northern fur seals (*Callorhinus ursinus*) in the study area from 1999-2002.

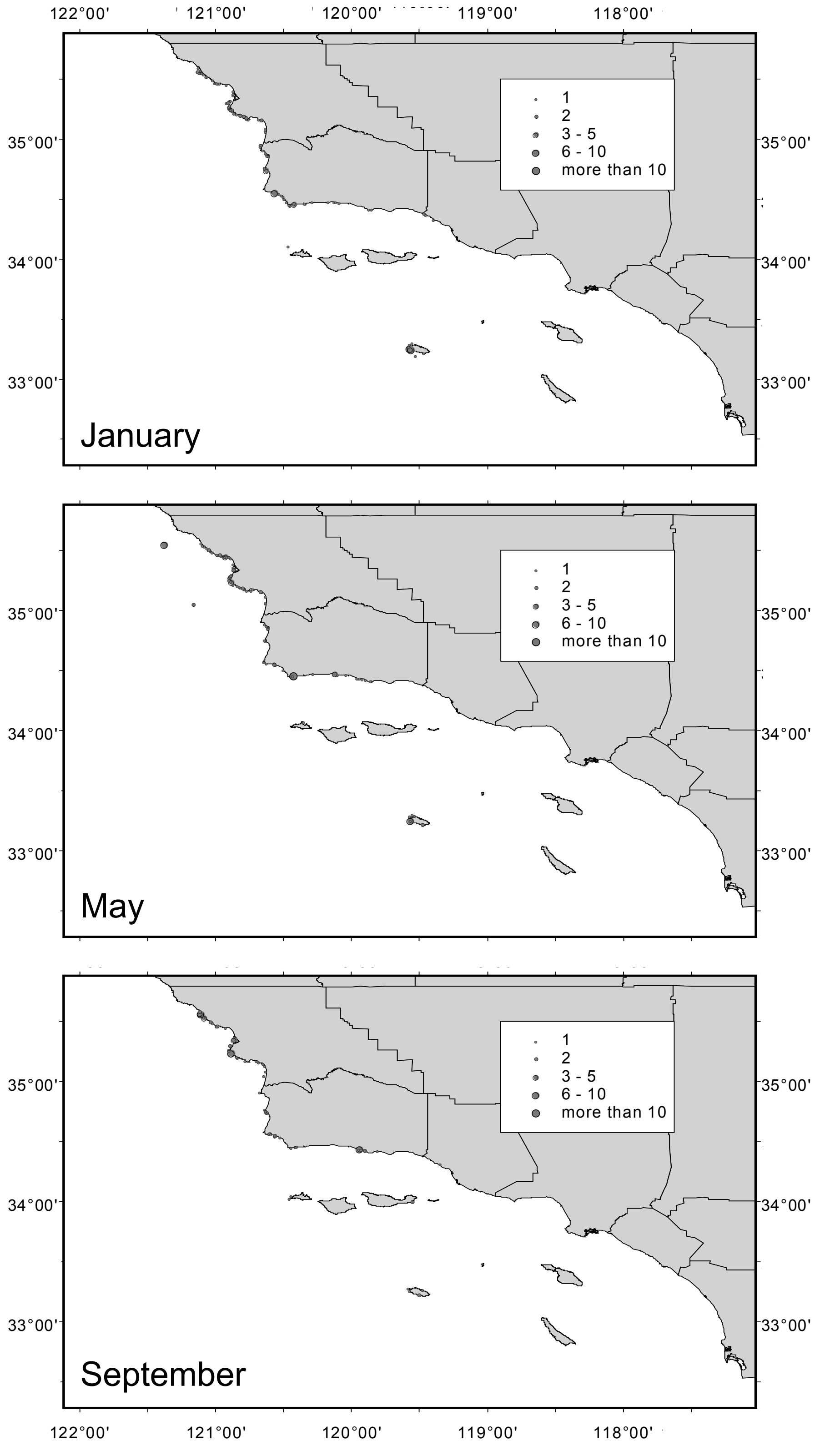


FIGURE 2.10. Sightings of southern sea otters (*Enhydra lutris nereis*) in the study area from 1999-2002 by survey month.

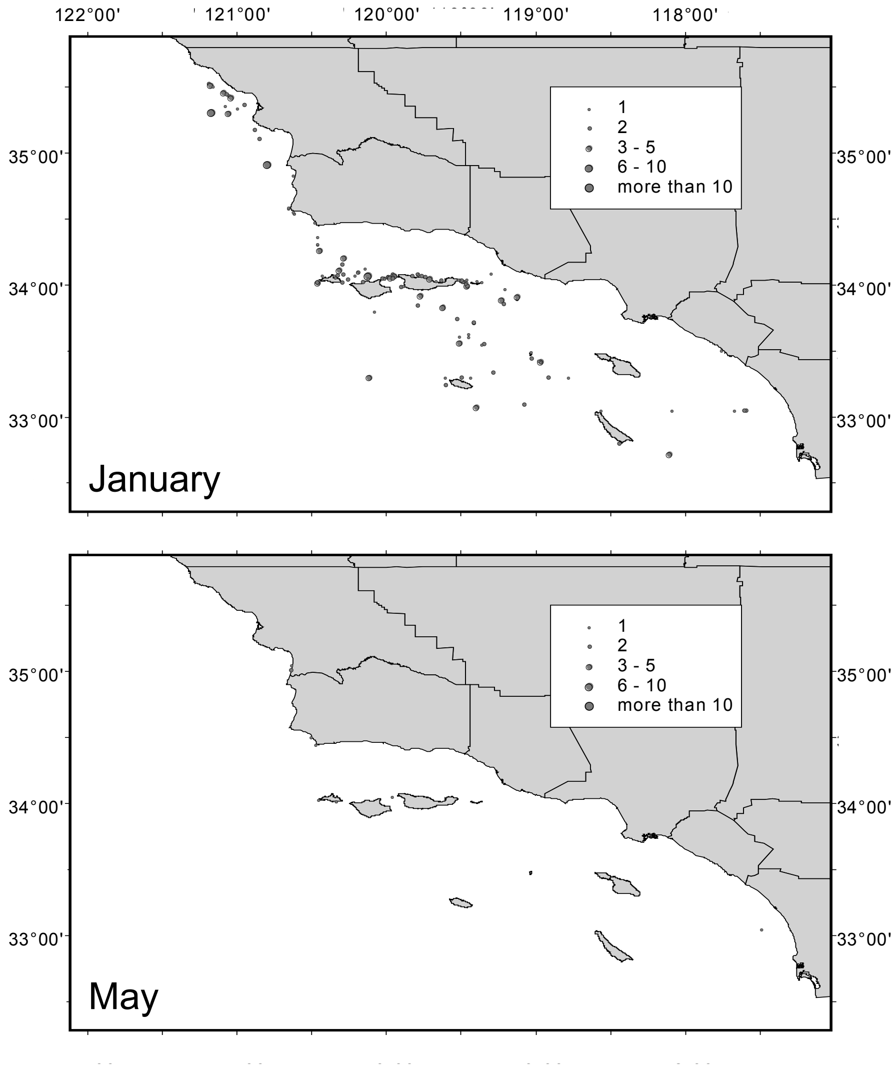


FIGURE 2.11. Sightings of gray whales (*Eschrichtius robustus*) in the study area from 1999-2002 for the January and May survey months.

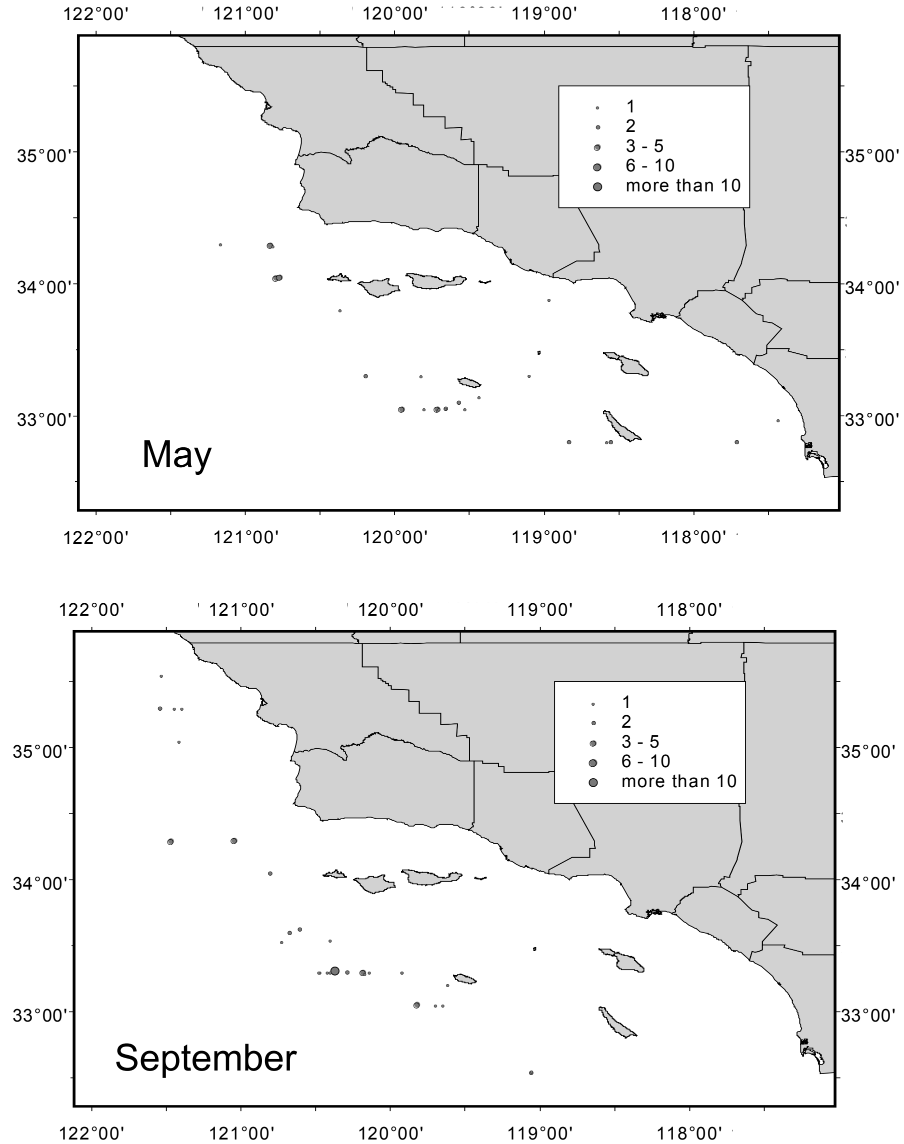


FIGURE 2.12. Sightings of fin whales (*Balaenoptera physalus*) in the study area from 1999-2002 for the May and September survey months.

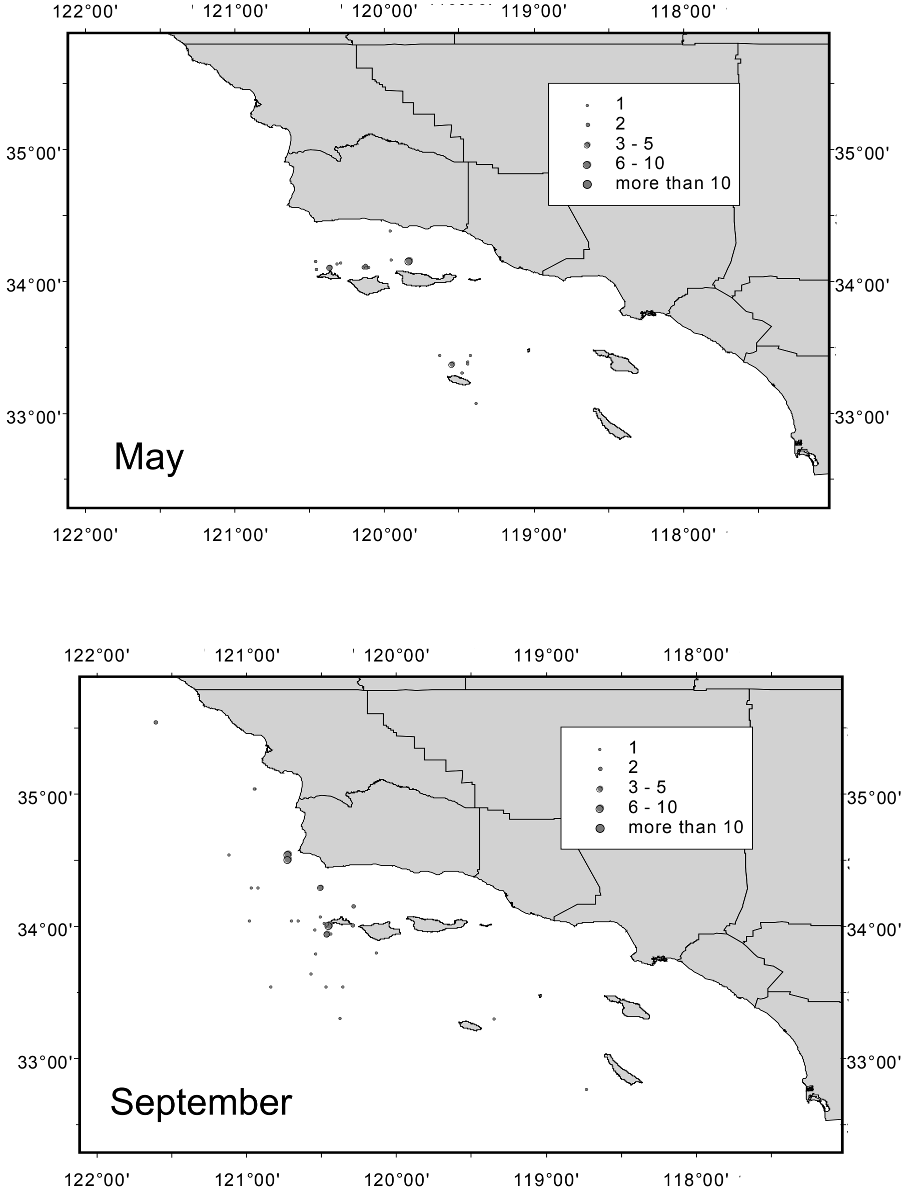
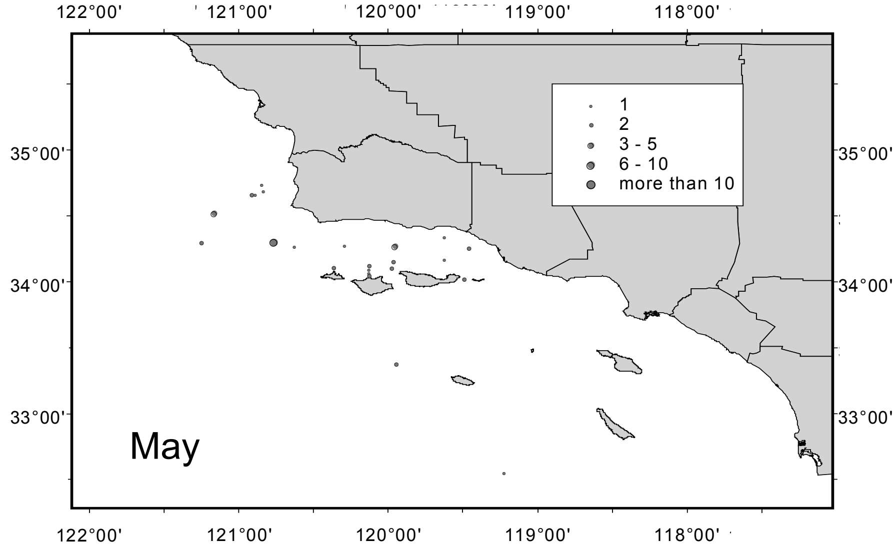


FIGURE 2.13. Sightings of blue whales (*Balaenoptera musculus*) in the study area from 1999-2002 for the May and September survey months.



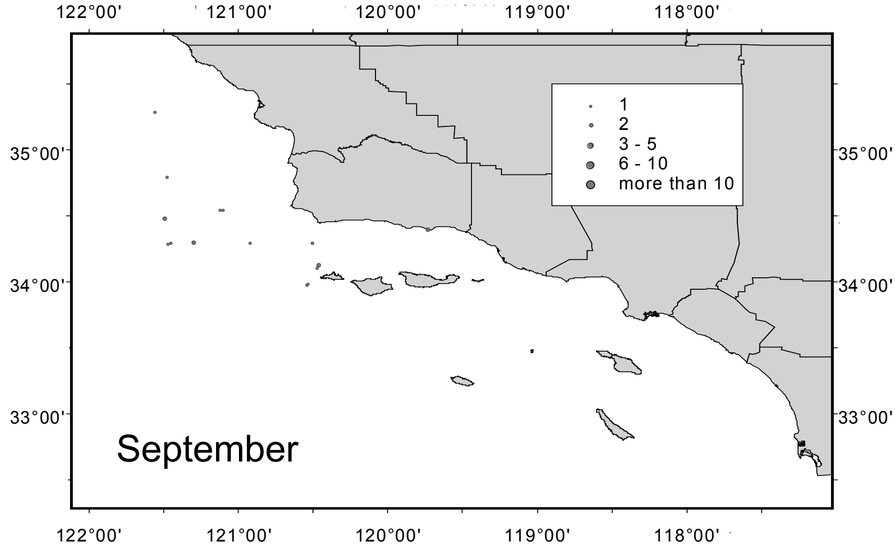


FIGURE 2.14. Sightings of humpback whales (*Megaptera novaeangliae*) in the study area from 1999-2002 for the May and September survey months.

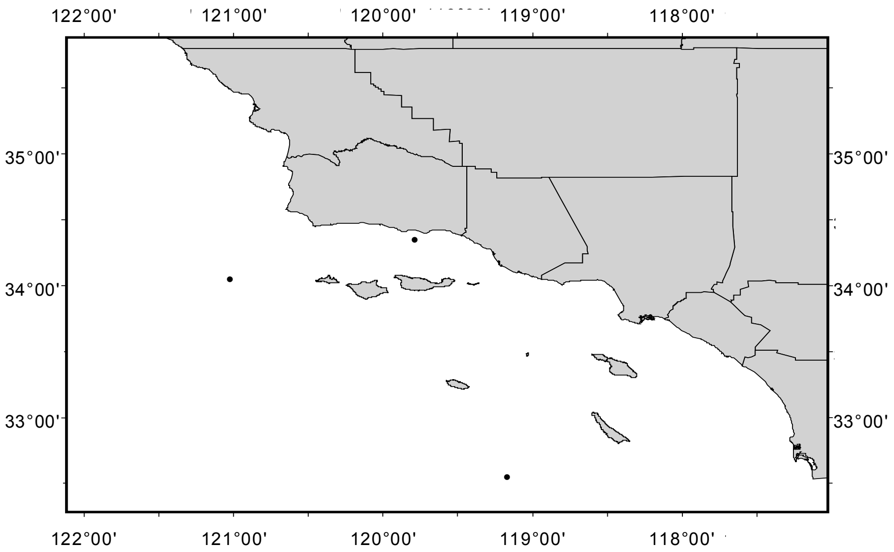


FIGURE 2.15. Sightings of minke whales (*Balaenoptera acutorostrata*) in the study area from 1999-2002.

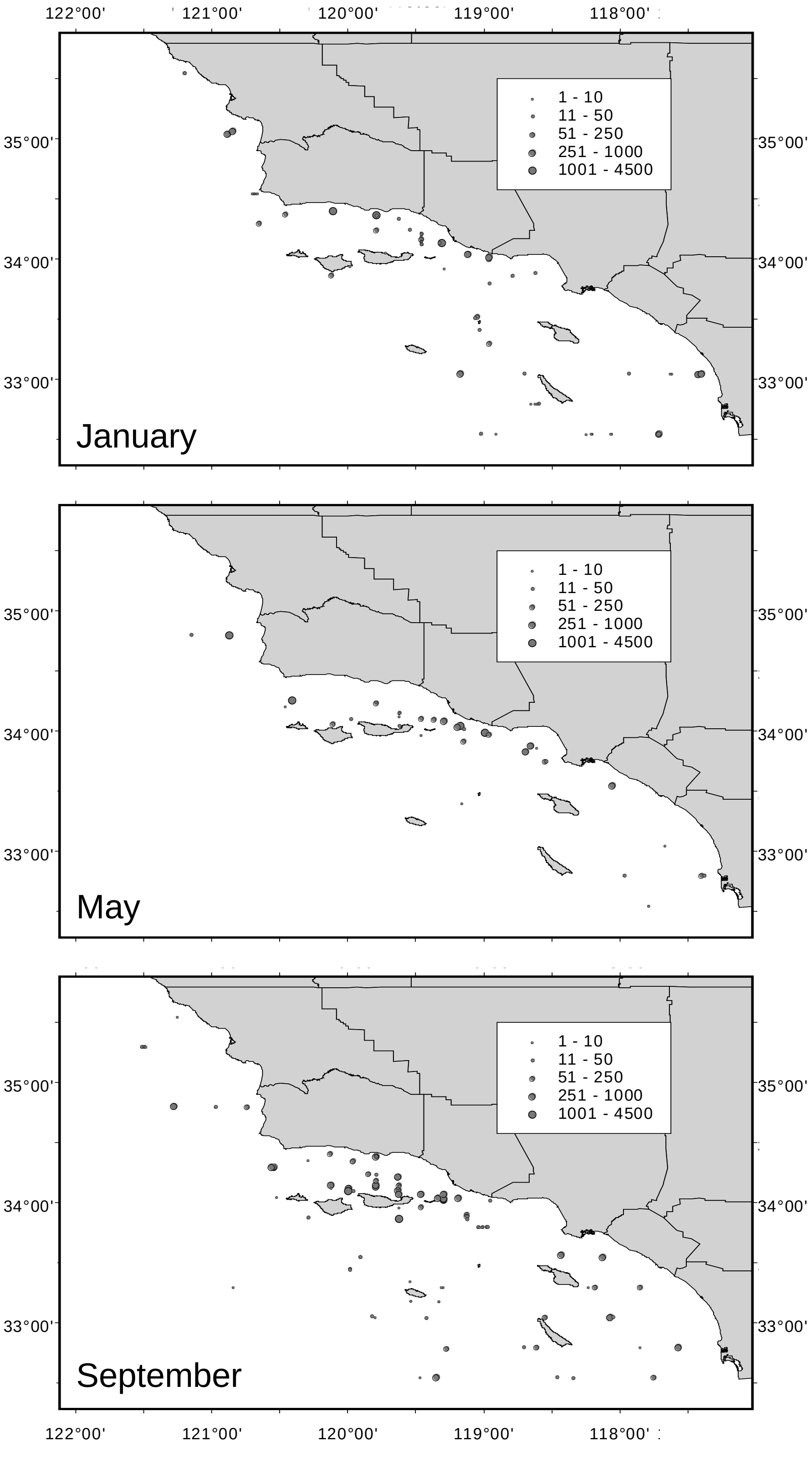


FIGURE 2.16. Sightings of common dolphins (*Delphinus capensis/D. delphis*) in the study area from 1999-2002 by survey month.

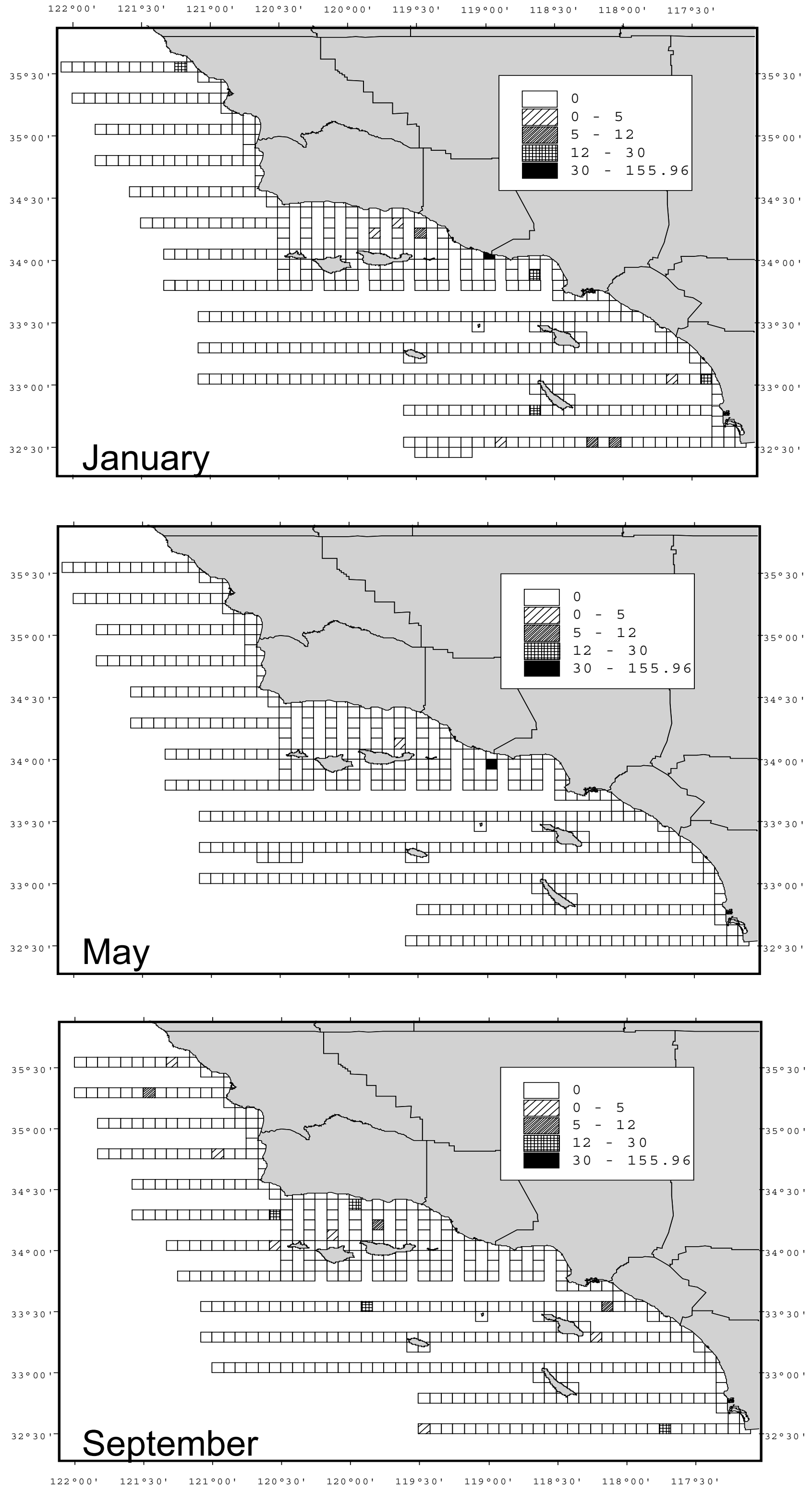


FIGURE 2.17. Observed densities of common dolphins (*Delphinus capensis /D. delphis*) in the study area from 1999-2002 by survey month.

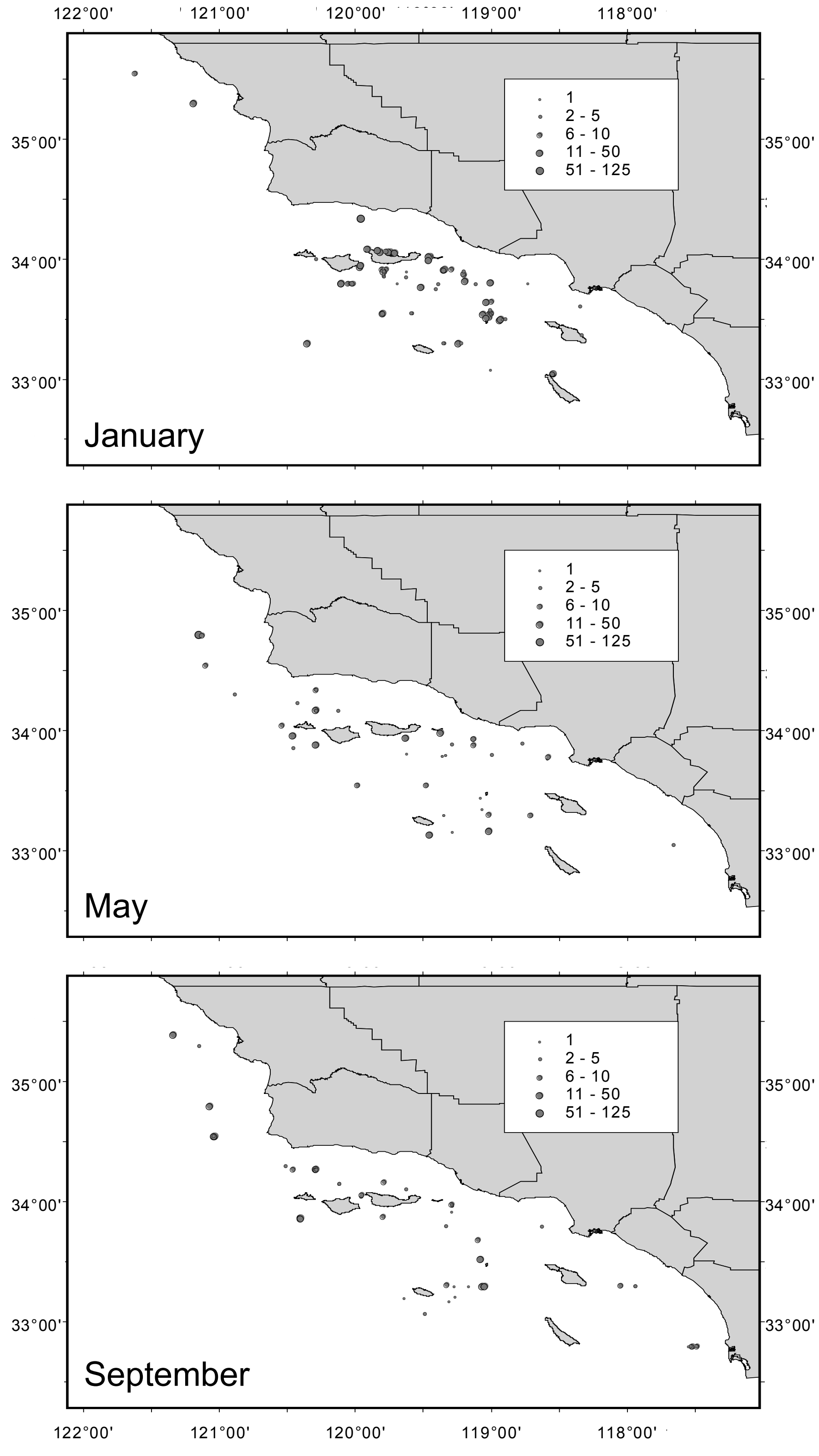


FIGURE 2.18. Sightings of Risso's dolphins (*Grampus griseus*) in the study area from 1999-2002 by survey month.

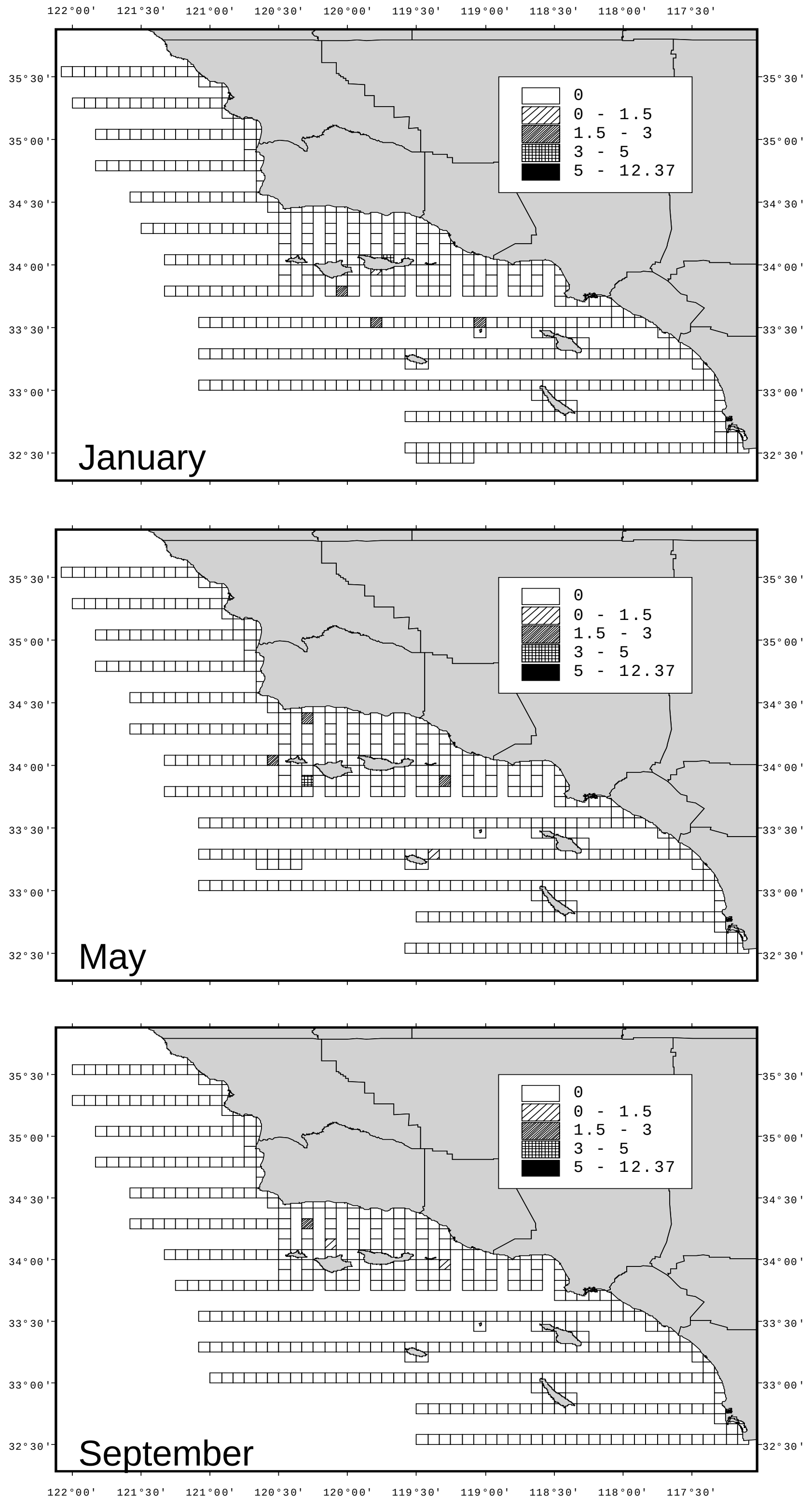


FIGURE 2.19. Observed densities of Risso's dolphins (*Grampus griseus*) in the study area from 1999-2002 by survey month.

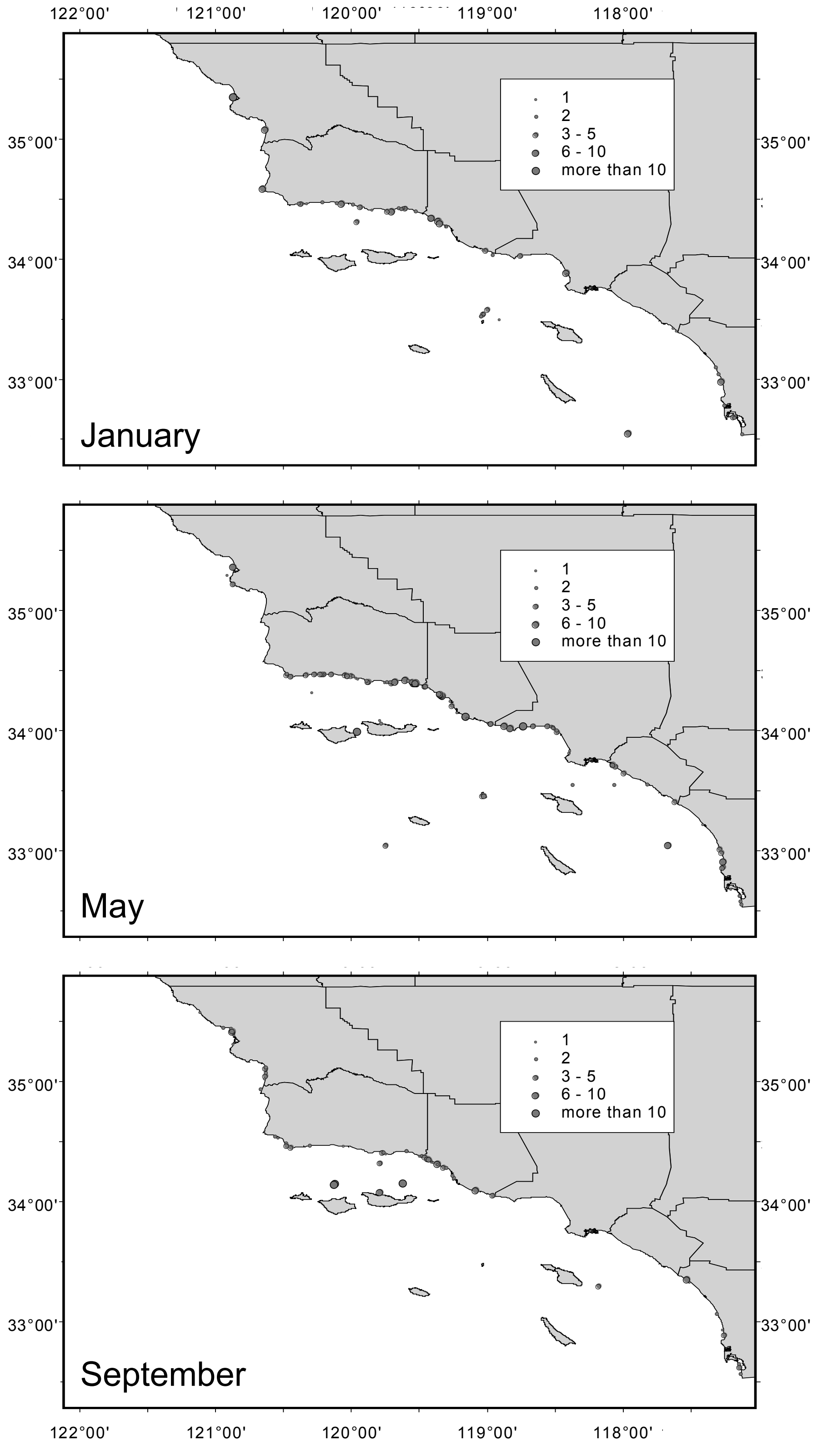


FIGURE 2.20. Sightings of bottlenose dolphins (*Tursiops truncatus*) in the study area from 1999-2002 by survey month.

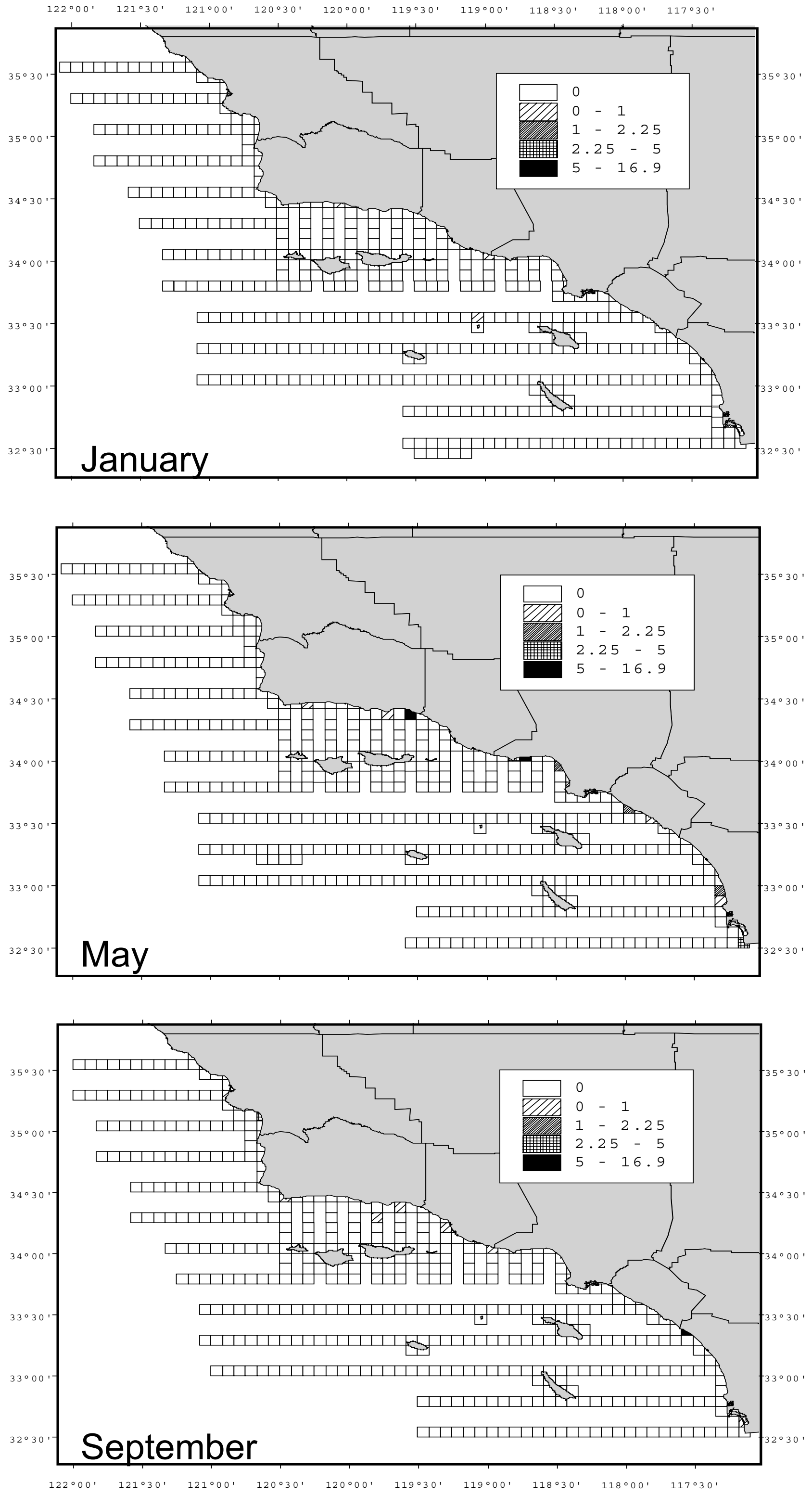


FIGURE 2.21. Observed densities of bottlenose dolphins (*Tursiops truncatus*) in the study area from 1999-2002 by survey month.

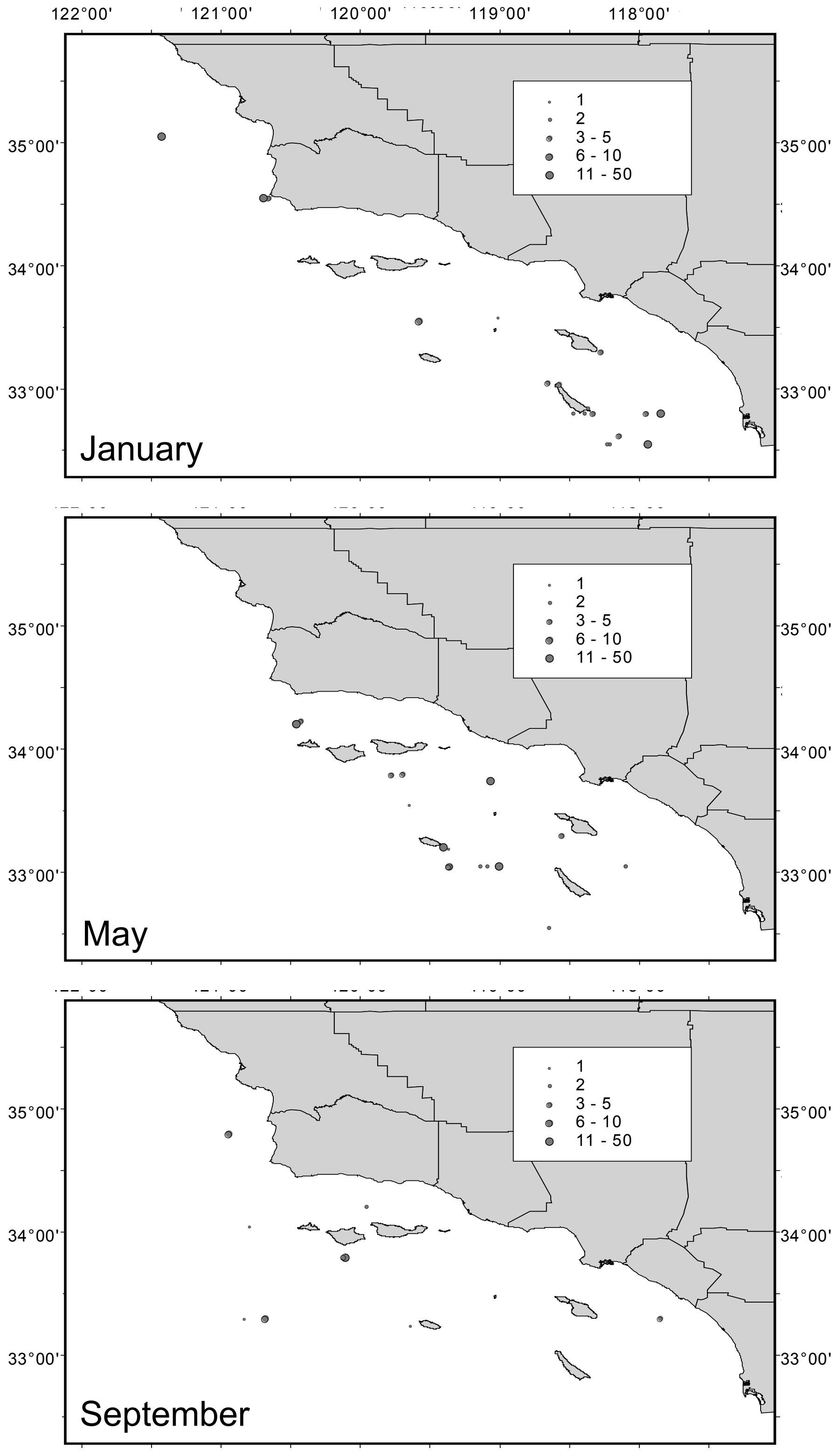


FIGURE 2.22. Sightings of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in the study area from 1999-2002 by survey month.

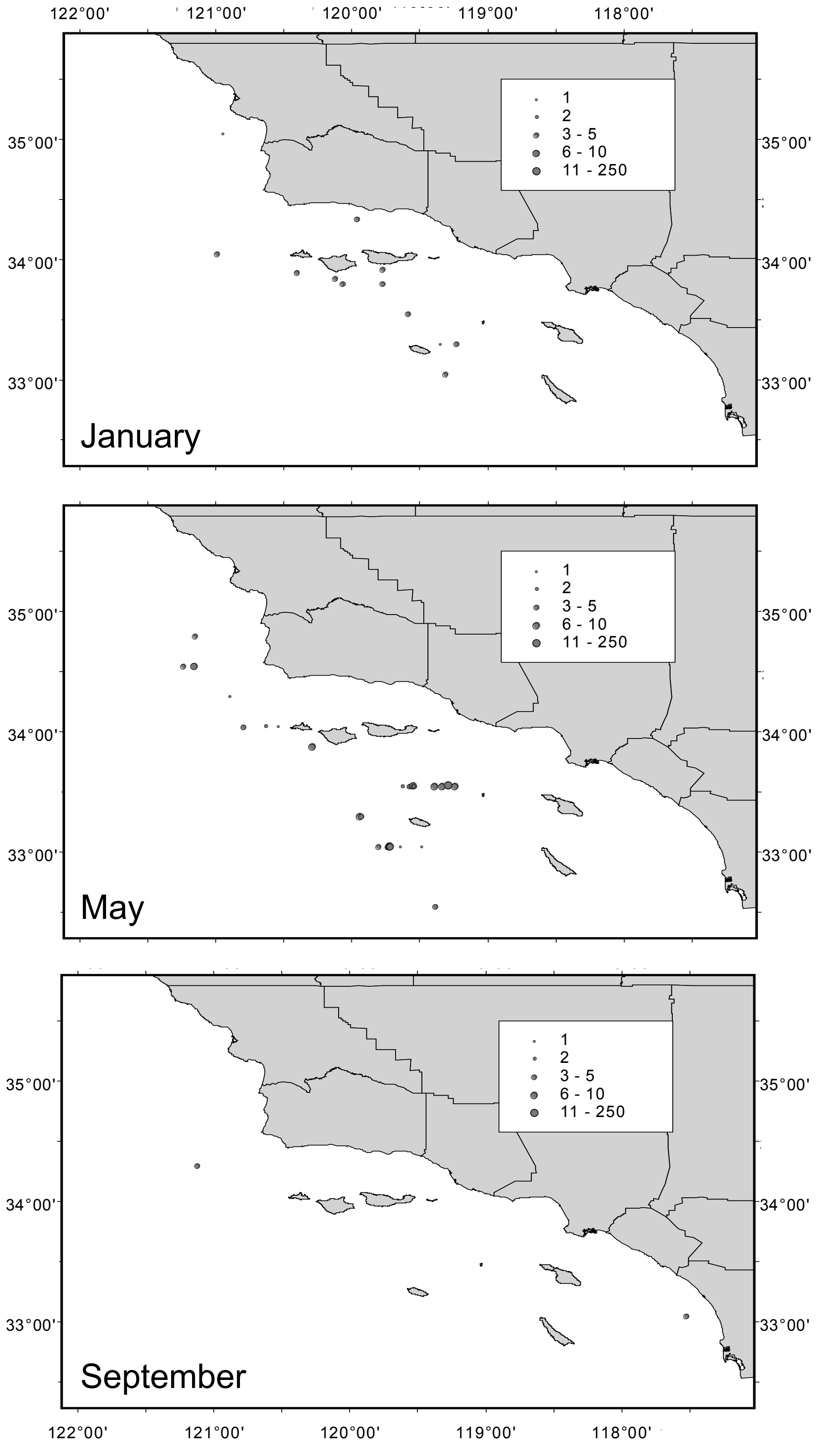


FIGURE 2.23. Sightings of northern right whale dolphins (*Lissodelphis borealis*) in the study area from 1999-2002 by survey month.

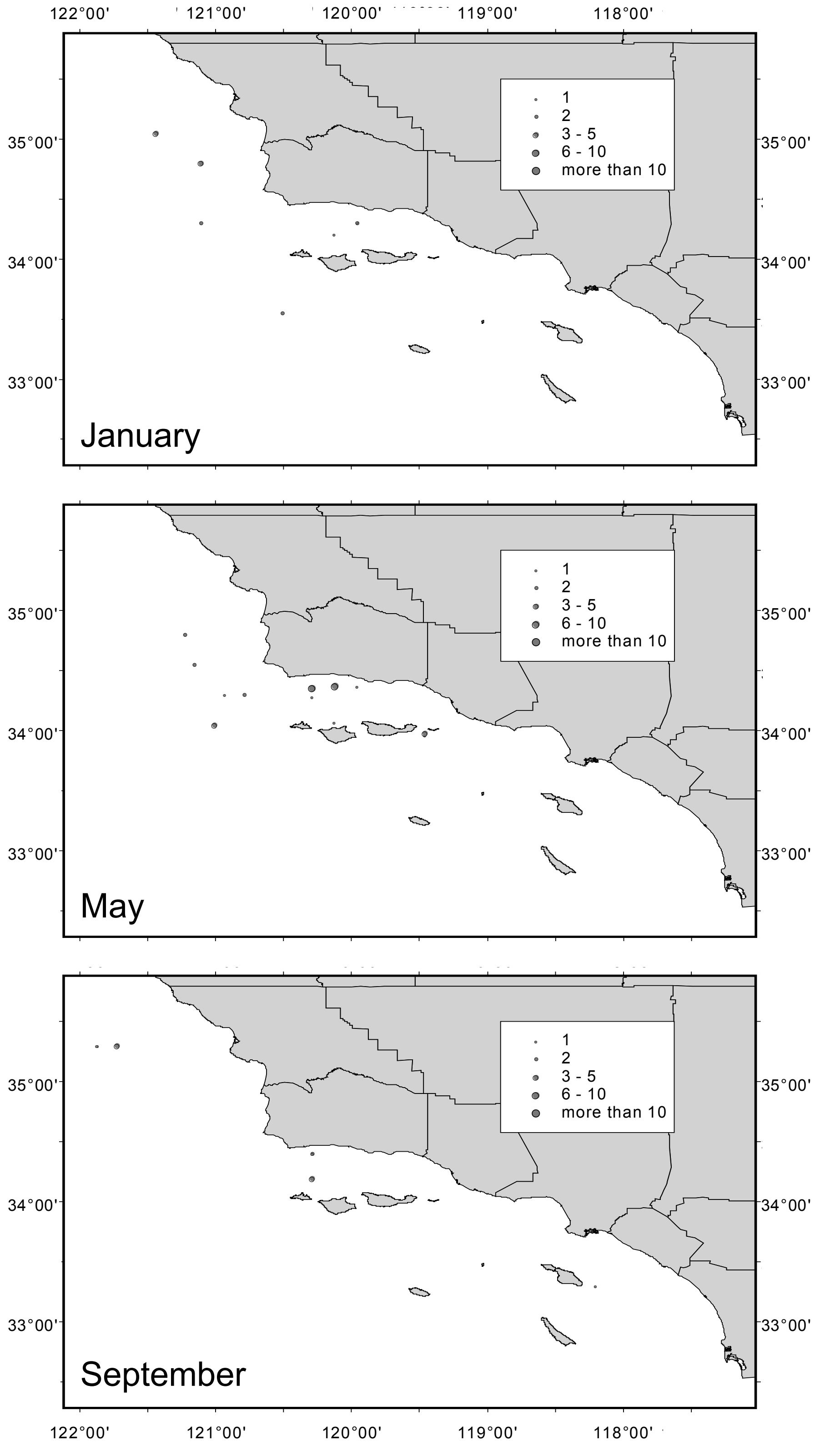


FIGURE 2.24. Sightings of Dall's porpoises (*Phocoenoides dalli*) in the study area from 1999-2002 by survey month.

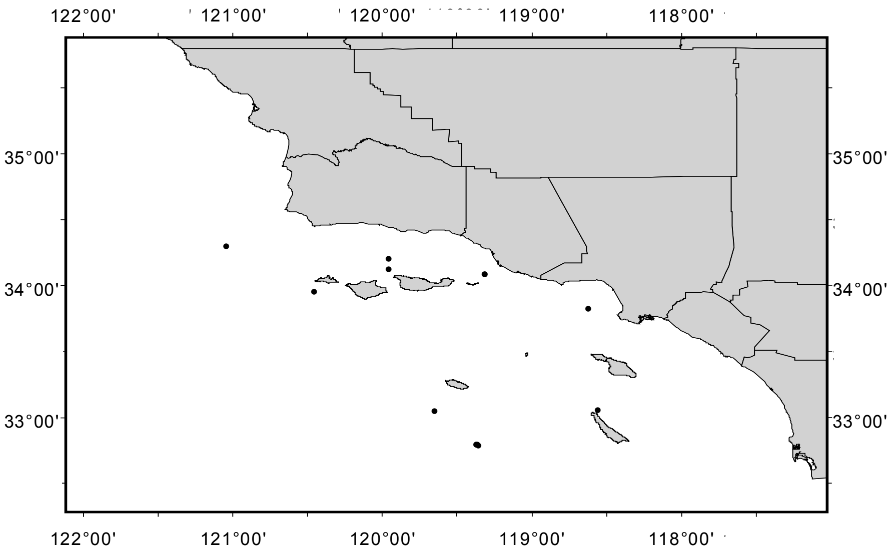


FIGURE 2.25. Sightings of killer whales (*Orcinus orca*) in the study area from 1999-2002.

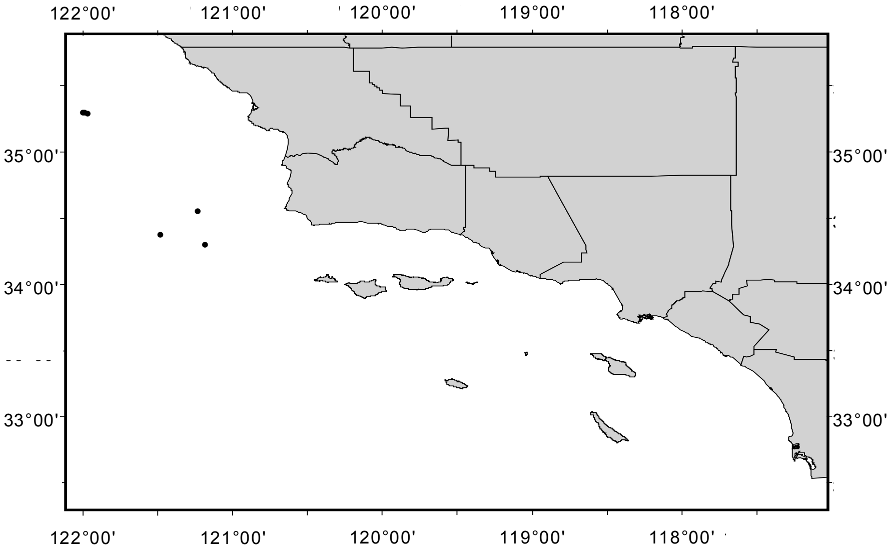


FIGURE 2.26. Sightings of sperm whales (*Physeter macrocephalus*) in the study area from 1999-2002.

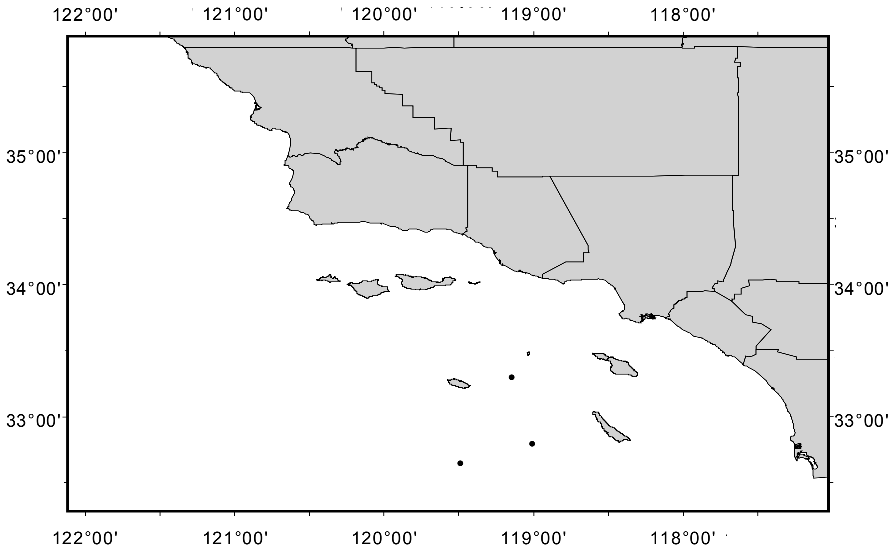


FIGURE 2.27. Sightings of Cuvier's beaked whales (*Ziphius cavirostris*) in the study area from 1999-2002.

CHAPTER 3:

FORAGING DISTANCE AND HOME RANGE OF CASSIN'S AUKLETS NESTING AT TWO COLONIES IN THE CALIFORNIA CHANNEL ISLANDS

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***Abstract*:** Few studies have examined the at-sea movements and foraging areas of breeding Alcidae throughout the chick-rearing period over multiple years and at different colonies simultaneously, yet this information is fundamental toward understanding a species' foraging ecology. We radio-marked 99 Cassin's Auklets (*Ptychoramphus aleuticus*) nesting at two colonies separated by 90 km in the California Channel Islands to quantify foraging distance, home range, and colony foraging areas during three consecutive breeding seasons. Locations of auklets from Prince Island (1999–2001) were aggregated north to northeast of the colony near the insular shelfbreak and in the western Santa Barbara Channel (SBC). Locations from Scorpion Rock (2000, 2001) were aggregated in two focal areas: the Anacapa Passage, a narrow inter-island passage adjacent to the colony, and over the southeastern SBC. Auklets generally foraged <40 km from both colonies in all years. At Prince Island, distance from colony was greater among females than males, especially during 2001 when females ranged farthest overall; the opposite trend was observed at Scorpion Rock. Significantly greater wind speeds near Prince Island compared with Scorpion Rock reduced foraging distances and affected distribution. Individual home ranges were largely variable (750 ± 944 km^2) and did not differ by year, colony, or sex. Colony foraging areas overlapped during 2000, but not during 2001. The Prince Island foraging area (1216 ± 654 km^2) was twice as large as the foraging area at Scorpion Rock (598 ± 204 km^2). Post-breeding auklets from both colonies dispersed from the SBC and were located near active upwelling centers along central California. Dispersal coincided with decreased upwelling off Point Conception and sea-surface warming throughout the SBC.

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Adams, J., J. Y. Takekawa, and H. R. Carter. Foraging distance and home range of Cassin's Auklets nesting at two colonies in the California Channel Islands. 2004. Pages 199–224 *in* Takekawa, J. Y., H. R. Carter, D. L. Orthmeyer, R. T. Golightly, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 309 pp.

INTRODUCTION

Seabird breeding strategies and foraging behaviors have evolved in response to the distribution and availability of prey surrounding suitable nesting areas when breeding adults have restricted movements at sea to coordinate nesting activities and share incubation and chick-rearing duties (Lack 1968). The foraging distances of breeding seabirds differ by orders of magnitude depending on species; wide-ranging pelagic albatrosses forage across ocean basins (Jouventin and Weimerskirch 1990), whereas neritic seabirds such as the Alcidae forage on aggregated prey near nest sites or breeding colonies (Gaston and Jones 1998). This plasticity in foraging distances among species makes seabirds convenient indicators of marine ecosystem productivity at multiple spatial scales (Cairns 1988, Monaghan et al. 1989, Croxall et al. 1999). The distribution of seabirds at sea can be used to identify important and productive marine areas (Nel et al. 2001). Furthermore, this information also provides insight regarding important oceanographic features that influence the distribution and abundance of lower-trophic level prey organisms such as zooplankton, and schooling fishes (Hunt et al. 1998). Ultimately, changes in prey dynamics within the foraging range can cause seabird population fluctuation by altering reproductive output (Ainley et al. 1995, Sydeman et al. 2001).

The foraging distances of alcids have traditionally been calculated by multiplying the duration of foraging trips by estimated flight speed, sometimes adjusted with activity budgets (Cairns et al. 1987, Falk et al. 2000, Benvenuti et al. 2001) or by recording the instantaneous distribution of birds at sea from ships (Hunt and Harrison 1990, Allen 1994, Oedekoven et al. 2001). Previous large-scale (100s km) aerial surveys of the distribution of seabirds only provided coarse information on distribution near nesting colonies during the breeding season (Briggs et al. 1981, 1987a). However, more recent studies with radio telemetry provided direct methods for measuring foraging distances (Ostrand et al. 1998, Whitworth et al. 2000a) and foraging areas among seabirds at breeding colonies.

The Cassin's Auklet (*Ptychoramphus aleuticus*) is one of five species of small planktivorous auklets endemic to the North Pacific Ocean, Bering and Okhotsk Seas (Gaston and Jones 1998). Parents depart their colony before dawn to forage for themselves and gather food for their young. Provisioning parents return to their colony after dark to deliver a partially digested meal to their nestling that may include crustaceans, larval to early-juvenile fishes, and squid (Manuwal and Thoresen 1993). Compared with alcids that perform multiple foraging trips per day, Cassin's Auklets (hereafter auklets) deliver only one meal per day and thus carry a greater relative mass burden (Gaston and Jones 1998). Auklets are wing-propelled divers and have attained a maximum recorded depth of 43 m, but spend most of their time underwater at depths <10 m (Burger and Powell 1990). With greater wing-loading (body mass-to-wing area) than other seabirds, alcids use energetically expensive flapping flight to travel between their colonies and foraging areas (Pennycuick 1987).

The diving behavior of alcids has exacted an evolutionary and energetic trade-off in their foraging capabilities during the breeding season. Therefore, parents provisioning nestlings should minimize foraging ranges and search areas by flying to nearest foraging areas with concentrated prey. This strategy allows parents to increase underwater foraging time, and maintain efficient use of patchy prey to maximize food delivery to developing nestlings. Because of large interannual variability in oceanographic conditions and fluctuating prey availability in the southern California Current System (CCS), foraging related movement parameters (distance and area) also should vary annually and between colonies with different marine environmental influences.

In this study, we used radio telemetry to measure foraging distance and home range, among individual auklets from two colonies in the northern Channel Islands, California. We also present a novel bootstrap method for quantifying colony foraging areas. In this analysis, we combined locations from all auklets at a specific colony to examine differences in foraging areas between a large and a small breeding colony, each located within areas of differing oceanographic conditions. In addition, we describe dispersal patterns of post-breeding auklets from both colonies.

METHODS

Study Area

We studied auklets nesting at two colonies separated by 90 km in the northern Channel Islands, California: Prince Island (hereafter Prince: 34º05′N, 120º20′W) and Scorpion Rock (hereafter Scorpion: 34º05' N, 119º30' W; Figure 3.1). Carter et al. (1992) estimated there were 8900 breeding auklets at Prince and 100 at Scorpion in 1991. The northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa) are located in the Southern California Bight and are separated from mainland California by the Santa Barbara Channel (SBC). The SBC is 100 km long and 40 km wide. The Santa Barbara Basin (500 m depth) is centrally located in the channel north of Santa Rosa Island. A shallow (<200 m depth) shelf, 3–10 km wide surrounds the four main islands. The islands are separated by narrow, shallow (40 m depth) passages. Prince (16 ha, 90 m elevation) is a steep-sided island flanked with loose soils, boulders, and many rocky crevasses located 2 km north of San Miguel Island. Surrounding waters are seasonally enriched by coastally upwelled waters from the region north of Point Conception that are advected into and recirculated within the SBC (Harms and Winant 1998; Figure 3.1). Scorpion (<1 ha, 15 m elevation) is a small, rocky islet topped with a mixture of loamy soil and guano, adjacent to the Anacapa Passage <1 km north of Santa Cruz Island. Scorpion is sheltered by the mainland from prevailing northwesterly winds during the spring and summer, and oceanographic influence from upwelling is more variable. During the spring and summer, ocean conditions near Scorpion generally are warmer and more stratified, whereas waters off Prince are cooler and more mixed.

Capture and Marking

During 1999–2001 at Prince, we captured and radio-marked 99 breeding auklets. Birds were captured at night by hand after they returned to previously marked nest sites. During 2000 and 2001 at Scorpion, we captured birds at night from artificial burrows located throughout the colony, from the surface of the ground, or with the aid of a nylon mist net (Avinet Inc., Dryden, New York). We attached radio transmitters (1999-2000: PD-2G, Holohil Systems Ltd., Carp, Ontario, Canada; 2001: #386, Advanced Telemetry Systems Inc. [ATS], Isanti, Minnesota, USA) with a life expectancy of 90 days to auklets dorsally between the scapulae (Newman et al. 1999) during late incubation or early chick rearing periods (Table 3.3.1). Transmitters with subcutaneous anchors and rear suture channels weighed 3 g (approximately 2% mean auklet mass = 164 ± 12 g, *n* = 128). Immediately after attachment, we returned birds to their nest sites or released them near the capture site if the nest location was unknown (Scorpion).

We banded auklets with U. S. Fish and Wildlife Service #3 leg bands and weighed them with a 300-g Pesola spring-scale (± 1.0 g). We measured bill depth perpendicular from the base of the gonys with calipers (± 0.1 mm). We assessed brood-patch feather development, and noted regurgitation of prey intended for chicks to help determine breeding status (Scorpion). To determine sex, we collected a drop of blood in a micro-capillary tube by pricking the auklet's tarsal vein with a sterile needle. Blood was stored in 70% ethanol and analyzed in a lab to determine sex using molecular techniques (Celera AgGen, Zoogen^{TM} sex analysis, Davis, California, USA). We determined sex of seven birds that we did not collect blood from by comparing bill depth between mated pairs; the bird with the greater measurement was classified as male (Nelson 1981). If we did not collect blood, and we lacked bill measurements from both members of a pair, we classified sex of the radio-marked parent as unknown.

Telemetry

We verified nightly colony visitation by radio-marked auklets with a radio receiver (ATS R-4000) linked to a data logger (ATS D5041). We used two H-antennas oriented toward the auklet colony on Prince and an omni-directional antenna placed in the center of the colony on Scorpion. Receivers were programmed to scan for each unique radio-frequency for 10 s every 10 min and the loggers stored frequency, year, Julian day, time-of-day, and number of pulses detected. Reference transmitters were placed at each colony to ensure that the system functioned properly. At Prince, the system failed to record data from 21 March to 16 April 1999 (26 days) after vandals removed the batteries. During this period, a researcher stationed on San Miguel Island monitored nightly colony attendance of radio-marked auklets with hand-held telemetry equipment.

During each breeding season, we surveyed for radio-marked auklets at sea during each consecutive nesting season, from 7 March to 24 June 1999, 12 April to 20 June 2000, and 6 April to 27 June 2001. Surveys were conducted on an average every two days (range = 1–8 days) with fixed-wing, twin-engine *Cessna* Skymaster 337 or *Partenavia* P-68 aircraft. To locate radio transmitters a maximum of once per day, we equipped survey aircraft with a receiver connected through a switch box to two wing-mounted 3- or 4-element directional Yagi-antennas (Gilmer et al. 1981). Observers scanned each frequency for 2 to 4 s, and determined locations by circling the loudest signal (Mech 1983). We recorded location coordinates from a GPS, time-of-day, signal strength, and signal direction. Survey speeds ranged from 220 to 260 km h^{-1} and tracking altitudes varied from 450 to 600 m. Survey patterns consisted of parallel track-lines spaced 7 to 20 km apart. The main survey coverage was concentrated over the SBC. Periodically, we flew wide-ranging surveys encompassing offshore waters from San Nicolas Island (33º30′N, 119º30′W) to Point Reyes (38º00′N, 123º00′W) to search for missing birds, dispersed post-breeders, and failed-breeders in previously documented auklet habitat (i.e., Santa Rosa Ridge, Point Buchon; Briggs et al. 1981; Figure 3.1). To obtain the maximum number of locations, we adjusted survey lines following results from previous surveys. Whitworth et al. (2000) reported location accuracy of 1 km with similar transmitters and tracking techniques. Because auklets engaged in bout-diving were occasionally difficult to locate by aircraft, we used the relationship between signal strength and location distance to reference transmitters located at each colony to adjust locations based on signal strength. For example, if the best detection for a radio-marked auklet was recorded as "weak" (12 km) toward the north, the radio-location was placed 12 km north of the aircraft.

We estimated effectiveness of our survey effort during regular nightly colony attendance before dispersal and documented radio failure as follows:

$$\%TL = \frac{L}{S} \times 100$$

where %TL is the percentage of the total potential locations, L is the number of individual locations obtained, and S is the number of survey days conducted after radio-marking, while the individual attended its colony, equivalent to the maximum possible number of locations. Weather conditions and military activities occasionally restricted survey flights from certain areas. We assumed that diurnal locations recorded at sea reflected the complete distribution of areas where auklets foraged because our island-based receiver indicated breeding adults usually spend the entire night attending the colony.

Sea-Surface Wind Measurements

Because auklets are small and use inefficient flapping-flight to commute between their colonies and offshore foraging areas, we were interested in measuring the effects of wind speed on foraging range and displacement (eastward and northward) of auklets from both colonies. Wind speed and direction were obtained from the National Data Buoy Center (NDBC; http://www.ndbc.noaa.gov/). We used continuous wind data collected on buoys located near the core auklet foraging areas. Buoy 46054, and buoy 46053 are located 34 km north from Prince, and 43 km northwest from Scorpion, respectively (Figure 3.1).

Statistical Analyses

We used a geographic information system (GIS; ArcView v. 3.2, ESRI Inc., Redlands, CA) to plot on maps the locations of 99 auklets with one or more locations per individual. We calculated distances from the colony to each radio-location and calculated vectors corresponding to eastward and northward displacement from each colony with MATLAB (functions distance.m and azimuth.m; The MathWorks, Inc., v. 5.3, Natick, MA). We analyzed three location parameters among individual auklets: mean distance from colony, maximum distance from colony, and individual home range area equivalent to the 100% minimum convex polygon (MCP) area. To standardize our comparisons to include only colony-restricted movement parameters, we restricted our analyses of foraging distance to a subset of at-sea locations from 83 radio-marked auklets (41 female, 39 male, and 3 of unknown sex) with ≥3 locations and with confirmed nightly attendance at Prince and Scorpion. Locations of auklets away from colonies >1 day were unusual and were removed from foraging range and home range analyses, and reported separately. Home ranges were calculated for 70 auklets (36 female, 32 male, and 2 of unknown sex) with ≥6 locations (ArcView GIS, Animal Movement extension v. 2.04; Hooge and Eichenlaub 1997).

We tested for differences in distances from the colonies ($\log_e$ transformation) by sex, colony, and year (2000, 2001) using a 3-factor ANOVA. Because we did not study auklets at Scorpion during 1999, distances for auklets from Prince in 1999–2001 were analyzed separately with a two-factor ANOVA (treatments: sex and year). We conducted a similar set of analyses to compare home ranges ($\log_e$ transformation). Because increasing number of locations can positively bias MCP area (Kernohan et al. 2001), we tested for collinearity with number of locations using GLM (Wilkinson and Coward 1996) prior to selecting ANOVA. Small sample size in 2001 at Scorpion prevented analysis of home range by sex, so we used a 2-factor ANOVA to test for differences by colony and year. We used Bonferroni multiple comparison tests to examine differences among groups with non-significant interaction terms.

We compared colony foraging areas with bootstrapping techniques (Kernohan et al. 2001). To generate multiple permutations of location sets equal to the number of radio-marked auklets, we designed a program (MATLAB; custom function MCP.m) that selected one location per auklet at random from the set of coordinates pooled among years for each colony. Unique MCPs were fit to the permuted sub-samples with the number of locations per MCP equal to the number of radio-marked auklets from Scorpion (n = 19). All auklets from Scorpion were used in the permutation, and to create an unbiased MCP for comparison with Prince (n = 80), the program randomly selected locations from 19 auklets from Prince. Permutations were repeated 500 times with replacement to build samples of random MCP areas for each colony. Areas were calculated (MATLAB; function convhull.m), and means were compared pair-wise using resampling (Resampling Stats, Inc., v. 5.0.2).

Daily wind speed (m s^{-1}) and direction (every 10 min from 07:00–18:00 PST) were averaged and compared between buoys, and among years and months with a 3-factor ANOVA. Meridional (***u***) and zonal (***v***) wind vectors were standardized by subtracting the mean of each divided by the standard deviation. We used principal components (PC) analysis to combine the vector components of wind speed, into a single component that represented northwesterly wind (i.e., blowing from the northwest). We then used linear regression to determine the relationship of PC1 to individual auklet distance (km, $\log_e$ transformed) and displacement from the two colonies. We assumed each daily auklet location was independent as auklets returned to their colony during each intervening night (see White and Garrott 1990). All statistical tests were performed with □□0.05 (SYSTAT, v. 10.0, SYSTAT Software, Inc., Richmond, CA). Means are reported throughout as ± SD.

RESULTS

Telemetry

During 331 hrs (N = 116 flights) of aerial surveying, 99 radio-marked auklets were located 1058 times at sea (Table 3.3.1). Observers detected each auklet at an average 12.7 ± 7.4 times, and individuals were located an average on 85 ± 14% of surveys during their period of nightly colony attendance (Table 3.3.1). Nesting auklets were located for a duration of 30.0 ± 20.4 days (Table 3.3.1). More locations were determined for individuals in 2000 than in 2001 and at Prince compared with Scorpion (Table 3.3.1). We detected no significant difference in the number of locations obtained for males and females ($F_{1,52} = 1.1$, $P = 0.31$); all interactions were non-significant.

In 1999, auklets continuously attended Prince on concurrent nights, although breaks in nightly attendance may have occurred while the remote telemetry system was not functioning. In 2000, we recorded 19 locations during breaks in nightly colony attendance (Prince: 13 locations, distance from colony = 23.1 ± 10.0 km, $n = 3$ auklets; Scorpion: six locations, distance from colony = 17.5 ± 14.4 km, $n = 2$ auklets). Similarly, we recorded eight locations during breaks in 2001 (Prince: three locations, 151.0 ± 90.2 km, $n = 3$ auklets; Scorpion: five locations, 115.2 ± 53.2 km, $n = 2$ auklets). The longest single-day movement recorded (178 km) was by a female that returned to Scorpion on 2 June 2001 after two consecutive days off Point Conception.

At-Sea Distribution

Auklets from both colonies foraged north of the northern Channel Islands in the SBC. Despite frequent survey coverage, auklets were rarely located south of the northern Channel

Islands. The overall distribution of auklets from both colonies indicated persistent (i.e., weeks to months) foraging areas occurred in each year near the colonies (<40 km). In all years, auklet locations from Prince were aggregated near the 200-m isobath, and in 2000 and 2001 auklets were located more frequently over the Santa Barbara Basin (Figures 3.2a–c). Auklet locations from Scorpion were aggregated in two areas: in the Anacapa Passage and northwest in the Santa Barbara Channel off Santa Cruz Island (Figures 3.2b–c).

Foraging Distances

Nesting auklets foraged <40 km from Prince and Scorpion in all years (Table 3.3.2). The frequency distributions in each year and at both colonies were skewed with peak distances from 10 to 15 km (Figure 3.4). In 2000 and 2001, distance from colony was not statistically different by year ($F_{1,52} = 3.7$, $P = 0.06$; Table 3.3.2), but the interaction between sex and colony was significant ($F_{1,52} = 8.8$, $P < 0.01$); the remaining interactions were all non-significant ($P > 0.05$). Therefore, to isolate the effect of colony on sex differences in foraging distance, we compared colonies independently with two-factor ANOVA. At Prince, distance differed among years ($F_{2,59} = 3.7$, $P = 0.03$; 1999 *vs.* 2000, $P = 0.05$), and females ranged farther than males ($F_{1,59} = 12.5$, $P = 0.001$; Table 3.3.2); the interaction between sex and year was not significant ($F_{2,59} = 2.6$, $P = 0.08$). At Scorpion, distance was not statistically different between years ($F_{1,11} = 1.0$, $P = 0.34$), or by sex ($F_{1,11} = 1.7$, $P = 0.22$; Table 3.3.2).

The maximum distance from Prince averaged 37 ± 19 km (range = 12–95) and 30 ± 20 km (range = 10–72 km) from Scorpion. Maximum distance was not different between 2000 and 2001 ($F_{1,52} = 2.4$, $P = 0.13$), and there was a significant interaction between sex and colony ($F_{1,52} = 6.5$, $P = 0.01$; Table 3.3.2). Females from Prince were located farther than females from Scorpion, whereas the distances of males from each colony did not differ. At Prince, maximum distance was not different among years ($F_{2,59} = 2.3$, $P = 0.11$), but differed by sex ($F_{1,59} = 4.3$, $P = 0.04$; Table 3.3.2) with a significant interaction ($F_{2,59} = 3.4$, $P = 0.04$; Table 3.3.2). In 1999, males flew slightly farther on average than females, but females ranged farthest overall in 2000 and 2001. At Scorpion, maximum distance was not statistically different between years ($F_{1,11} = 2.0$, $P = 0.18$) or between sexes ($F_{1,11} = 1.2$, $P = 0.29$; Table 3.3.2).

Individual Home Range and Colony Foraging Area

At Prince, individual home range was not different among years ($F_{2,49} = 2.1$, $P = 0.14$), or between sexes ($F_{1,49} = 3.6$, $P = 0.06$; Table 3.3.2), and the interaction was not significant ($F_{2,49} = 1.9$, $P = 0.16$). At Prince during 1999 and 2000, there were greater numbers of auklets with adequate samples to create MCPs ($F_{2,49} = 9.0$, $P < 0.001$; Table 3.3.1), yet in 2001, the year with the fewest locations per auklet had the largest home range (Table 3.3.2). At Scorpion, home range was not significantly different between years (2000 and 2001; ANCOVA, $F_{1,10} = 0.9$, $P = 0.37$). Home range did not differ between Prince and Scorpion (years and sexes combined and including unknown sex; $F_{1,68} = 1.7$, $P = 0.20$; Table 3.3.2). On the basis of the maximum foraging distance at each colony (37 km *vs.* 30 km), total circular foraging area would be 4300 km^2 at Prince and 2827 km^2 at Scorpion. Thus, on average individual auklets used 17% of the available area in their foraging range at Prince and 31% at Scorpion.

We detected interannual differences in area-overlap between the two colonies. In 2000, maximum area extent (single MCP with all locations pooled for each colony) for auklets from

Prince (6450 km^2) overlapped that of Scorpion (2349 km^2) by 24% (1550 km^2; Figure 3.2b). In contrast, colony foraging areas overlapped by <1% in 2001. Whereas we detected no differences in individual home range between colonies or among years, bootstrapped colony areas at Prince (1287 ± 665 km^2), were twice as large as those at Scorpion (518 ± 174 km^2: pair-wise resampling, $P < 0.01$).

Wind Speed and its Effect on Foraging Distance

We compared daily-averaged offshore wind speeds (April–June) between colonies (2000, 2001) and among years and months (Prince separately; Figure 3.3). During the two years when we located radio-marked auklets from both colonies, daily averaged wind speeds were significantly greater off Prince over the western SBC (Buoy 46054) than over the eastern SBC off Scorpion (Buoy 46053) (2000 and 2001: $F_{1,358} = 175.6$, $P < 0.001$). Wind speed was greater during April than May ($F_{2,361} = 4.0$, Bonferroni $P = 0.03$). Off Prince, wind speed was significantly different among years (1999–2001: Buoy 46054; $F_{2,264} = 5.50$, $P = 0.01$); we detected no difference among months ($F_{2,264} = 0.27$, p = 0.76), and the interaction was significant ($F_{4,264} = 6.11$, $P < 0.001$). PC1 explained 96% of the variance of vector components at Prince and 74% at Scorpion. At Prince, distance from the colony varied inversely with PC1 ($P < 0.001$, $r^2 = 0.04$). Wind speed was positively related to eastward displacement ($P < 0.001$, $r^2 = 0.04$) and negatively related to northward displacement ($P < 0.001$, $r^2 = 0.15$). In contrast, wind speed did not significantly affect distance from colony for birds marked on Scorpion ($P = 0.17$), and we found no statistical effect of wind speed on eastward or northward auklet displacement ($P = 0.57$, and 0.72, respectively).

Post-Breeding Dispersal

During 2000 and 2001, radio-marked auklets were located within 55 km of the coast north of Point Conception, at least as far as Point Reyes and the Farallon Islands (600 km north) after colony attendance had ceased. Dispersed auklets in 2000 and 2001 were located off Point Buchon, Point Sur, Point Año Nuevo, and Point Reyes, all near active upwelling centers (Figures 3.6a–d). During June 2000, 30% (3 of 10) of post-breeding auklets from Scorpion and 16% (5 of 31) of those from Prince were located north of Point Conception (Figures 3.6a, b). In 2001, 49% (18 of 37) of post-breeding auklets from Prince and 53% (10 of 19) of auklets from Scorpion were located north of Point Conception (Figures 3.6c, d). Auklets from Scorpion were first located within the core Prince foraging area from 22 May to 1 June 2000 and from 3 May to 20 June 2001, before leaving the SBC area. We did not survey for dispersed auklets outside the SBC area during 1999, but the absence of signals on the data logger at the colony and during surveys from late May through June indicated that birds had dispersed from the SBC area.

DISCUSSION

Our study provides the first extended observations of the distribution and movements at sea of individual radio-marked auklets throughout their provisioning period. Auklets foraged <40 km from their colonies, with subtle variation among years. Because predator-free islands, in the CCS are scarce, availability of nesting habitat is the main factor that determines the distribution of breeding auklets at sea (Briggs et al. 1987b, Allen 1994, Oedekoven et al. 2001). Secondarily, foraging ranges of auklets breeding in the CCS likely are determined by the proximity of colonies to persistent and aggregated concentrations of prey. This scenario is different from other regions such as the eastern Bering Sea, where island habitat is less limiting and variability in the sizes and distribution of auklet colonies results from the circulation of distinct, plankton-rich water masses (Springer and Roseneau 1985).

Oceanographic Features and Consistent At-Sea Distribution

Our results are similar to the distribution reported by Hunt et al. (1979) who used boat surveys conducted every 2 to 3 weeks during the nesting season (March to July) within 18 km of the island. However, ship-based surveys are limited by the length of the transects, incomplete knowledge of the colony origin, and nesting status of sighted auklets. During 1975–1977, auklets aggregated north and west of San Miguel Island with greatest numbers near the 200-m insular shelfbreak. Auklets were rarely observed south of San Miguel (Hunt et al. 1979), indicating that consistent prey resources exist within the SBC or that the colony location on the north side of the islands prevents birds from easily accessing waters to the south side. We found a low percentage of sightings in all years occurred west of San Miguel, with westward distribution most apparent during 2001. Auklets sighted to the west of San Miguel and reported by Hunt et al. (1979) likely included birds nesting five km west at Castle Rock, the second largest auklet in the Southern California Bight (Carter et al. 1992). Even though Prince and Castle Rock are separated by only a short distance, our results from Prince and Scorpion suggest that nearby colonies may have very distinct foraging areas.

The distribution of locations from both colonies revealed that auklets used areas with unique circulation and bathymetry. Frontal regions near islands and in island passes are important for seabirds that forage on euphausiids (Vermeer et al. 1987, Coyle et al. 1992, Decker and Hunt 1996). We suggest that the spatial and temporal persistence of auklets near the shelfbreak, northeast from Prince, resulted from predictable prey concentrated in this area. The combination of southward, near-surface currents flowing from the Point Conception upwelling region over shoaling bathymetry north of San Miguel and Santa Rosa Islands may cause spatially and temporally predictable fronts to occur along the shelfbreak, and these fronts may concentrate euphausiids (Fiedler et al. 1998). Additionally, differential horizontal advection of vertically migrating or surface-schooling euphausiids could trap these prey over the shallow shelf, thereby enhancing availability to foraging auklets (Genin et al. 1988, Hunt et al. 1996). Convergent fronts created by tidally-forced internal waves propagating toward the island chain also may concentrate prey above the thermocline during periods characterized by stratified ocean conditions (Kingsford and Choat 1986) as might occur during extended periods of post-upwelling relaxation and surface warming. Off British Columbia, greatest densities of auklets occurred at the shelfbreak and to a lesser degree over seamounts (Vermeer et al. 1985). Off central California, relatively stationary fronts oriented parallel to the shelfbreak (Schwing et al. 1991) were identified as important physical features influencing the at-sea distribution of auklets (Oedecoven et al. 2001).

Subtle shifts in auklet distribution occurred during May and June, 2000 and 2001. During these periods, auklets from both colonies ranged farther over the westcentral SBC, an area that is characterized by seasonal occurrence of cyclonic eddies (Harms and Winant 1998, Washburn et al. 2000), convergences associated with spiraling eddies (DiGiacomo and Holt 2001, Munk 2001), and downwelling along strong thermal boundaries separating distinct water masses (Breaker et al. 2003). These dynamic features influence the distribution, and transport of larval to early-juvenile fishes (Fortier et al. 1992, Logerwell and Smith 2001) and euphausiids (Huntley et al. 2000). Furthermore, Nishimoto and Washburn (2002) documented significantly greater concentrations of juvenile rockfish (*Sebastes* spp.) near the surface within the center of a persistent cyclonic eddy located in the western SBC. Pelagic larval and juvenile rockfish are an important auklet prey item at Prince (Adams et al. unpublished data), and the aggregation within the core foraging area highlights the importance of these features to auklets.

Auklets from Scorpion used two areas near their colony: the Anacapa Passage and the southeastern SBC. The mechanisms that cause auklets to shift between these two areas probably are related to variability in the supply of cool, nutrient enriched water and associated prey to areas within the foraging range of provisioning adults. During the first half of April 2000, satellite derived AVHRR sea-surface temperature images (http://coastwatch.pfel.noaa.gov, not shown) revealed an extensive tongue of cool water that extended along the southern SBC east to Anacapa Island. This typical seasonal feature is consistent with "upwelling" flow described by Oey et al. (2001). Cool surface temperatures persisted through mid June 2000 (Figure 3.6b) and may have influenced the movements of auklets as they sought prey affiliated with these types of water masses (Brinton 1981). A similar movement response was reported by Briggs et al. (1988) who detected a rapid shift in the at-sea distribution of Cassin's Auklets observed from ship as birds apparently tracked the formation of a cool upwelling filament near the Farallon Islands. Least Auklets (*Aethia pusilla*) also were observed to shift foraging areas in response to altered circulation and prey abundance near their colonies (Hunt and Harrison 1990). Upwelling flow was reduced in 2001, and the waters surrounding Scorpion were 3–4°C warmer during the same time period (Figures 3.6c, d). During these conditions auklets may take advantage of tide-forced fronts in the vicinity of the Anacapa Passage, where currents can approach 50 cm s^{-1}, four times stronger than currents over the offshore basins (Hickey 1993).

Factors Effecting Foraging Distance

Foraging range of seabirds is determined by physical ability, energetic demands, and distance to profitable foraging areas from nest sites. During the breeding season, seabird parents must balance the food requirements of nestlings with the maintenance of their own body condition, and therefore they may adjust their foraging distances accordingly (Weimerskirch 1998). In addition, abiotic factors such as wind also can affect flight behavior (Spear and Ainly1997a), flight speed (Spear and Ainley 1997b), foraging (Stienen et al. 2000), and colony attendance (Ojowski et al. 2001). Auklets nesting on Prince were located perpendicular to prevailing winds with respect to the colony location, but auklets nesting at Scorpion often were located in areas both upwind and downwind from their colony. At Prince where winds were twice as strong as winds at Scorpion, we detected a significant relationship between wind speed and distance from colony. However, only a low amount of variability (4–15%) was explained, indicating that wind has only a small effect on foraging distance at this site. Auklet movements appear relatively unaffected by typical wind speeds over their foraging area, and certainly other factors such as the distribution of prey resources and location of important habitat features in relation to their colony likely determine foraging distance. For example, telemetry studies on slightly larger Marbled Murrelets (*Brachyramphus marmoratus*) also revealed that birds typically forage within 40 km of their nest sites (Hull et al. 2001). In southeast Alaska, however, Whitworth et al. (2000b) repeatedly located radio-marked murrelets 75 km from nest sites in an area subjected to enhanced tidal mixing and increased prey availability.

The only comparable radio telemetry data on foraging distance of Cassin's Auklets, however, were based on two aerial surveys each during 1999 and 2000 in which radio-marked auklets breeding at Triangle Island, British Columbia, were located 30 to 60 km from their colony (Ryder et al. 2001). This is two- to four-times the foraging distance measured in our study, and likely resulted in part from differences in the availability or energetic quality of prey consumed by auklets at the two sites. Cassin's Auklets at Triangle Island fed predominantly on *Neocalanus spp.* copepods (Hedd et al. 2002), which may have occurred at greater abundance farther from the colony. *Neocalanus spp*. copepods are more energy dense than the euphausiid and fish prey also taken off British Columbia (Hedd et al. 2002), and predominantly by auklets off southern California (Adams et al. unpublished data). Furthermore, dense aggregations of slow-swimming copepods may be easier to capture. Obst et al. (1985) found that Least Auklets breeding at St. Lawrence Island flew 56 km to waters possessing more energy-dense prey (*Neocalanus spp.*), whereas those breeding at St. Matthew Island ranged only 5 km to forage on abundant prey of lower energetic quality (*Calanus marshallae*). Despite extreme differences in foraging range, energetic expenditure between provisioning adults at both colonies was similar indicating that increased flight cost was offset by reduced foraging cost (Obst et al. 1995).

There are no measurements of the at-sea activity budgets among auklet species for estimating foraging ranges, but there are data for several larger alcids. Breeding Common Murres (*Uria aalge*) outfitted with activity loggers spent 10% of their time at sea in flight (Cairns et al. 1987). Razorbills (*Alca torda*), spend 12% of their time flying and have a potential foraging range of 35 km based on foraging trip durations and flight speed; away from the colony they make a series of short flights punctuated by brief stops en route to foraging areas, and generally uninterrupted return flights (Benvenuti et al. 2001). Assuming a constant crosswind flight speed of 45 km h^{-1} (Spear and Ainley 1997b) and 17-hr period at sea (J. Adams unpublished data), an auklet flying 10% of the time would have a maximum foraging radius of 38 km, very close to the average maximum foraging distance that we determined for auklets (30–37 km). If auklets use a similar foraging strategy, they could maximize time spent foraging on patchily distributed prey by reducing their foraging range and prey-searching movements.

Our results at Prince demonstrated differences in foraging distances of male and female auklets. Females increased their mean foraging distance from 1999 through 2001, whereas male foraging distance remained consistent. Differences became pronounced in 2000 and especially 2001, with females were located 10 km farther than males with a maximum difference of 24 km. Differential reproductive costs (Chappel et al. 1993) and parental roles in provisioning might create differences in foraging strategies between the sexes (Fraser et al. 2002). Females may require different food resources that are available to them at a greater distance from the colony in certain years, or males may provision chicks with more food than females thus benefiting from a shorter foraging distance. For example, Fraser et al. (2002) found that female Crested Auklets (*Aethia cristatella*) provisioned nestlings with a greater proportion of copepods than males, which took more euphausiids perhaps because the two sexes might forage in different areas, depths, or time-of-day. Alternatively, females may deliver more copepods because they are presumably easier to capture than euphausiids or they satisfy different nutritional needs. Male Dovekie (*Alle alle*) provisioned chicks more often and spent more time at the colony than females during the late chick-rearing period (A. M. A. Harding, T. I. Van Pelt, J. T. Lifjeld, and F. Mehlum, unpublished data), and male Marbled

Murrelets visited nests more often than females during the latter half of chick-rearing (Bradley et al. 2002). Female Cassin's Auklets may need to seek more distant foraging areas to replenish body stores associated with reproductive costs (i.e., egg formation), whereas males may contribute more food to nestlings.

Individual Home Range, Colony Foraging Area, and Area Overlap

Auklets at Prince returned to similar locations throughout their tracking period and thus did not increase their home range. In contrast, auklets from Scorpion increased their home ranges with additional locations. Positive bias with increasing number of locations among individuals at Scorpion indicated that auklets at this colony experienced a more variable foraging environment compared with auklets from Prince. Whereas individual home range was not different among years or between colonies, resulting in part from large variability among individuals, we were able to detect significant differences in colony foraging area with our bootstrap technique. Because bootstrapping draws a random set of independent locations (one location per individual bird) with a fixed sample size from the entire location data set, it is a useful method for measuring and comparing foraging areas at specific colonies. The greater colony foraging area off Prince compared with Scorpion, indicates that prey resources can occur over a wider area within the auklets' foraging range off Prince, however, at Scorpion, parents rely on resources that are aggregated within more fixed areas (e.g., the Anacapa Passage).

During 2000, the spatial overlap in colony foraging areas was disjunct in time. Whereas auklets from Prince ranged eastward into the overlap area during late April to early May before returning to their core foraging area north of San Miguel and Santa Rosa Islands, auklets from Scorpion foraged westward approximately one month later, primarily during late May to early June after a period of concentrated foraging in the Anacapa Passage. Although we did not measure changes in the temporal distribution of auklet prey, the timing either indicated transport of prey through the channel from west to east, or decreased availability of prey in the Anacapa Passage. Non-overlap in the foraging areas of the two colonies in 2001 can be explained by the reliance of auklets from Scorpion on the Anacapa Passage during a period influenced less by advection of cool water upwelled north of Point Conception (Figure 3.6c, d); coupled with the observation of auklets from Prince foraging toward the north and northwest.

Post-Breeding Dispersal To Areas off Central California

Cassin's Auklet has an extended wing-molt coincident with the breeding season that allows them to retain the ability to fly, thus enabling them to disperse widely in response to changing prey conditions. The timing of auklet nest initiation is thought to coincide with changes in prey availability associated with the spring transition to upwelling (Ainley et al. 1990, 1996), however, factors affecting the post-breeding dispersal away from colonies are less well understood. Information regarding the timing and post-breeding dispersal patterns of auklets was only generally inferred from the timing of fledging and from aerial surveys (e.g., Briggs et al. 1987). Based on observations at sea, and year-round colony attendance patterns at the Farallon Islands, Manuwal (1974) and Ainley et al. (1990) suspected that nesting birds remained off central California after breeding. Similarly, Briggs et al. (1981) recorded small numbers at scattered locations throughout the Southern California Bight during winter. Farther north, the occurrence of auklets over the shelf between Point Sur and Point Conception was described as primarily an autumn through late-winter phenomenon (Briggs et al. 1981);

however, Briggs et al. (1987b) observed "thousands" of auklets concentrated off Point Sur in early June 1985. Based on our observations of radio-marked auklets rapidly dispersing north after breeding, these auklets could have been birds that had dispersed from southern California. The post-breeding dispersal of auklets during May and June of 2000 and 2001, coincided with a decrease in upwelling-favorable winds off Point Conception, and subsequent relaxation and increased surface warming of SBC waters (Figures 3.6b–d). Post-breeding auklets from Scorpion were located in the core foraging area off Prince during May–June 2000 and 2001, before dispersing north along the central California Coast indicated that favorable foraging conditions persisted for longer off Prince in the western SBC. This general pattern of birds moving west is consistent with the seasonal intrusion of warmer, more stratified, and less productive water that enters the SBC from the east as upwelling flow relaxes in the west (Harms and Winant 1998).

Changes in Cassin's Auklet diet, distribution at sea, and population numbers, likely reflect changes in oceanographic conditions within colony-specific foraging ranges (Ainley et al. 1990, 1996). Our findings indicate that auklets nesting in the California Channel Islands make use of seasonally aggregated prey resources near their colonies and that these resources occur in predictable areas from year to year. When these resources become unavailable to auklets later in the summer coincident with changing oceanographic conditions, birds move to productive regions located near active upwelling centers along central California. Future studies that combine assessments of foraging behavior with prey dynamics will help to elucidate critical ocean features that affect foraging Cassin's Auklets breeding in the California Channel Islands and elsewhere.

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LITERATURE CITED

AINLEY, D. G., R. J. BOEKELHEIDE, S. H. MORRELL, AND C. S. STRONG. 1990. Cassin's Auklet, p. 307–338. *In* D. g. Ainley and R. J. Boekelheide [eds.], Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling-system community. Stanford University Press, Stanford, California.

AINLEY, D. G., W. J. SYDEMAN, AND J. NORTON. 1995. Upper trophic level predators indicate interannual negative and positive anomalies in the California Current food web. Marine Ecology Progress Series 118:69–79.

AINLEY, D. G., L. B. SPEAR, AND S. G. ALLEN. 1996. Variation in the diet of Cassin's Auklet reveals spatial, seasonal, and decadal occurrence patterns of euphausiid off California, USA. Marine Ecology Progress Series 137:1–10.

ALLEN, S. G. 1994. The distribution and abundance of marine birds and mammals in the Gulf of the Farallones and adjacent waters, 1985–1992. PhD dissertation, University of California, Berkeley.

BENVENUTI, S., L. DALL'ANTONIA, AND P. LYNGS. 2001. Foraging behaviour and time allocation of chick-rearing razorbills *Alca torda* at Græsholmen, central Baltic Sea. Ibis 143:402–412.

BRADLEY, R. W., L. A. MCFARLANE TRANQUILLA, B. A. VANDERKIST, AND F. COOKE. 2002. Sex differences in nest visitation by chick-rearing Marbled Murrelets. Condor 104:178–183.

BREAKER, L. C., GEMMILL, W. H., AND DEWITT, P.W. 2003. A curious relationship between the winds and currents at the western entrance of the Santa Barbara Channel. Journal of Geophysical Research-Oceans 108 (C5): article no. 3132.

BRIGGS, K. T., E. W. CHU, D. B. LEWIS, W. B. TYLER, R. L. PITMAN, AND G. L. HUNT, JR. 1981. Final Report: Summary of Marine Mammal and Seabird Surveys of the Southern California Bight Area 1975–1978. Volume III: Investigators Reports. Part III. Seabirds Book I, Chapter I. Distribution, Numbers, and Seasonal Status of Seabirds of the Southern California Bight. Unpublished report, University of California, Institute of Marine Sciences, Santa Cruz, California.

BRIGGS, K. T., D. G. AINLEY, D. R. CARLSON, D. B. LEWIS, W. B. TYLER, L. B. SPEAR, AND L. A. FERRIS. 1987a. California Seabird Ecology Study. Volume I: Feeding ecology of California nesting seabirds. Unpublished report, University of California, Institute of Marine Sciences, Santa Cruz, CA.

BRIGGS, K. T., W. B. TYLER, D. B. LEWIS, AND D. R. CARLSON. 1987b. Bird communities at sea off California: 1975–1983. Studies in Avian Biology 11. 74 pp.

BRIGGS, K. T., D. G. AINLEY, L. B. SPEAR, P. B. ADAMS, AND S. E. SMITH. 1988. Distribution and diet of Cassin's Auklet and Common Murre in relation to central California upwellings. Acta XIX Congressus Internationalis Ornithologici, Ottawa, Canada Vol. 1:982–990.

BRINTON, E. 1981. Euphausiid distributions in the California Current during the warm winter-spring of 1977-78, in the context of a 1949-1966 time series. California Cooperative Oceanographic Fisheries Investigation Reports Vol. 22:135–154.

BURGER, A. E., AND D. POWELL. 1990. Diving depths and diets of Cassin's Auklet at Reef Island, British Columbia. Canadian Journal of Zoology 68:1572–1577.

CAIRNS, D. K., K. A. BREDIN, AND W. A. MONTEVECCHI. 1987. Activity budgets and foraging ranges of breeding Common Murres. Auk 104:218–224.

CAIRNS, D. K. 1988. Seabirds as indicators of marine food supplies. Biological Oceanography 5(4):261–271.

CARTER H. R., G. J. MCCHESNEY, D. L. JAQUES, C. S. STRONG, M. W. PARKER, J. E. TAKEKAWA, D. L. JORY, AND D. L. WHITWORTH. 1992. Breeding populations of seabirds in California, 1989–1991. Unpublished Draft Final Report, U. S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California.

CHAPPEL, M. A., D. N. JANES, V. H. SHOEMAKER, T. L. BUCHER, AND S. K. MALONEY. 1993. Reproductive effort in Adélie penguins. Behavioral Ecology and Sociobiology 33:173–182.

COYLE, K. O., G. L. HUNT JR., M. B. DECKER, AND T. J. WEINGARTNER. 1992. Murre foraging on epibenthic sound scattering and tidal advection over a shoal near St. George Island, Bering Sea. Marine Ecology Progress Series 83:1–14.

CROXALL, J. P., K. REID, AND P. A. PRINCE. 1999. Diet, provisioning and productivity responses of marine predators to differences in availability of Antarctic krill. Marine Ecology Progress Series 177:115–131.

DECKER, M. B., AND G. L. HUNT JR. 1996. Foraging by Murres (*Uria* spp.) at tidal fronts surrounding the Pribilof Islands, Alaska, USA. Marine Ecology Progress Series 139:1–10.

DIGIACOMO, P. M., AND B. HOLT. 2001. Satellite observations of small coastal ocean eddies in the Southern California Bight. Journal of Geophysical Research-Oceans 106 (C10):22521–22543.

FALK, K., S. BENVENUTI, L. DALL'ANTONIA, K. KAMPP, AND A. RIBOLINI. 2000. Time allocation and foraging behaviour of Brünnich's guillemots *Uria lomvia* in High-Arctic Greenland. Ibis 142:82–92.

FIEDLER, P. C., S. B. REILLY, R. P. HEWITT, D. DEMER, V. A. PHILBRICK, S. SMITH, W. ARMSTRONG, D. A. CROLL, B. T. TERSHY, AND B. R. MATE. 1998. Blue whale habitat and prey in the California Channel Islands. Deep-Sea Research II 45:1781–1801.

FORTIER, L, M. E. LEVASSEUR, R. DROLET, AND J. C. THERRIAULT. 1992. Export production and the distribution of fish larvae and their prey in a coastal jet frontal region. Marine Ecology Progress Series 85:203–218.

FRASER, G. S., I. L. JONES, AND F. M. HUNTER. 2002. Male-female differences in parental care in monogamous Crested Auklets. Condor 104:413–423.

GASTON A. J., AND I. L. JONES. 1998. The Auks: Alcidae. Oxford University Press Inc., New York, NY.

GENIN, A, L. HAURY, AND P. GREENBLATT. 1988. Interactions of migrating zooplankton with shallow topography: predation by rockfishes and intensification of pachiness. Deep–sea Research 35(2):151–175.

GILMER, D. S., L. M. COWARDIN, R. L. DUVAL, L. M. MECHLIN, C. W. SHAIFFER, AND V. B. KUECHLE. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies.

United States Department of the Interior, Fish and Wildlife Service, Resource Publication 140, Washington, D. C. 19 p.

HARMS, S., AND C. D. WINANT. 1998. Characteristic patterns of the circulation in the Santa Barbara Channel. Journal of Geophysical Research 103:3041–3065.

HEDD A., J. L. RYDER, L. L. COWEN, AND D. F. BERTRAM. 2002. Inter-annual variation in the diet, provisioning and growth of Cassin's auklet at Triangle Island, British Columbia: responses to variation in ocean climate. Marine Ecology Progress Series 229:221–232.

HICKEY, B. M. 1993. Physical Oceanography. *In* M. D. Dailey, D. J. Reish, and J. W. Anderson [eds.], Ecology of the Southern California Bight: a synthesis and interpretation. University of California Press, Berkeley, California. pp. 19–70.

HOOGE, P. N., AND B. EICHENLAUB. 1997. Animal movement extension to ArcView. Ver. 2.04. Alaska Biological Science Center, USGS, Anchorage, AK.

HULL, C.L., G. W. KAISER, C. LOUGHEED, L. LOUGHEED, S. BOYD, AND F. COOKE. 2001. Intraspecific variation in commuting distance of Marbled Murrelets (*Brachyramphus marmoratus*): Ecological and energetic consequences of nesting further inland. Auk 118(4):1036–1046.

HUNT, G. L., JR., R. L. PITMAN, M. NAUGHTON, K. WINNET, A. NEWMAN, P. R. KELLY, AND K. T. BRIGGS. 1979. Summary of marine mammal and seabird surveys of the southern California Bight area 1975–1978. Volume III: investigators reports. Part III. Seabirds. Book II. Reproductive ecology and foraging habits of breeding seabirds. Unpublished report, University of California, Institute of Marine Sciences, Santa Cruz, California.

HUNT, G. L. JR., AND N. M. HARRISON. 1990. Foraging habitat and prey taken by least auklets at King Island, Alaska. Marine Ecology Progress Series 65:141–150.

HUNT, G. L. JR., K. O. COYLE, S. HOFFMAN, M. DECKER, AND E. N. FLINT. 1996. Foraging ecology of Short–tailed Shearwaters near the Pribilof Islands, Bering Sea. Marine Ecology Progress Series 141:1–11.

HUNT, G. L. JR., R. W. RUSSEL, K. O. COYLE, T. WEINGARTNER. 1998. Comparative foraging ecology of planktivorous auklets in relation to ocean physics and prey availability. Marine Ecology Progress Series 167: 241–259.

HUNTLEY, M. E., A. GONZALEZ, Y. ZHU, M. ZHOU, AND X. IRIGOIEN. 2000. Zooplankton dynamics in a mesoscale eddy-jet system off California. Marine Ecology Progress Series 201:165–178.

JOUVENTIN, P., AND H. WEIMERSKIRCH. 1990. Satellite tracking of Wandering Albatrosses. Nature (343):746–748.

KERNOHAN, B. J., R. A. GITZEN, AND J. J. MILLSPAUGH. 2001. Analysis of animal space use and movements. p. 125–166. *In* J. J. Millspaugh and Marzluff [eds.], Radio Tracking and Animal Populations. Academic Press, San Diego, CA.

KINGSFORD, M. J., AND J. H. CHOAT. 1986. Influence of surface slicks on the distribution and onshore movements of small fish. Marine Biology 91:161–171.

LACK, D. 1968. Ecological Adaptations for Breeding in Birds. Methuen, London.

LOGGERWELL, E. A., AND P. E. SMITH. 2001. Mesoscale eddies and survival of late stage Pacific sardine (*Sardinops sagax*) larvae. Fisheries Oceanography 10(1):13–25.

MANUWAL, D. A. 1974. The natural history of Cassin's Auklet (*Ptychoramphus aleuticus*). Condor 76:421–431.

MANUWAL, D. A., AND A. C. THORESEN. 1993. Cassin's Auklet (*Ptychoramphus aleuticus*). *In* A. Poole and F. Gill [eds.], The Birds of North America, No. 50. 16 p.

MECH, L. D. 1983. Handbook of animal radio–tracking. University of Minnesota Press, Minneapolis, MN. pp. 61–70.

MONAGHAN, P., J. D. UTTLEY, AND J. D. OKILL. 1989. Terns and sandeels: seabirds as indicators of changes in marine fish populations. Journal of Fish Biology 35 (Suppl. A):339–340.

MUNK, W. 2001. Spirals on the sea. Scientia Marina 65 (Suppl. 2):193–198.

NEL, D. C., J. R. E. LUTJEHARMS, E. A. PAKHOMOV, I. J. ANSORGE, P. G. RYAN, N. T. W. KLAGES. 2001. Exploitation of mesoscale oceanographic features by Grey-headed Albatross *Thalassarche chrysostoma* in the southern Indian Ocean. Marine Ecology Progress Series 217:15–26.

NELSON, D. A. 1981. Sexual differences in measurements of Cassin's Auklet. J. Field Ornith. 52:233–234.

NEWMAN, S. H., J. Y. TAKEKAWA, D. L. WHITWORTH, AND E. BURKETT. 1999. Subcutaneous anchor attachment increases retention of radio transmitters on Xantus' and Marbled Murrelets. Journal of Field Ornithology 70(4):520–534.

NISHIMOTO, M. M., AND L. WASHBURN. 2002. Patterns of coastal eddy circulation and abundance of pelagic juvenile fish in the Santa Barbara Channel, California, USA. Marine Ecology Progress Series 241:183–189.

OBST, B. S., R. W. RUSSELL, G. L. HUNT, JR., Z. A. EPPLEY, AND N. M. HARRISON. 1995. Foraging radii and energetics of Least Auklets (*Aethia pusilla*) breeding on three Bering Sea islands. Physiological Zoology 68(4): 647–672.

OEDEKOVEN, C. S., D. G. AINLEY, AND L. B. SPEAR. 2001. Variable responses of seabirds to change in the marine climate: California Current, 1985–1994. Marine Ecology Progress Series 212:265–281.

OEY, L-Y., D. P. WANG, T. HAYWARD, C. WINANT, AND M. HENDERSHOTT. 2001. "Upwelling" and "cyclonic" regimes of the near-surface circulation in the Santa Barbara Channel. Journal of Geophysical Research 106 (C5):9213–9222.

OJOWSKI, U., C. EIDTMANN, R. W. FURNESS, AND S. GARTHE. 2001. Diet and attendance of incubating and chick-rearing northern fulmars (*Fulmarus glacialis*) in Shetland. Marine Biology 139(6):1193–1200.

OSTRAND, W. D., G. S. DREW, R. M. SURYAN, AND L. L. MCDONALD. 1998. Evaluation of radio–tracking and strip transect methods for determining the foraging ranges of Black–legged Kittiwakes. Condor 100:709–718.

PENNYCUICK, C. J. 1987. Flight of auks (Alcidae) and other northern seabirds compared with southern Procellariiformes: ornithodolite observations. Journal of Experimental Biology 128: 335–48.

RYDER, J. L., W. S. BOYD, S. G. SHISKO, AND D. F. BERTRAM. 2001. At–sea foraging distributions of radio–marked Cassin's Auklets breeding at Triangle Island, B.C., 2000. Technical Report Series No. 368 Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.

SCHWING, F. B., D. M. HUSBY, N. GARFIELD, AND D. E. TRACY. 1991. Meso–scale oceanic response to wind events off Central California in spring 1989: CTD surveys and AVHRR imagery. California Cooperative Oceanic Fisheries Investigations Report 32:47–64.

SPEAR, L. B., AND D. G. AINLEY. 1997a. Flight behaviour of seabirds in relation to wind direction and wing morphology. Ibis 139:221–233.

SPEAR, L. B., AND D. G. AINLEY. 1997b. Flight speed of seabirds in relation to wind speed and direction. Ibis 139:234–251.

SPRINGER, A. M., AND D. G. ROSENEAU. 1985. Copepod-based food webs: auklets and oceanography in the Bering Sea. Marine Ecology Progress Series 21:229–237.

STIENEN, E. W. M., P. W. M. VAN BEERS, A. BRENNENKMEIJER, J. M. P. M. HABRAKEN, M. H. J. E. RAAIJMAKERS, AND P. G. M. VAN TIENEN. 2000. Reflections of a specialist: Patterns in food provisioning and foraging conditions in sandwich terns *Sterna sandvicensis*. Ardea 88(1):33–49.

SYDEMAN, W. J., M. M. HESTER, J. A. THAYER, F. GRESS, P. MARTIN, AND J. BUFFA. 2001. Climate change, reproductive performance and diet composition of marine birds in the southern California Current system, 1969–1997. Progress in Oceanography 49:309–329.

VERMEER, K., J. D. FULTON, AND S. G. SEALY. 1985. Differential use of zooplankton prey by Ancient Murrelets and Cassin's Auklets in the Queen Charlotte Islands. Journal of Plankton Research 7(4):443–459.

VERMEER, K., I. SZABO, AND P. GREISMAN. 1987. The relationship between plankton–feeding Bonaparte's and Mew Gulls and tidal upwelling in Active Pass, British Columbia. Journal of Plankton Research 9(3):483–501.

WASHBURN, L., B. M. EMERY, AND J. D. PADUAN. 2000. The surface circulation of the Santa Barbara Channel as observed with high frequency radar. *In* D. R. Browne, K. L. Mitchell, and H. W. Chaney [eds.], Proceedings of the fifth California Islands symposium, 29 March to 1 April 1999. U.S. Mineral Management Service, Camarillo, CA [Available on CD–ROM].

WEIMERSKIRCH, H. 1998. How can a pelagic seabird provision its chick when relying on a distant food resource? Cyclic attendance at the colony, foraging decision and body condition in sooty shearwaters. Journal of Animal Ecology 67:99–109.

WHITE, G. C., AND R. A. GARROT. 1990. Analysis of Wildlife Radio-tracking Data, Academic Press Inc., San Diego, CA.

WHITWORTH, D. L., J. Y. TAKEKAWA, H. R. CARTER, S. H. NEWMWN, T. W. KEENEY, AND P. R. KELLY. 2000a. Distribution of Xantus' Murrelet *Synthliboramphus hypoleucus* at sea in the Southern California Bight, 1995–97. Ibis 142:268–279.

WHITWORTH, D. L., S. K. NELSON, S. H. NEWMAN, G. B. VAN VLIET, AND W. P. SMITH. 2000b. Foraging distances of radio-marked Marbled Murrelets from inland areas in southeast Alaska. Condor 102:452–456.

WILKINSON, L., AND M. COWARD. 1996. Analyses of Variance, *In* SPSS, SYSTAT 6.0 for Windows, Statistics. SPSS Inc., Chicago, IL.

Table 3.1. Number of Cassin's Auklets radio-marked at Prince Island (1999–2001) and Scorpion Rock (2000–2001). Numbers of individuals with ≥1 location and tracking location summary values presented for auklets classified as attending their colony nightly. Means are presented ± SD.

	Prince			Scorpion		
	1999	2000	2001	2000	2001	Total
Individuals						
Female	16	15	8	4	5	48
Male	11	11	14	5	4	45
Unknown	3	0	2	0	1	6
Total	30	26	24	9	10	99
Locations						
Number of locations	346	435	149	87	41	1058
Mean No. locations per auklet[a]	14.6±8.1	17.2±7.1	7.5±3.2	9.7±4.5	6.2±2.3	12.7±7.4
Mean No. days tracked[a]	40.8±29.1	31.0±14.1	25.1±14.2	17.3±10.0	18.2±10.4	30.0±20.4
Mean percentage of total locations[b]	86±15	89±11	78±18	79±16	93±10	85±14

[a] Locations per auklet and tracking duration calculated for individual auklets with ≥3 locations, excludes failed transmitters and dispersed individuals.

[b] Percentages of total locations were calculated as the proportion of locations obtained for an individual out of the total possible locations had a bird been located on every flight, before dispersal or radio failure (see Methods).

Table 3.2. Foraging distances, and individual home ranges (100% minimum convex polygon) for nesting Cassin's Auklets radio-marked on Prince Island (1999–2001), and Scorpion Rock (2000–2001). Means are presented ± SD. Sample sizes (number of auklets) are in parentheses.

	Foraging Distance (km)				Foraging Area (km^2)	
	Mean		Maximum		Home range	
	Female	Male	Female	Male	Female	Male
Prince						
1999	15.4±3.0	15.1±5.4	28.8±10.9	34.0±18.7	408±210	507±316
	(12)	(8)	(12)	(8)	(11)	(7)
2000	21.6±6.5	16.7±4.6	42.0±13.5	36.1±13.4	957±697	599±266
	(15)	(11)	(15)	(11)	(13)	(11)
2001	25.2±9.7	14.9±3.6	56.7±28.0	32.1±21.3	1227±835	658±1016
	(7)	(12)	(7)	(12)	(5)	(8)
Totals	20.2±7.3	15.6±4.4	40.4±19.1	34.0± 7.6	796±654	593±587
	(34)	(31)	(34)	(31)	(29)	(26)
Scorpion						
2000	13.7±5.8	17.2±9.7	27.8±16.4	42.8±26.6	305±252	494±293
	(4)	(5)	(4)	(5)	(4)	(5)
2001	8.6±0.9	14.2±4.4	16.0±5.2	23.3±8.6	2499±3627	108
	(3)	(3)	(3)	(3)	(3)	(1)
Totals	11.5±5.0	16.1±7.9	22.7±13.5	35.5±23.0	1245±2407	430±306
	(7)	(8)	(7)	(8)	(7)	(6)

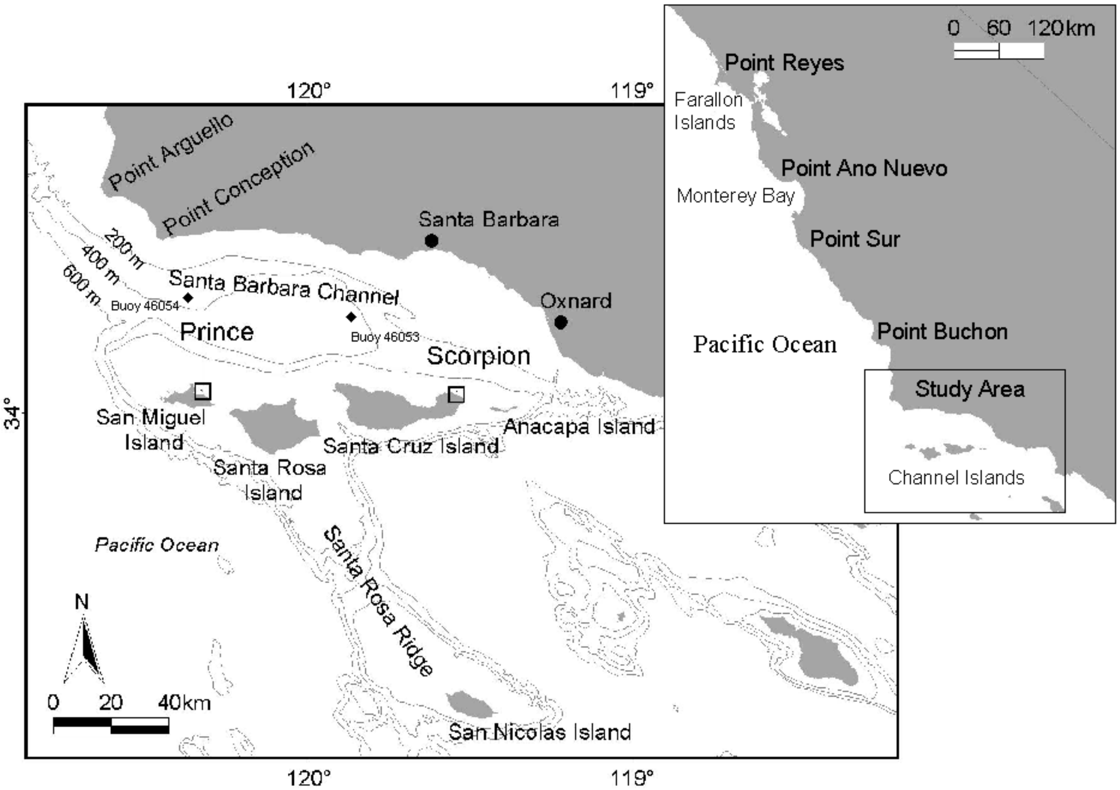

Figure 3.1. California coast (inset) and the principal study area in the northern Channel Islands, California. The two study colonies, Prince Island and Scorpion Rock, are shown within the small boxes. Lines show bathymetric features at 200-m intervals.

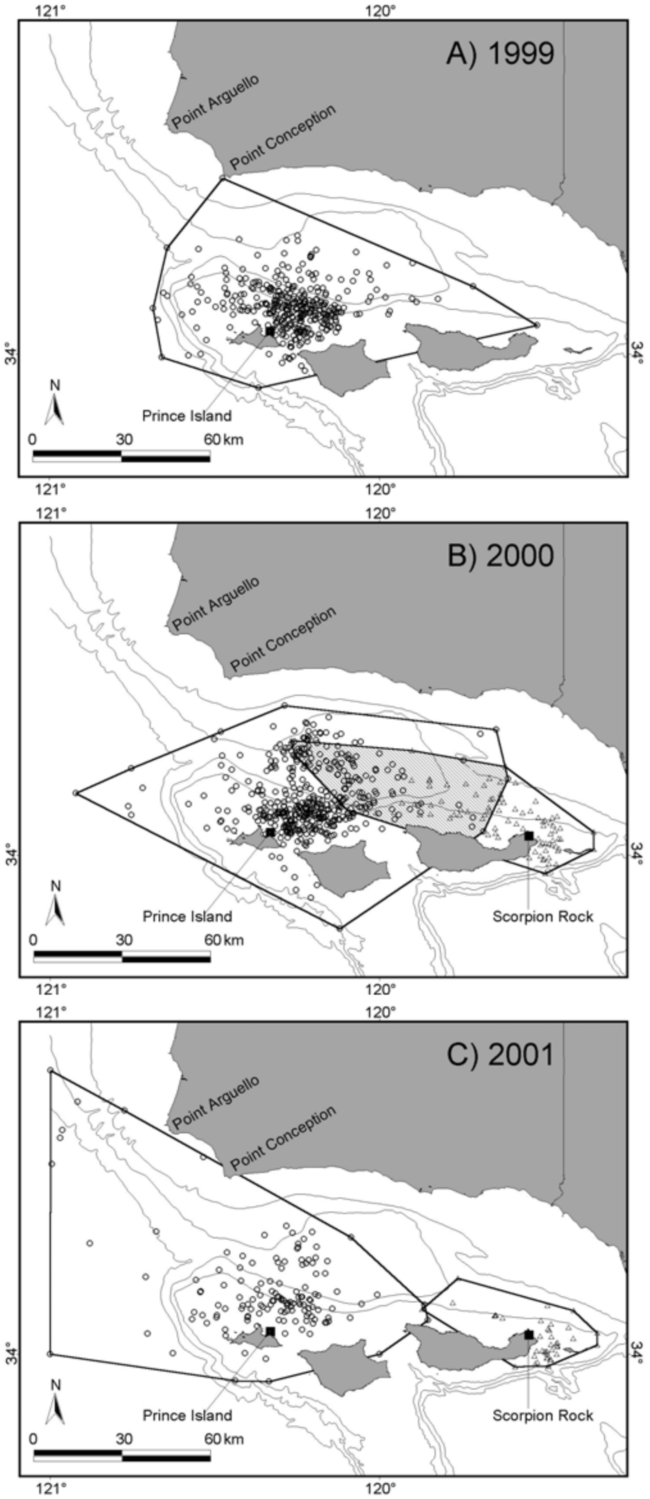

Figure 3.2. Minimum convex polygons (MCP) enclosing all Cassin's Auklet locations detected during colony attendance periods: (A) 1999, (B) 2000 [cross-hatched area represents overlapping colony foraging area], and (C) 2001. Auklets from Prince are represented by open circles and auklets from Scorpion by open triangles. Lines show bathymetric features at 200-m intervals.

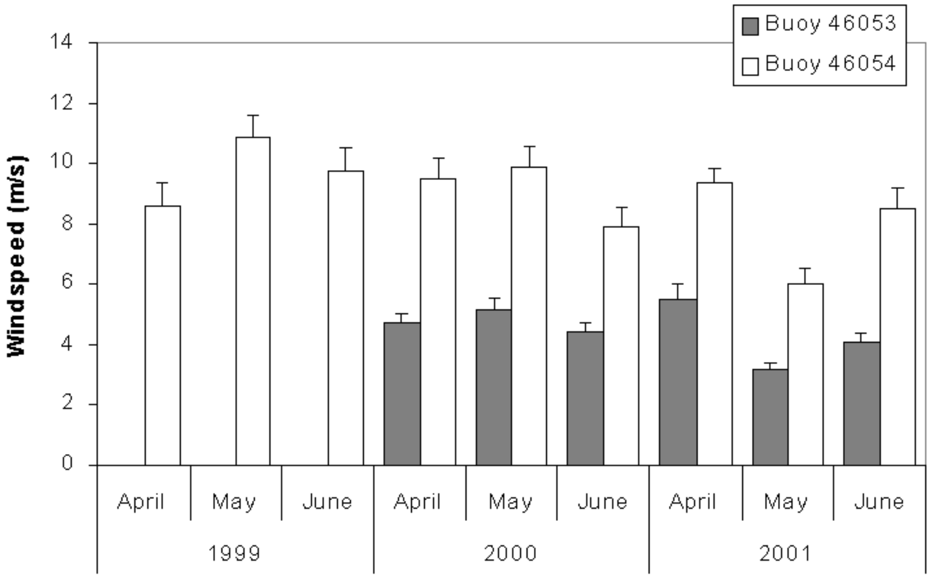

Figure 3.3. Daily-averaged wind speed (m s^{-1}) from offshore marine buoys during April–June, 1999 through 2001. Buoy 46053 is located in the eastern SBC, 43 km northwest of Scorpion, and buoy 46054 is located in the western SBC, 34 km north of Prince. No data are presented for buoy 46053 in 1999 as no studies were conducted at Scorpion in this year. Error bars represent standard error (+1 SE).

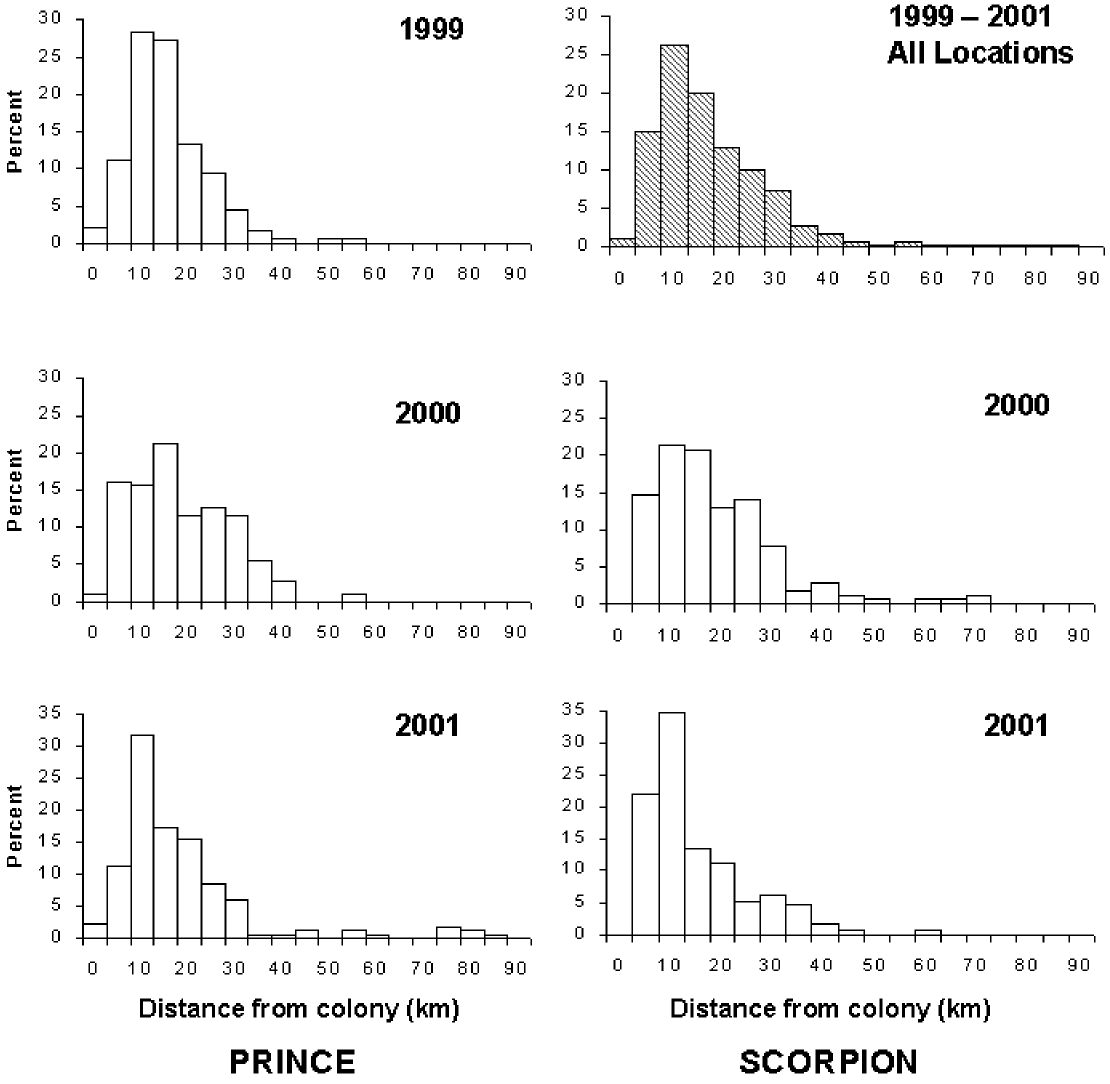

Figure 3.4. Frequency distributions of radio-location distances for Cassin's Auklets attending Prince and Scorpion during 1999–2001.

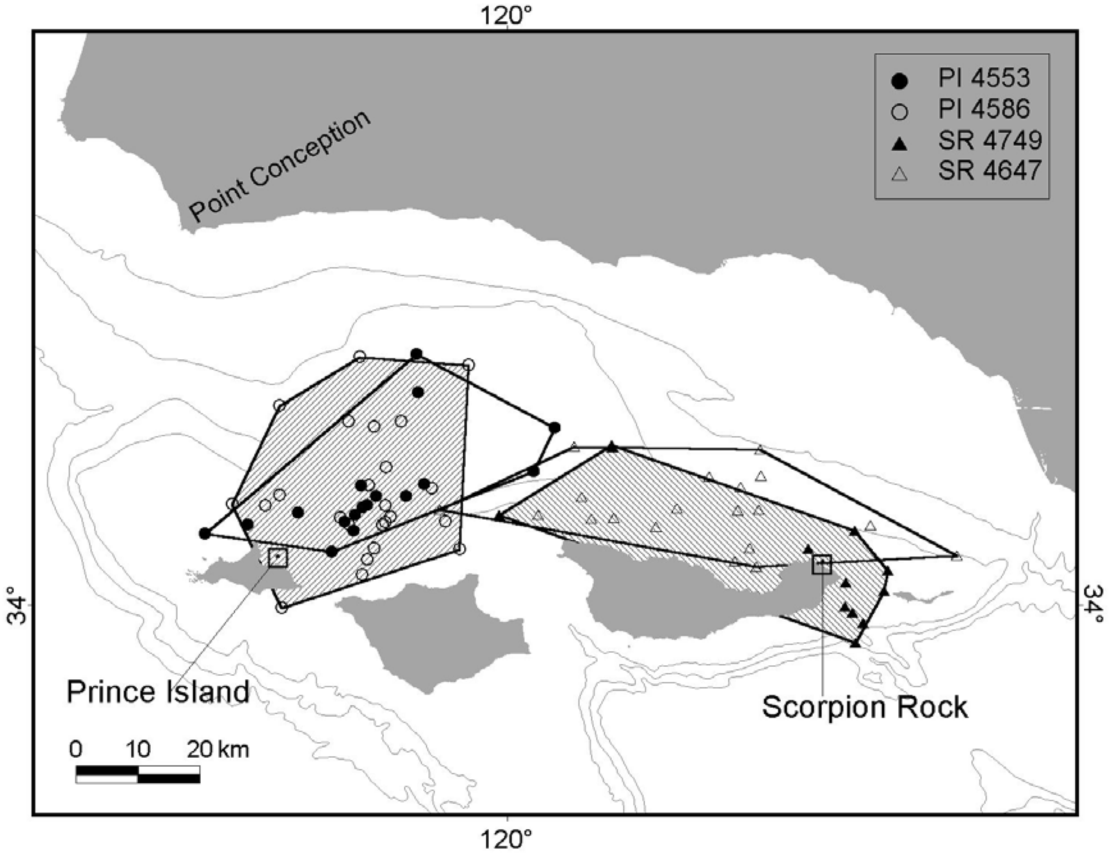

Figure 3.5. Example minimum convex polygons indicating individual home ranges for auklet PI4568 (filled circles) and PI4553 (open circles) marked on Prince during 2000, and auklet SR4647 (open triangles) and SR4749 marked on Scorpion during 2000.

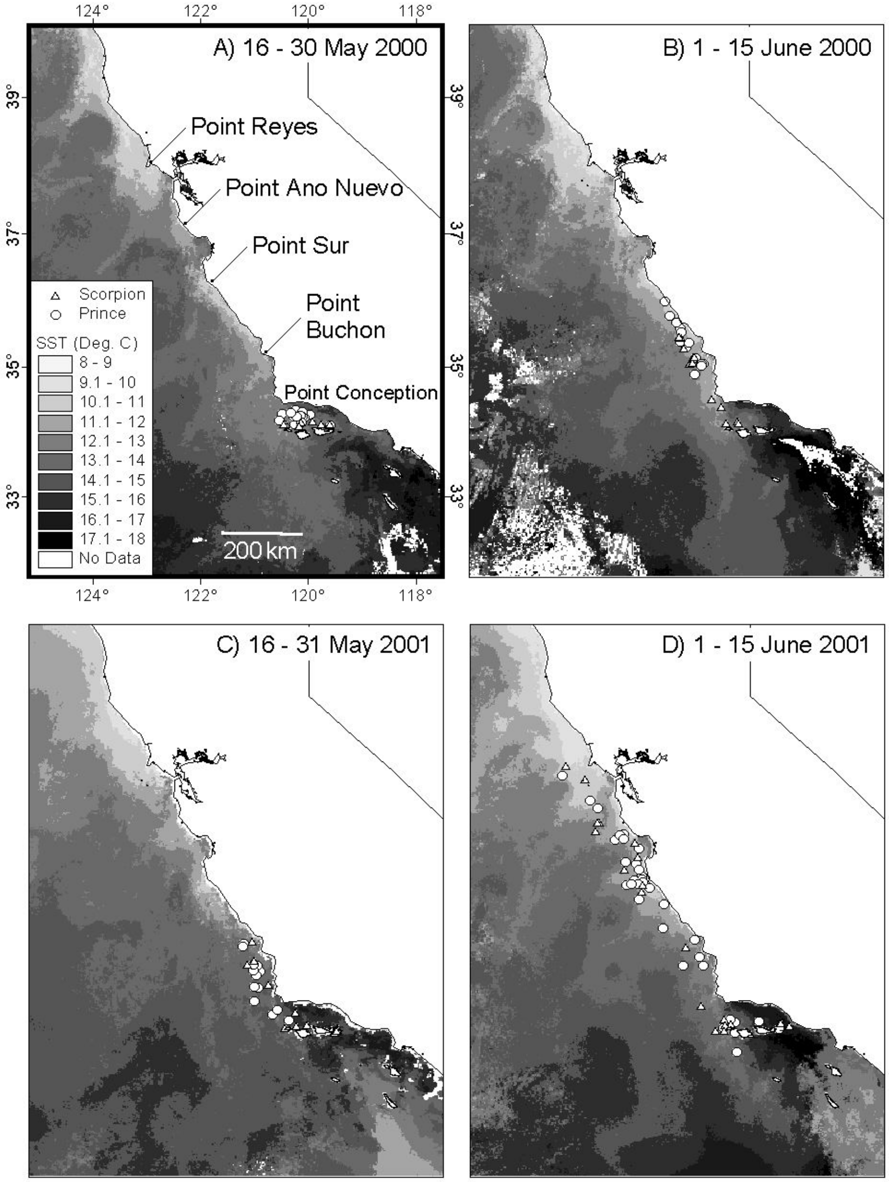

Figure 3.6. Locations of auklets radio-marked on Prince (circles) and Scorpion (triangles) during post-breeding 2000 and 2001. Background is semimonthly, Advanced Very High Resolution Radiometry (AVHRR) composite images of sea-surface temperature depicting intra- and interannual changes in temperature (grey-scale represents sea-surface temperatures in °C; NOAA CoastWatch AVHRR; http://coastwatch.pfel.noaa.gov). The light shades (8–11°C) indicate mesoscale structure of cool, upwelled water along the coast, and prominent upwelling centers located at Point Reyes, Point Año Nuevo, Point Sur, Point Buchon, and Point Conception. The dark shades (14–18°C) south of Point Conception and in the eastern Santa Barbara Channel represent warmer surface-water developing and flowing into the Santa Barbara Channel resulting from relaxation of upwelling north of Point Conception: (A) 16–31 May 2000, (B) 1–15 June 2000, (C) 16–31 May 2001, and (D) 1–15 June 2001.

CHAPTER 4:

STABLE FORAGING AREAS AND VARIABLE CHICK DIETS: INSIGHT TO OCEAN VARIABILITY AND REPRODUCTIVE SUCCESS OF CASSIN'S AUKLETS IN THE CALIFORNIA CHANNEL ISLANDS

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Abstract: We studied foraging areas, chick diets, and reproductive success of Cassin's Auklets during three consecutive breeding seasons (1999–2001) at Prince Island in the California Channel Islands. Large intra- and inter-annual variability occurred in local oceanographic conditions during a prolonged La Niña phase of the Southern Oscillation. Radio-marked parents used consistent foraging areas within 40 km of their colony. Provisioning adults aggregated in shelf waters (<200 m depth) along the southern Santa Barbara Channel and occasionally foraged in deeper waters (>200 m depth). Chick diets varied within seasons and among years. Seven items comprised 87% by number and mass of the food delivered. In all years, parents provisioned chicks with euphausiids, age-0 fishes, and minor amounts of cephalopods. *Thysanoëssa spinifera* (Euphausacea) juveniles and adults were the most important items, followed by *Euphausia pacifica* (Euphausacea). *Thysanoëssa spinifera* was most important during 1999 and 2001, whereas *E. pacifica* replaced *T. spinifera* in 2000 after an anomalous eastward inflection of the California Current occurred off Point Conception during March and April. Parents delivered adult *T. spinifera* in each year, but greater amounts of juveniles during the second half of the chick-rearing period, especially in 1999 and 2000. During 2001, parents delivered the least amount of adult *T. spinifera*, and equal amounts of euphausiids (mostly juvenile *T. spinifera*) and fish. Auklets used a similar foraging area in each year, and dietary composition appeared strongly influenced by fluctuations in upwelling and regional circulation. Differences in chick-diet, however, did not significantly influence fledging success and growth among alpha chicks, but the proportion of nesting pairs successfully fledging an alpha chick and initiating a second clutch was exceptionally great in 1999 (63%) and 2000 (75%), and less (7%) in 2001.

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INTRODUCTION

Variability in ocean climate conditions dramatically affects the diet and reproductive performance of seabirds (Monaghan et al. 1989, Kitaysky and Golubova 2000, Takehashi et al. 2001) including species in the California Current System (CCS; Ainley et al. 1995, Sydeman et al. 2001). Primary productivity in the CCS is driven by wind-forced coastal upwelling during the spring and summer. Seasonal phytoplankton blooms regularly fuel abundant zooplankton and forage fish populations that in turn provide food for large numbers of resident and migratory seabirds, fishes, and marine mammals. Variability in circulation can rapidly modify the distribution and abundance of zooplankton (Huntley et al. 2000) and larval–juvenile fishes (Bjorksedt et al. 2001). Pronounced changes in hydrography and zooplankton community assemblages (McGowan et al. 1998, Peterson and Keister 2002) occur periodically in response to El Niño Southern Oscillation events (Barber and Chavez 1986), fluctuation in the Aleutian Low Pressure phenomenon (Norton and Mclain 1994), and long-term changes in the Pacific Decadal Oscillation (Hare et al. 1999). Colony-nesting seabirds have foraging areas that are restricted during the breeding season, thus, variability in prey availability near colonies should be reflected in the food delivered to chicks (Flint and Golovkin 2002).

The Cassin's auklet *Ptychoramphus aleuticus* (Family Alcidae), is an opportunistic planktivore throughout its range in the northeastern Pacific Ocean. During the nesting season (March through July), parents feed chicks a mixed diet of crustaceans and age-0 fishes (Hunt et al. 1993, Ainley et al. 1996, Hedd et al. 2002). Reproduction varies among colonies located within different oceanographic regimes, and presumably is influenced by the occurrence of certain prey of varying energy content or availability. For example, off British Columbia in the transition between the California and Alaska currents, the occurrence in the diet of large amounts of slow-swimming, energy-dense *Neocalanus* copepods versus euphausiids and fish, led to greater chick growth-rates and breeding success in years when the spring peak in copepod production coincided with the chick-rearing period (Bertram et al. 2001, Hedd et al. 2002). Off the west coast of the United States and Mexico, breeding colonies of Cassin's auklet are restricted to only a few islands (Carter et al. 1992) located near coastal upwelling centers characteristic of the inner CCS. Within the upwelling-dominated system of central California, Cassin's auklets respond to marine environmental changes that affect lower-trophic-level prey abundance and availability on both annual and decadal time scales (Ainley and Lewis 1974, Ainley et al. 1990). For example, at the Farallon Islands, diet varied intra-annually according to the onset of upwelling and presumably with changes in the size and availability of certain prey throughout the breeding season (Ainley et al. 1996).

The Southern California Bight (SCB) is a large, unique physical feature along the west coast of North America and its northern boundary at Point Conception marks a transition from relatively cool, nutrient enriched subarctic waters to warmer, less productive subtropical waters that enter the region from the south. Studies located at such oceanographic transitions can provide unique information on the effects of climate change to marine ecosystems. For example, changes in zooplankton community assemblages are expected to be detected more rapidly in transition areas where species distribution boundaries occur. Foraging ecology of Cassin's auklet off southern California provides information that helps interpret how auklets respond to changes in different marine environments, and also provides insight regarding how ocean conditions and processes affect important regional prey resources within the CCS. We used independent estimates of chick diet, foraging range, and reproductive success to examine how variability in ocean conditions in the SCB affected variability in the composition of food delivered to chicks and breeding success of Cassin's auklets.

METHODS

Study Area

We conducted diet collections, radio-telemetry surveys, and reproductive monitoring during three consecutive nesting seasons (1999, 2000, and 2001) in the northern Channel Islands of the SCB (Figure 1). The northern Channel Islands are separated from mainland California by the 100 km long and 40 km wide anta Barbara Channel (SBCH). The main feature of the channel consists of the Santa Barbara Basin (600 m maximum depth), located north of Santa Rosa Island. A shallow (<200 m depth), 3 to10 km-wide shelf surrounds the northern islands (Figure 1). We studied a Cassin's auklet colony located on Prince Island (34º05'N, 120º15'W) that is 2 km north of San Miguel Island and is the largest auklet colony in southern California. Approximately 8900 birds nest in shallow burrows excavated in loose, rocky soil and within scattered rocky crevices (Carter et al. 1992). Ocean transport through the SCB during the spring upwelling period is modified as the California Current narrows, accelerates southward into a jet-like feature, and moves onshore from Point Conception south to the Santa Rosa Ridge (Bray et al. 1999). Coastal upwelling that occurs in the vicinity of Point Conception seasonally enriches the nearshore waters, which then become entrained along the southern margin of the SBCH near Prince Island (Harms and Winant 1998). To the south and east of Point Conception, wind-forcing, wind-curl, and coastal divergence are reduced, forcing persistent and closed cyclonic circulation in the western SBCH (Oey et al. 2001). Such an 'upwelling shadow', with closed circulation, can act as a plankton retention zone, significantly affecting dispersal and settlement of planktonic larvae, biological productivity, trophic dynamics, and pollutant dispersal (Graham and Largier 1997).

Ocean Conditions

To describe variability in broad-scale ocean conditions influencing the SBCH study area during the auklet nesting season, we obtained daily sea surface temperature (SST; expressed as the anomaly from the long-term mean) from data buoy 46023 located off Point Arguello (National Oceanic and Atmospheric Administration, National Data Buoy Center; Figure 1). We obtained daily indices of upwelling and alongshore transport (Bakun 1973) integrated over a three-degree latitudinal section of coastline centered at 36°N (Point Sur) from the Pacific Fisheries Environmental Laboratory (PFEL; http://www.pfeg.noaa.gov). Upwelling indices were based on estimates of offshore Ekman transport driven by geostrophic wind stress derived from surface atmospheric pressure fields (Schwing et al. 1996).

Chick Diet

Provisioning parents feed their single chick once nightly by regurgitating partially digested meal-loads stored in a specially adapted sublingual pouch (Speich and Manuwal 1974). We captured parents by hand and with a 5-m rectangular, woven-nylon net supported by two upright poles approximately one hour after sunset as they returned to Prince Island (West Coast Netting, Inc.; mesh-size 2.2 cm; Vermeer 1981, Hedd et al. 2002). We sampled approximately 5 separate areas within the colony located on the southeast slope of Prince Island. Although, netting locations were selected haphazardly in order to avoid areas monitored for reproductive success and radio telemetry, and to avoid recapturing individuals on multiple occasions, it is possible that a small proportion of individuals were captured more than once. We collected meal-loads an average of every 8 ± 1 SE d (range = 1–18 d) from 6 March to 19 July 1999, 27 March to 27 June 2000, and 30 April to 28 June 2001, concurrent with radio-telemetry surveys. Regurgitated meal-loads were captured directly into plastic Whirl-Pak™ bags. In the field, meal-loads were weighed (±1.0 g) with a 100-g Avinet™ spring scale, and then fixed with 100 ml, 10% buffered formalin or preserved in 70% isopropyl alcohol for later analyses. We collect the entire meal-load from each captured bird by gently massaging the auklet's throat pouch. If the contents spilled, we excluded these samples from our analysis of complete meal-load mass.

Ainley et al. (1990) determined that nesting phenology on the Farallon Islands, CA was correlated with the seasonal decrease in sea-surface temperature (SST) associated with the spring transition to coastal upwelling; therefore, we split seasons into 'early' and 'late' periods based on chick-rearing phenology. Off southern California, the early period was more likely influenced by early, pronounced upwelling conditions, whereas the late period reflected ocean conditions resulting from reduced upwelling, increased thermal stratification, and intrusion of warmer waters from the south. Early meal-loads included those collected from hatching to 21 days (one-half the average rearing duration of 42 d; Ainley et al. 1990), the midpoint hatching date; late meal-loads were collected after this date (Table 4.1). We compared meal-load mass between periods and among years with a 2-way ANOVA.

For the analyses of prey composition and importance, meal-load samples were rinsed through nested sieves, and prey remains were identified and sorted to lowest taxonomic level (Martin and Davis 2001) and classified into age-classes (larval, juvenile, or adult for euphausiids). Prey items within each sample were enumerated, sorted into unique prey groupings, and wet masses (± 0.0001 g) were determined with an analytic balance after excess water was removed.

We plotted cumulative prey curves to determine whether an adequate number of samples were obtained (following Ferry and Cailliet 1996, Preti et al. 2001). We used a permutation procedure with replacement repeated 100 times to randomize the order in which cumulative samples were analyzed. We then plotted the cumulative mean (± 1 SD); an asymptotic relationship indicated whether the number of samples was sufficient to describe trophic diversity (Hurtubia 1973).

Analyses of Chick Diet Composition

Meal-loads were pooled within periods and years, and analyzed by unique prey category using three relative measures of prey quantity (RMPQ): percent composition by number (%*N*), percent composition by mass (%*M*), and percent frequency of occurrence (%*F*), defined as samples containing a unique prey category divided by the total samples × 100. Unidentifiable, partially-digested slurry was excluded when calculating percentages and indices. To quantify importance of prey category by year, we used RMPQ values to calculate the geometric index of importance (GII, Assis 1996), defined as:

$$\mathrm{GII}_j = \frac{\left(\sum_{i=1}^{n} \boldsymbol{V_i}\right)_j}{\sqrt{n}}$$

where $\boldsymbol{V_i}$ = the vector containing the ith RMPQ of the jth prey category, and n = the number of RMPQ used in the analysis. We report RMPQ and GII for the data set pooled by year (1999, 2000, and 2001).

We tested for differences in presence *vs*. absence among the top four prey items among years and between chick-rearing period with separate mixed-models logistic regression. Sample night was treated as a random effect to control for same-night correlations.

We calculated diet diversity by period within years using the Shannon-Weiner equation (Hurtubia 1973):

$$H' = -\sum p_j \ln p_j,$$

where p is the proportion by mass of the diet contributed by each j prey category. We converted H' to the number of unique items (N_1; MacArther 1965):

$$N_1 = e^{H'}$$

We compared prey composition between periods and among years using the percent similarity index (PSI: Whitaker 1952, Whitaker and Fairbanks 1958):

$$\mathrm{PSI} = 100 - 0.5\sum A_j - B_j = \sum \min(A_i, B_i),$$

where A_j, B_j = percentages of category j in samples A and B, respectively. Because PSI is strongly influenced by the most abundant items, and in this study sample periods were dominated by few prey items (see ‘Results’), an index that gives greater importance to the most abundant species was considered appropriate (Rebstock 2001).

We evaluated co-occurrence of prey within individual meal-loads for the 13 top-ranking prey groupings by calculating Fager’s (1957) index of affinity (*IA*) for prey-category pairs and modified by Fager and McGowan (1963):

$$IA = \frac{J}{\sqrt{(n_A n_B)}} - \frac{1}{2\sqrt{n_B}}$$

where n_A is the number of samples in which A occurred, n_B is the number of samples in which B occurred, and J is the number of co-occurrences of A and B; in this equation, $n_B \geq n_A$. We regarded an $IA \geq 0.30$ between categories as indicating affinity (Moser and Smith 1993). Affinities ≥0.30 were used to form groupings in which all prey categories in a group co-occurred with other members in the group.

Radio-Telemetry

We hand-captured nesting adults during night at nest sites marked during the day. We attached 3-g radio-transmitters (Holohil Systems Ltd., Toronto Ontario, Canada; model PD-2G in 1999; Advanced Telemetry Systems, Inc., Isanti Minnesota, USA; model 386 in 2000-2001) to nesting auklets dorsally between their scapulae with the subcutaneous anchor and rear suture technique (Newman et al. 1999). Auklets were located at sea (maximum of one location per day) using a receiver in a fixed-wing aircraft every 1 to 8 days throughout most of the chick-rearing season, from 7 March to 24 June 1999, 12 April to 20 June 2000, and 6 April to 27 June 2001 (described in Adams et al., in review; Table 4.1). We analyzed auklet locations of parents that were attending Prince Island, confirmed nightly by a remote telemetry system located at the colony. We plotted the distribution of radio-locations by early and late period (see Chick diet) as fixed-kernel probability contours (50, 75, and 95% probability density; ArcView 3.2 GIS, Animal Movement extension v. 2.04; Hooge and Eichenlaub 1997). Because of the shortened breeding season and dispersal of post-breeding birds out of the SBCH area in 2001 (Adams et al. in review), we could not collect sufficient telemetry locations in the late season; therefore, all locations for 2001 are presented on one map.

Phenology, Breeding Success, and Chick Growth

We conducted independent monitoring of breeding auklets at nest sites located within the same portion of the colony as our diet collections and radio telemetry. We visited nest sites periodically throughout each nesting season (January through July). Most natural burrows on Prince Island are extremely fragile and susceptible to damage from repeated visits by researchers, therefore, 50 artificial nest-boxes were placed within the colony in 1984 (Lewis et al. 1988). In 2000 and 2001, we increased the sample of accessible nest sites by adding 48 new artificial burrows (described in Adams et al. 2001). Thus, we used a combination of natural sites, artificial nest-boxes, and artificial burrows for monitoring auklet reproduction and chick growth. During each visit, we recorded nest contents to determine nesting phenology, estimate breeding success, and to measure chicks. Nest sites used for radio-telemetry were included to determine phenology, but excluded from our analyses of reproductive success and annual chick growth rates to avoid potential bias.

For comparison among years, we used five parameters related to reproduction and chick development: fledging success, proportion of pairs initiating a second clutch, mass growth rate (g d^{-1}), wing growth rate (mm d^{-1}), and peak mass. Fledging success and peak mass were treated as indices based on expected fledging age and mass. Off central California, Cassin's auklet chicks typically reach peak mass at 37 d (range: 35–45 days; Manuwal 1974, Ainley et al. 1990) and fledge after 41–42 d (95% CI: 36–49; Manuwal 1974, Ainley et al. 1990) at 147–158 g (Farallon Islands range of annual means: 1970 to 1983; Ainley et al. 1990). We defined peak mass as the maximum mass recorded between 35 to 45 d. Chicks reach asymptotic growth between ages 35 and 45 d, therefore, our peak mass was an index of true fledging mass because chicks may undergo pre-fledging mass recession (Manuwal 1974, Vermeer 1981, Ainley et al. 1990, Hedd et al. 2002). Chicks not measured between ages 35 and 45 d were excluded from analysis of peak mass. We classified a chick as having fledged if it was alive ≥30 d, was mostly feathered (traces of down remaining on head and neck), and weighed ≥100 g on our last visit before the chick disappeared from the nest site (Martin and Sydeman 1998). Conversely, chicks that were found dead at the nest site, disappeared from its nest site before 35 days, or weighed <100 g at ≥30 days were classified as failed. We measured the maximum, flattened wing-chord with a ruler (FWC; ± 1.0 mm), and determined chick body mass with 100- and 300-g Avinet™ spring scales (± 1.0 g). We determined hatching phenology from the relationship between FWC and age determined by linear regression on a subset of chicks with known hatch-dates (± 2 d), where age (d) = FWC - (14.68)/2.25; n = 22 auklets, $R^2 = 0.93$). We used the first chicks raised each breeding season for all analyses except when we specifically examined double brooding.

Pair quality (e.g. age, experience, pair bond duration) may have differed among the existing nest-types (i.e. natural burrows, nest boxes, and artificial burrows), therefore, we statistically controlled for potential differences in breeding parameters between years by including nest type as a covariate in each analysis. We also included Julian hatching date as a covariate in each analysis because fledging success and chick growth rates often decline as the nesting season progresses (Morbey and Ydenberg 1997, Ainley et al. 1990). We controlled for yearly variation in nesting phenology by using z-scores calculated by taking the difference between a pair's Julian hatching date and the mean Julian hatching date, and dividing this value by the standard deviation for that year. We tested for annual differences in fledging success with multiple logistic regression; the nominal dependent variable was fledge or fail and the explanatory variables were year (1999, 2000, or 2001), nest type (natural nest site, artificial burrow, or artificial nest-box), and Julian hatching date (z-score). We used a similar multiple logistic regression to analyze annual differences in the probability that a pair would initiate a second clutch after successfully fledging their alpha chick. To examine annual differences in mass growth rates (g d^{-1}) and wing growth rates (mm d^{-1}) during the linear growth phase (5–25 d; Manuwal 1974, Vermeer 1981), and different peak fledging masses, we used separate analysis of covariance (ANCOVA); factors were year and covariates included nest type and Julian hatching date (z-score). We conducted statistical analyses with JMP (version 4.0.4; SAS Institute Inc., Sall et al. 2001) or StatView (version 5.0.1; SAS Institute Inc. 1998), and tests were considered statistically significant when $P < 0.05$. All tests were two-tailed. We report means ± SE unless otherwise noted.

RESULTS

Oceanographic Conditions

Despite persistent La Niña conditions affecting the northeast Pacific throughout 1999–2001, monthly upwelling off southern California was variable both within and among years during the auklet chick-rearing period (March through July), and among years (Figure 2A). The coastal region north (upstream) of the SBCH experienced sustained periods of positive upwelling anomalies in 1999 compared with the long-term climatologic mean (1967–1991), with much stronger-than-normal upwelling during April through July (Figure 2A). In 2000, the region experienced periods of relaxation indicated by negative upwelling anomalies during February preceding chick-rearing in April and June; positive upwelling anomalies occurred during March, May and July. The upwelling index again was variable in 2001, near the climatological mean in February, March, and May, with pronounced upwelling in April, June, and July. Overall, weaker upwelling conditions persisted throughout the 2000 and 2001 breeding seasons, compared with 1999 (Figure 2A). Monthly average daily alongshore transport (m^3 s^{-1} per 100-m coastline) was consistent and oriented equatorward throughout 1999, variable in 2000 with equatorward transport in February that switched abruptly to poleward flow in March through May (Figure 2A). Alongshore flow in 2001 was more variable compared with 1999 and 2000 (Figure 2A). Anomalously low average SSTs prevailed throughout the study with the exception of June 2000 and May and June 2001 (Figure 2B).

Chick Diet

We identified 34,109 prey items (3636 g) from 277 regurgitated food-load samples from provisioning Cassin's auklets in 1999, 2000, and 2001. We identified 51 unique taxa (Table 4.2). Unidentified prey remains (digested slurry) accounted for 6% of the total by mass. Cumulative prey curves indicated sample sizes were adequate to characterize diet diversity in all three years (Figure 3). Seven principal prey items accounted for 87% of the total mass and 87% of the total number (Figure 4). Diet diversity was greatest during early 1999 (N_1 = 6.7 items) when auklets delivered a variety of crustaceans and fish, and least during early 2000 (N_1 = 2.0 items) when auklets delivered mainly *Euphausia pacifica* (Figure 5C). We found no differences in diet diversity between early (4.5 ± 2.4 items) and late periods (4.3 ± 0.7 items); however, diet composition was dissimilar between early and late periods (PSI = 43.3 ± 17.8), and among years (PSI = 43.9 ± 2.1). Diet composition was most similar (PSI = 60.0) between early and late chick-rearing periods during 2001 when age-0 fishes (Pleuronectidae, Clupeiformes) and juvenile *Thysanoëssa spinifera* were co-dominant (Figure 5E, F). Despite large variability in diet composition, parents delivered similar amounts of food (22.8 ± 9.1 g) to chicks during all three years (2-way ANOVA: $F_{2,116} = 1.65$, $p = 0.197$), with no difference between periods ($F_{1,116} = 0.79$, $p = 0.377$; Table 4.3). Co-occurrences of species within individual meal-loads ranged from negative values (extremely low co-occurrence, e.g. Clupeiformes and *E. pacifica*, *IA* = -0.10) to large values indicating a high degree of co-occurrence (e.g. adult *T. spinifera* and *Nyctiphanes simplex*, *IA* = 0.51; Table 4.4). Among the 13 top-ranking prey categories, we observed significant co-occurrences in 21 category pairs (Table 4.4). Within meal-loads we observed three, multi-species groupings of co-occurrence: Cephalopoda-Decapoda-Pleuronectids, Copepoda-Decapoda-Pleuronectids, and *Euphausia-Nyctiphanes*-adult *Thysanoëssa*-Pleuronectids.

Crustaceans

Overall crustaceans dominated by number (86%*N*) and mass (66%*M*; Table 4.3), with euphausiids being most important prey in all years. Juvenile *Thysanoëssa spinifera* ranked first (GII = 64.5; Table 4.2) and dominated meal-loads during the late periods in 1999 and 2000; juveniles were not detected during early 2000 (Figure 5C). In contrast, juvenile *T. spinifera* were slightly more important in early *vs.* late periods during 2001 (Figure 5E, F). Despite large intra-annual and inter-annual variability in %*N* and %*M* of juvenile *T. spinifera*, we detected no significant difference in %*F* among years (logistic regression: $F_{2,239} = 0.00$, $p = 0.998$), or between periods (logistic regression: $F_{1,239} = 0.00$, $p = 0.996$). Adult *T. spinifera* ranked second (GII = 55.4) and occurred more frequently in 1999 than 2001 (logistic regression: $F_{2,239} = 18.07$, $p < 0.0001$), with intermediate occurrence in 2000 (Figure 5); %*F* did not differ by period (logistic regression: $F_{1,239} = 2.37$, $p = 0.125$), and the interaction between year and period was non-significant (logistic regression: $F_{2,239} = 0.74$, $p = 0.480$). Despite no differences in %*F* by period, both %*N* and %*M* increased substantially during late 1999 (Figure 5B). *Euphausia pacifica* ranked third overall (GII = 37.3) and was the dominant prey in 2000 by *%N, %M,* and *%F* (logistic regression: $F_{2,239} = 7.23$, $p = 0.001$; Fig 5C). We did not detect a significant difference in %*F* by period (logistic regression: $F_{1,239} = 3.71$, $p = 0.055$); increased *%F* during late 2001 resulted in a significant interaction between year and period (logistic regression: $F_{2,239} = 5.42$, $p = 0.005$). The euphausiid *Nyctiphanes simplex* ranked fifth (GII = 17.5) and was more important during the early periods, especially during 1999 (Figure 5A). Remaining crustacean prey items including 15 species of Copepoda (Order Calanoida), six species of amphipods (Suborder Hyperiidea), and a variety of decapod crustaceans, were of minor importance in the chick diet (Table 4.2).

Fish and Cephalopods

Age-0 fishes combined (6 families) ranked second (8%*N* and 29%*M*), followed by cephalopods (<1%*N* and 4%*M*; Table 4.3). Flat-fishes (Family Pleuronectidae) ranked fourth (GII = 37.1), and were delivered consistently throughout the study (Figure 5), with no significant differences in *%F* detected among years (logistic regression: $F_{1,239} = 1.63$, $p = 0.198$) or between seasons (logistic regression: $F_{1,239} = 1.15$, $p = 0.284$). Cephalopods (probably *Loligo opalescens*, and *Octopus* spp.), ranked sixth (GII = 16.1), and were most important during early 2001 (Figure 5E). Rockfish *Sebastes* spp. ranked seventh (GII = 14.9) and were most important during early 1999 (Figure 5A). The occurrence in 2001 of age-0 Clupeiformes (*Sardinops sagax*, or *Engraulis mordax*) was unique, and these fishes contributed significantly to the chick diet (29%*F*, 14%*M*; Figure 5F).

Foraging Area

We determined 346 (30 birds), 435 (26 birds), and 149 (24 birds) locations of breeding auklets in 1999, 2000, and 2001, respectively (Table 4.1). Fixed-kernel density plots indicated low variability in the size and spatial extent of foraging during 1999 through 2001 (Figure 6). Auklets generally foraged within 40 km of Prince Island, primarily in shallow waters (<200 m depth) over the insular shelf, north and northeast of San Miguel Island (Figure 6). In early 1999, auklets aggregated in shallow water north of the San Miguel–Santa Rosa Passage (Figure 6A). Foraging auklets aggregated near the 200-m isobath in late 1999 (Figure 6B). During early 2000, the foraging area extended farther east and north (Figure 6C). Locations in late 2000 indicated a westward shift with split focal areas centered along the inshore side of the 200-m isobath and over the western SBCH (Figure 6D). The 2001 distribution was more widely dispersed, with a focal aggregation centered over the 200-m isobath, and also revealed a slight westward shift compared with 1999 and early 2000 (Figure 6E).

Phenology, Reproductive Success, and Chick Growth

Hatching was early in 1999, and was progressively later by about one month in each subsequent year. Hatching commenced on 31 January and extended to 9 July (159 d) in 1999, from 4 March to 26 June (114 d) in 2000, and from 31 March to 29 June (90 d) in 2001. We found no significant differences among years in alpha-chick fledging success (multiple logistic regression, n = 131 pairs; year: Wald $\chi^2 = 1.38$, p = 0.51; nest type: Wald $\chi^2 = 0.36$, p = 0.83; z-score Julian hatch date: Wald $\chi^2 = 2.37$, p = 0.12; Table 4.5). We found no significant difference in alpha-chick mass growth rates among years (ANCOVA: year: $F_{2,16} = 0.96$, p = 0.41; nest type: $F_{2,16} < 0.01$, p > 0.99; z-score Julian hatch date: $F_{1,16} = 3.47$, P = 0.087; Table 4.5). Wing growth rates also were not statistically different among years (ANCOVA: year: $F_{2,32} = 0.45$, p = 0.64; nest type: $F_{2,32} = 1.14$, p = 0.34; z-score Julian hatch date: $F_{1,32} = 5.49$, p = 0.03). We also found no significant differences in peak fledging mass (ANCOVA: year, $F_{2,43} = 0.25$, p = 0.78; nest type: $F_{2,43} = 0.07$, p = 0.93; z-score Julian hatch date: $F_{1,43} = 8.41$, p = 0.001; Table 4.5). However, when we examined second-clutch initiation, we found significant differences among years (multiple logistic regression, n = 61 pairs; year: Wald $\chi^2_2 = 9.69$, p = 0.008; nest type: Wald $\chi^2_2 = 4.43$, p = 0.11; z-score Julian hatch date: Wald $\chi^2_1 = 4.24$, p = 0.039; Table 4.5). Among pairs that fledged alpha chicks, 63% in 1999 (10 of 16), 75% in 2000 (12 of 16), and 7% in 2001 (2 of 29) initiated second-clutches (Table 4.5).

DISCUSSION

Evaluating the diet of Cassin's auklet chicks within the context of a known foraging area provides better information regarding factors affecting spatial and temporal patterns in the distribution, abundance, and community composition of key prey resources. Cassin's auklets foraged on the most available zooplankton and fish. Parent auklets delivered similar meal-load masses within and among years, during a period when adult foraging areas were similar, however, chick diet composition varied significantly among years. Variable diet composition did not affect fledging success, mass gain, or wing growth among alpha chicks. The proportion of pairs successfully initiating a second clutch, however, was exceptionally high in 1999 and 2000, but reduced in 2001 indicating that the period of high prey availability occurred later and for shorter duration in 2001. Alternatively, auklet breeding was asynchronous with the seasonal peak in prey abundance. Variability in prey delivered to chicks at Prince Island resulted in part from dynamic oceanographic conditions that likely influenced zooplankton distribution in the SBCH, rather than from shifts in parental foraging areas.

At the scale of an auklet's foraging area (<1000 km^2), mechanisms regulating the supply and availability of zooplankton are complex. Predators foraging on zooplankton must take advantage of patchy prey aggregations that result from the interaction of zooplankton behavior, such as diel vertical migration and surface spawning (Smith and Adams 1988), with environmental factors including currents, hydrography, and bathymetry (Huntley et al. 2000, Allen et al. 2001). For example, the mean current velocity in the upper California Current (~15 cm s^{-1}) exceeds the cruising velocities measured for euphausiids (e.g. 2 cm s^{-1} for *Euphausia pacifica*; Torres and Childress 1983), and larval fish (Stobutski and Bellwood 1997). The dispersion of euphausiids and larval fishes, therefore, is substantially influenced by near-surface flow fields. For example, ff central California, *E. pacifica* was the most abundant euphausiid near the surface (<50 m) and associated with the pycnocline within a cyclonic eddy shed from the coast (Huntley et al. 2000).

Auklets in our study foraged within the SBCH, a unique area located downstream from a major upwelling zone near Point Conception. Two features within the foraging area aggregate zooplankton and age-0 fishes: processes associated the shelf-break delineated by the 200-m isobath, and characteristic cyclonic flow over the western SBCH. In 1999, and to a lesser degree in 2001, auklets aggregated primarily inshore from the shelf-break and delivered greater amounts of the coastal, 'cold-water' species *T. spinifera*. In 2000, when the more oceanic, 'cold-water' species *E. pacifica* dominated the diet, auklets ranged more frequently beyond the shelf-break, to forage in deeper SBCH waters, a pattern that is consistent with the known distributions of these two euphausiids (Fiedler et al. 1998). Migrating blue whale *Balaenoptera musculus* fed exclusively on *E. pacifica* and *T. spinifera*, north of San Miguel and Santa Rosa Islands during a period when *E. pacifica* dominated subsurface krill layers near or offshore from the shelf-break, and *T. spinifera* was most abundant over the shelf and to the east of Santa Rosa Island (Fiedler et al. 1998).

The predominance of euphausiids over fish in chick diets in 1999 together with the distribution of auklets aggregated along the shelf-break occurred during a year when strong equatorward, cross-shelf flow may have aggregated euphausiids along the inshore side of the shelf-break. This mechanism has been invoked to explain similar aggregations and diet variation of auklets (Oedecoven et al. 2001), other krill predators such as blue whales that forage near the shelf-break (Schoenherr 1989), and the abundance of larval *Sebastes* spp. parallel to the coast (Bjorkstedt et al. 2002). The euphausiid dominated diet in 1999 also was consistent with surveys that revealed low concentrations of pelagic juvenile fishes, an alternative auklet prey, over the SBCH during a period characterized by an unstable, open flow-field (Nishimoto and Washburn 2002). In contrast, relaxation in along-shore wind stress as evidenced by reduced upwelling indices during April–June 2000 and March–April 2001 (Figure 2A), contributed to stable and closed cyclonic flow (Beckenbach and Washburn, unpublished data), which coincided with auklets shifting to more offshore areas (Figure 6C–E). For shallow diving auklets, these conditions in 2001 may have enhanced the availability to of certain key early stage fishes that occur in the upper mixed layer (i.e. *Sebastes* spp., flatfish larvae, and anchovy; Ahlstrom 1959) during a period of reduced euphausiid abundance. Nishimoto and Washburn (2002) demonstrated that off Prince Island in the western SBCH, dramatically increased near-surface abundances of key auklet prey, including juvenile Pacific sanddab *Cytharichthys sordidus* and rockfishes *Sebastes* spp., occurred in areas with vertically compressed isotherms near the surface in the eddy center. Although not quantified in their study, we strongly suspect that this mechanism also would act to concentrate euphausiid prey with similar swimming capability (Allen et al. 2001).

Thysanoëssa spinifera and *Euphausia pacifica* were the two most important euphausiids in meal-loads delivered by parents at Prince Island in this study. These species also were important in samples collected at Prince Island in 1976 and 1977 (Hunt et al. 1979), and are the two most abundant and common euphausiid prey taken by planktivorous marine predators over the nearshore shelf-slope upwelling domains of the CCS (Peterson et al. 1982, Harvey 1989, Schoenherr 1989, Ainley et al.1990, Brodeur and Pearcy 1992, Fiedler et al. 1998, Sydeman et al. 2001). Differences in the importance of the two species in the auklet diet parallel region-wide changes in interannual abundances of the two species. During annual spring California Cooperative Oceanographic and Fisheries Investigation (CalCOFI) surveys from 1950 to 2002 off southern California, *T. spinifera* peaked in abundance 1999 (second largest peak since 1950); *E. pacifica* peaked in abundance the following year in 2000 (largest peak since 1950; Brinton and Townsend 2003). Fluctuation in the relative abundances of the two species in auklet diets also results from variability in ocean conditions (i.e. upwelling) near colonies (Ainley et al. 1996). For example, off the Farallon Islands, Ekman transport of surface waters during pronounced upwelling displaced *E. pacifica* offshore and forced a dietary switch by auklets to the more coastal *T. spinifera* (Ainley et al. 1996, Oedekoven et al. 2001), which becomes super-abundant and readily available to foraging auklets especially during conspicuous, daytime surface swarms (Smith and Adams 1988).

We suggest that the offshore displacement of the southern CCS during the spring of 1999 and the entrainment of cool, northern neritic waters caused *E. pacifica* to be less well represented than *T. spinifera* in the food loads delivered to chicks on Prince Island. CalCOFI surveys and climatic summaries of the southern CCS during spring 1999, 2000, and 2001 reveal the variable nature of current flow surrounding the SBCH (Hayward et al. 1999, Bograd et al. 2000, Durazo et al. 2001). During April 1999, main current flow (dynamic height isopleths, proxies for geostrophic flow) was displaced well offshore (124°W) from Point Conception (Figure 7A). Derived near-surface flow west off Santa Rosa Island revealed the presence of a cyclonic eddy around which nearshore, equatorward flow from north of Point Conception was split, partially deflected offshore and also partially directed toward the SBCH. Such conditions would be expected to displace *E. pacifica* (off-shore distributed) and facilitate the transport of *T. spinifera* (shelf distributed) along the coast and into the SBCH. Dominance of *E. pacifica* over *T. spinifera* in meal-loads during early 2000, likely resulted from reduced equatorward flow nearshore and a collapsing of the meandering CCS toward the northern Channel Islands during March and April. In April 2000, isopleths centered between 121 and 123°W indicated pronounced zonal (eastward) flow in the CCS was directed toward the Channel Islands (Figure 7B), isopleths near Point Conception were curled shoreward consistent with reduced upwelling and equatorward alongshore transport (Figure 2A). These conditions would be expected to transport *E. pacifica* into the area and reduce the alongshore transport of *T. spinifera* into the SBCH. During April 2001, equatorward flow was compressed along the coast near Point Conception, and equatorward flow extended through the SBCH (Figure 7C), conditions again favoring transport of *T. spinifera*, especially weak swimming larvae and juveniles, from upwelling regions north of Point Conception.

Juvenile *Thysanoëssa spinifera* were the most important prey item delivered to auklet chicks on Prince Island (44%*N*, 26%*M*). Auklets take juvenile *T. spinifera* (see Vermeer et al.

1985), however, our results indicate large variability both within and among years in delivery to chicks of this important life-phase, indicating that auklets responded to the seasonal increase in availability of juvenile *T. spinifera*. Juvenile *T. spinifera* were taken in much greater numbers and proportional mass during late chick-rearing in all years except 2001 (Figure 5). During 2001, adults were poorly represented in both periods compared with juveniles. We offer several explanations for these patterns. First, persistent upwelling in 1999 allowed for extended surface spawning events in the SBCH which would cause adults to be most available to shallow diving auklets (Smith and Adams 1988, J. Adams pers. obs.). The presence of juveniles early in 1999 compared with 2000 also indicated the onset of early spawning. Furthermore, the importance of juvenile *T. spinifera* in late 1999 and 2000 diets coincides with the seasonal trend in the abundance of juveniles, when they are substantially more abundant than adults in surface waters (Marinovic et al. 2002). Second, as described above, greater reliance on juvenile *T. spinifera* may have resulted from greater supply of larvae and juveniles entering the SBCH foraging area from spawning regions north of Point Conception that experienced more persistent upwelling and favorable spawning conditions during 1999 and 2001 (Durazo et al. 2001). Third, extensive concurrent aerial surveys throughout the SCB revealed a significant decline in the occurrence of euphausiid surface swarms during the duration of our study from many sightings in 1999, fewer in 2000, and none observed in 2001 (G. McChesney and J. W. Mason, pers. comm.). Both juvenile and adult *T. spinifera* showed significant affinity within individual meal-loads indicating that they co-occur in the upper watercolumn, but auklets apparently caught age-classes according to their relative abundances. More extensive surveys of the distributions and abundances of the two age-classes, coupled with additional diet observations is required to better understand patterns in diet composition.

Greater importance of *Nyctiphanes simplex* in 1999 likely resulted from ocean conditions in the previous 1997–98 El Niño year. *Nyctiphanes simplex* is usually centered off Baja California, Mexico (Gómez-Gutiérrez 1995). The occurrence of this species in the diets of marine predators north of Point Conception (Brodeur 1986, Brodeur and Pearcy 1992, Sydeman et al. 2001), and taken in nets (Marinovic et al. 2002, Tanasichuk and Cooper 2002) signals anomalous northward coastal transport in the CCS commonly associated with El Niño. In summer 1997, Marinovic et al. (2002) detected a pulse of *N. simplex* coincident with declines in the abundances of the two cold water euphausiids *Euphausia pacifica* and *Thysanoëssa spinifera* off central California. Hunt et al. (1979) found *N. simplex* also increased in importance in auklet chick diet on Prince Island during the warm-water year of 1977. *Thysanoëssa spinifera* and *N. simplex* had significant co-occurrence within meal-loads, consistent with other observations that indicate the two species overlap spatially, yet generally have an inverse relationship in areal extent throughout the SCB; both have nearshore shelf distributions (Brinton and Wyllie 1976, Brinton 1981, Gómez-Gutiérrez 1995). During cool-water years with strong upwelling and strong equatorward transport (i.e. 1999), we expected *T. spinifera* to be proportionately more abundant than *N. simplex* in the auklet diet, a pattern consistent with time series data from southern California (Brinton and Townsend 2003).

At Prince Island in 2001, age-0 fish comprised about half the diet by mass; the most important fishes included pleuronectids, *Sebastes* spp. in all years, and Clupeiformes only in 2001. Of the fishes taken, pleuronectids, occurred throughout the study with no apparent seasonal or inter-annual trend, and were the most important fish overall. Pleuronectids were the only prey that significantly co-occurred in all three multi-species prey groups indicating they are ubiquitous in the upper water column within the nearshore foraging extent of provisioning auklets. Pleuronectids, such as arrowtooth flounder *Atheresthes stomias* and Pacific halibut *Hippoglossus stenolepis* have an extended larval duration (Moser 1996); larvae (>10 *A. stomias* and >18 mm *H. stenolepis*), comparable in length to prey taken by auklets (J. Adams unpublished data), migrate to the upper 50 m where they would be available to auklets in the upper watercolumn for greater duration (i.e. throughout the chick-provisioning period ~ 3 mo; Bailey and Piquelle 2002) than other fish species. Furthermore, it is interesting to note the significant co-occurrence within individual meal-loads of pleuronectids with young *Sebastes* spp., copepods, and decapod larvae as both fishes depend on concentrations of these crustaceans for growth and development. Rockfishes (*Sebastes* spp.) were most important in 1999 and decreased in importance during the following two seasons. The year 1999 had particularly strong recruitment year for rockfish off southern California.

Hunt et al. (1979) reported similar contribution of fish to the chick diet at Prince Island in 1976 (30% by volume) and 1977 (44% by volume). Ainley et al. (1996) observed auklets collected at sea during the day off central California apparently selected more fish than euphausiids when the two co-occurred in the upper ocean, however, the relative abundances of these prey were not quantified and their sample of birds was limiting. With the exception of pleuronectids, prey co-occurrence groupings in our study indicated that auklets alternate between foraging on euphausiids and fish depending on what is most available to them. In the absence of euphausiids, auklets relied more on secondary prey including fish, cephalopods, copepods, hyperiid amphipods, and decapods. It seems more likely that variation in diet of auklets is driven by availability rather than selection, however, Vermeer (1981) reported that auklets off Triangle Island, BC appared to select larger copepods and amphipods (>6 mm) over more abundant, but smaller copepods (<5 mm). For example, when diet composition data are presented according to sample period (i.e. by night; Bertram et al. 2001, or by sampling period; Vermeer 1981), relatively clear patterns emerge in the dominance of a single category of prey. These trends also indicate the decline of principle prey through time (i.e. copepods to euphausiids, or copepods to fish; Bertram et al. 2001). Our analysis of co-occurrence provided more specific information on a sample-by-sample basis, however, thus providing further evidence indicating that auklets take prey according to relative availability in their foraging habitat. Moreover, the observation that auklets switch between fish and euphausiids is consistent with patterns observed in gut content analyses of another opportunistic predator with virtually the same diet as auklets, juvenile chinook *Oncorhynchus tshawytscha* and coho *O. kisutch* salmon in the CCS upwelling environment off Oregon. Individual juvenile *O. tshawytscha* and *O. kisutch* contained large amounts of either euphausiids (juvenile *Thysanoëssa spinifera*) or fish (*Ammodytes hexapterus*, flatfishes, *Sebastes* spp.), but not both simultaneously (Peterson et al. 1982). The authors attributed this lack of co-occurrence to prey patchiness, rather than selection.

Auklets nesting at Prince Island maintained similar reproductive output despite large variability in the composition of the principal prey items. In our study, food load mass, reproductive success, mass gain, and peak mass did not differ among years. These results are inconsistent with other studies of alcids that indicated compositional changes in food delivered to chicks can significantly influence the amount and rate of energy transfer to developing chicks, thereby influencing chick growth and fledging success (Takahashi et al. 2001). In British Columbia, Hedd et al. (2002), suspected that reduced chick-growth rates in some years were related to dietary composition. When consuming lipid-rich copepods, *Neocalanus cristatus* (6200 cal g^{-1}; Vermeer 1981, Hedd et al. 2002), auklet chicks gained mass more rapidly than during years when their diet contained greater proportions of euphausiids and fish. More variable inter-annual chick growth and reproductive output associated with changes in diet composition in British Columbia likely was driven by the availability of *N. cristatus*, which does not occur in the diet of auklets off California. Overall, calanoid copepods form only a minor component in the chick diet at California breeding colonies. Unlike British Colombia, small differences in energy densities exist among taxa available to auklets foraging in the SBCH (Spear 1993, JR Mooney in Hedd et al. 2002). Therefore, if adults at Prince Island can maintain sufficient prey delivery, despite changes in prey composition, we do not expect chick growth and reproduction to vary significantly solely as a function of diet composition. This plasticity in diet may help explain the lack of significant relationship between reproductive performance and inter-annual variability in the proportion of *E. pacifica* and *T. spinifera* taken by auklets nesting on the Farallon Islands off central California (Sydeman et al. 2001). Given that our study coincided with one of the strongest and most prolonged cool-water La Nina's on record (Schwing et al. 2000), further study of diet and reproduction of Cassin's auklets in the Channel Islands during contrasting ocean conditions is needed. Differences in reproductive parameters such as growth and fledging success are expected when comparing across extreme events off southern California, such La Niña vs. a strong El Niño event (e.g. 1998; Point Reyes Bird Observatory, unpublished data).

Auklet distribution and diet measured in our study is consistent with observations of other krill predators (Fiedler et al. 1998) and highlights the importance of the western SBCH as a productive and predictable feeding ground. Furthermore, auklets sample the relative abundance of key zooplankton and larval fish species available to them in the northern SCB, and thus provide an independent measure of species trends and zooplankton community composition. he opportunistic feeding habits of Cassin's auklet, and its extensive breeding range, from Mexico to Alaska, make it an ideal species to examine variability in food-webs influenced by regional differences in oceanography and by changing ocean climate. More information is needed on foraging energetics and prey quality at multiple sites throughout the auklet's breeding range. We still need more information regarding oceanographic processes that affect food availability for foraging adults. Surveys targeting specific processes such as persistent cyclonic eddies and frontal regions will help determine mechanisms that enhance prey availability to foraging auklets in the SCB and elsewhere, and will provide a more complete understanding of auklet foraging ecology.

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LITERATURE CITED

ADAMS J, TAKEKAWA JY, CARTER HR (2001) Foraging distribution and movement patterns of Cassin's Auklets nesting at Prince Island and Scorpion Rock, California in 2000. In: Orthmeyer DL, Carter HR, Takekawa JY, Golightly (eds) At-sea distribution of seabirds and marine mammals in the Southern California Bight: 2000 Progress Report. US Geological Survey, Western Ecological Research Center, Vallejo and Dixon, California; and Humboldt State University, Department of Wildlife, Arcata California, p 88–117

ADAMS J, TAKEKAWA, JY, CARTER HR (In Prep) At-sea distribution of Cassin's Auklets nesting at two colonies in the California Channel Islands.

AHLSTROM EH (1959) Vertical distribution of pelagic fish eggs and larvae off California and Baja California. Fish Bull US 161:107–146

AINLEY DG, LEWIS TJ (1974) The history of the Farallon Islands marine bird populations 1834–1972. Condor 76:432–446

AINLEY DG, BOEKELHEIDE RJ, MORRELL SH, STRONG CS (1990) Cassin's Auklet. In: Ainley DG, Boekelheide RJ (eds) Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling–system community. Stanford University Press, Stanford, California, p 306–338

AINLEY DG, SYDEMAN WJ, NORTON J (1995) Upper trophic level predators indicate interannual negative and positive anomalies in the California Current food web. Mar Ecol Prog Ser 118:69–79

AINLEY DG, SPEAR LB, ALLEN SG (1996) Variation in the diet of Cassin's Auklet reveals spatial, seasonal, and decadal occurrence patterns of euphausiid off California, USA. Marine Ecology Progress Series 137:1–10.

ALLEN SE, VINDEIRINHO C, THOMPSON RE, FOREMAN MGG, MACKAS DL (2001) Physical and biological processes over a submarine canyon during an upwelling event. Can J Fish Aquat Sci 58:671–684

ASSIS CA (1996) A generalized index for stomach contents analysis in fish. Sci Mar 60(2–3):385–389

BAILEY KM, PIQUELLE SJ (2002) Larval distribution of off shore spawning flatfish in the Gulf of Alaska: potential transport pathways and enhanced onshore transport during ENSO events. Mar Ecol Prog Ser 236:205–217

BAKUN A (1973) Costal upwelling indices, west coast of North America, 1946–1971. U.S. Dep. Commer., NOAA Tech. Rep., NMFS SSRF-671, 103 pp

BARBER RT, CHAVEZ FP (1986) Ocean variability in relation to living resources during the 1982–83 El Niño. Nature 319:279–285

BERTRAM DF, MACKAS DL, MCKINNELL SM (2001) The seasonal cycle revisited: interannual variation and ecosystem consequences. Progress in Oceanography 49:283–307

BJORKSTEDT EP, ROSENFELD LK, GRANTHAM BA, SHKEDY Y, ROUGHGARDEN J (2002) Distribution of larval rockfishes *Sebastes* spp. across nearshore fronts in a coastal upwelling region. Mar Ecol Prog Ser 242:215–228

BOGRAD SJ, HAYWARD TL, SCHWING FB, DIGIACOMO PM, LYNN RJ, SYDEMAN WJ, MOORE CS, DURAZO R, MANTYLA AW, BAUMGARTNER T, LAVANIEGOS B (2000) The state of the California Current, 1999–2000: forward to a new regime? Calif Coop Ocean Fish Invest Rep 41:26-53

BRAY NA, KEYES A, MORAWITZ WML (1999) The California Current system in the Southern California Bight and the Santa Barbara Channel. J Geophys Res 104(C4):7695–7714

BRINTON E (1981) Euphausiid distributions in the California Current during the warm-water spring of 1977-1978, in the context of a 1949-66 time series. Calif Coop Ocean Fish Invest, Rept. 22:135–154

BRINTON E, WYLLIE JG (1976) Distributional atlas of euphausiid growth stages off southern California, 1953, through 1956. Calif Coop Ocean Fish Atlas No. 24

BRINTON E, TOWNSEND A (2003) Decadal variability in abundances of the dominant euphausiid species in southern sectors of the California Current. Deep-Sea Res II 50:2449–2472

BRODEUR RD (1986) Northward displacement of the euphausiid *Nyctiphanes simplex* Hansen to Oregon and Washington waters following the El Niño event of 1982–83. J. Crustacean Biol. 6:686–692

BRODEUR RD, PEARCY WG (1992) Effects of environmental variability on trophic interactions and food web structure in a pelagic upwelling ecosystem. Mar. Ecol. Prog. Ser. 84:101–119

CARTER HR, MCCHESNEY GJ, JAQUES DL, STRONG CS, PARKER MW, TAKEKAWA JE, JORY DL, WHITWORTH DL (1992) Breeding populations of seabirds in California, 1989–1991. Unpublished Draft Final Report, U. S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California.

DURAZO R, BAUMGARTNER TR, BOGRAD SJ, COLLINS CA, DE LA CAMPA S, GARCIA J, GAXIOLA-CASTRO G, HUYER A, HYRENBACH KD, LOYA D, LYNN RJ, SCHWING FB, SMITH RL, SYDEMAN WJ, WHEELER P (2001) The state of the California Current, 2000–2001: a third straight La Niña year. Calif Coop Ocean Fish Invest Rep 42:29–60

FAGER, E.W. 1957. Determination and analysis of recurrent groups. Ecology 38:586-595.

FAGER, E.W., AND J.A. MCGOWAN. 1963. Zooplankton species groups in the North Pacific. Science 140:453-460.

FERRY LA, CAILLIET GM (1996) Sample size and data analysis: are we characterizing and comparing diet properly? In: MacKinlay D, Shearer K (eds) Gutshop '96: Feeding ecology and nutrition in fish, physiology section, American Fisheries Society, International Congress on the Biology of Fishes, San Francisco State University, July 14-18, 1996 p 71–80

FIEDLER PC, REILLY SB, HEWITT RP, DEMER D, PHILBRICK VA, SMITH S, ARMSTRONG W, CROLL DA, TERSHY BT, MATE BR (1998) Blue whale habitat and prey in the California Channel Islands. Deep-Sea Res II 45:1781–1801

FLINT MV, GOLOVKIN AN (2002) How do planktivorous least auklets (*Aethia pusilla*) use foraging habitats around breeding colonies? Adaptation to mesoscale distribution of zooplankton. Oceanology 42 Suppl 1:S114–S121

Gomez, JG (1995) Distribution patterns, abundance and population dynamics of the euphausiids Nyctiphanes simplex and Euphausia eximia off the west coast of Baja California, Mexico. Mar Ecol Prog Ser 119:63–76

Graham WM, Largier JL (1997) Upwelling shadows as nearshore retention sites: the example of northern Monterey Bay. Cont Shelf Res 17(5):509–532

Hare SR, Mantua NJ, Francis RC (1999) Inverse production regimes: Alaska and West Coast Pacific salmon. Fisheries 24: 6-14

Harms S, Winant CD (1998) Characteristic patterns of the circulation in the Santa Barbara Channel. J Geophys Res 103:3041–3065

Harvey JT (1989) Food habits, seasonal abundance, size, and sex of the blue shark, *Prionace glauca*, in Monterey Bay, California. Cal Fish and Game 75(1):33–44

Hayward TL, Baumgartner TR, Checkley DM, Durazo R, Gaxiola-Castro G, Hyrenbach KD, Mantyla AW, Mullin MM, Murphree T, Schwing FB, Smith PE, Tegner M (1999) The state of the California Current, 1998–1999: transition to cool-water conditions. Calif Coop Ocean Fish Invest Rep 40:29–62

Hedd A, Ryder JL, Cowen LL, Bertram DF (2002) Inter-annual variation in the diet, provisioning and growth of Cassin's auklet at Triangle Island, British Columbia: responses to variation in ocean climate. Mar Ecol Prog Ser 229:221–232

Hooge PN, Eichenlaub B (1997) Animal movement extension to ArcView. ver. 2.04. Alaska Biological Science Center, USGS, Anchorage, AK

Hunt GL Jr, Pitman RL, Naughton M, Winnet K, Newman A, Kelly PR, Briggs KT (1979) Summary of marine mammal and seabird surveys of the southern California Bight area 1975–1978. Volume III: investigators reports. Part III. Seabirds. Book II. Reproductive ecology and foraging habits of breeding seabirds. Unpublished Final Report, University of California, Institute of Marine Sciences, Santa Cruz, California.

Hunt GL Jr, Harrison NM, Piatt JF (1993) Foraging ecology as related to the distribution of planktivorous auklets in the Bering Sea. In: K. Vermeer, KT Briggs, KH Morgan, Siegel-Causey D (eds) The Status and Ecology, and conservation of marine birds in the north Pacific, pp. 18-26. Canadian Wildlife Service, Ottawa.

Huntley ME, Gonzalez A, Zhu Y, Zhou M, Irigoien X (2000) Zooplankton dynamics in a mesoscale eddy-jet system off California. Mar Ecol Prog Ser 201:165–178

Hurtubia, J (1973) Trophic diversity measurement in sympatric predatory species. Ecology 54(4):885–890

Kitaysky AS, Golubova EG (2000) Climate change causes contrasting trends in reproductive performance of planktivorous and piscivorous alcids. J of Animal Ecol 69(2):248–262

Lewis DB, Gress F, Ingram T, Hunt GL Jr, Anderson DW (1988) Seabird monitoring handbook. Natural Science Report CHIS-99-0002, Channel Islands National Park, Ventura, California.

MacArthur RH (1965) Patterns of species diversity. Biol Rev 40:510–533

Manuwal DA (1974) The natural history of Cassin's Auklet (*Ptychoramphus aleuticus*). Condor 76:421-431

Marinovic BB, Croll DA, Gong N, Benson SR, Chavez FP (2002) Effects of the 1997–1999 El Niño and La Niña events on zooplankton abundance and euphausiid community composition within the Monterey Bay coastal upwelling system. Prog in Oceanogr 54:265–277

MARTIN JW, DAVIS GE (2001) An updated classification of the recent Crustacea. Science Series 39, Natural History Museum of Los Angeles County.

MARTIN PL, SYDEMAN WJ (1998) Seabird Monitoring Channel Islands National Park. National Park Service, Channel Islands National Park Technical Report 98-03.

MCGOWAN JA, CAYAN DR, DORMAN LM (1998) Climate-ocean variability and ecosystem response in the northeast Pacific. Science 281:210–217

MONAGHAN PJ, UTTLEY D, OKILL JD (1989) Terns and sandeels: seabirds as indicators of changes in marine fish populations. J Fish Bio 35 (Suppl. A):339–340

MORBEY E, YDENBERG RC (1997) Intraspecific variability in nestling growth and fledging behavior of Cassin's auklets at Triangle Island, British Columbia. Condor 99:361–371

MOSER GH (ed) (1996) The early stages of fishes in the California Current region. California Cooperative Fisheries Investigations Atlas No. 33. 1505 p

MOSER GH, SMITH PE (1993) Larval fish assemblages of the California Current region and their horizontal and vertical distributions across a front. Bull Mar Sci 53(2):645–691

NISHIMOTO MM, WASHBURN L (2002) Patterns of coastal eddy circulation and abundance of pelagic juvenile fish in the Santa Barbara Channel, California, USA. Mar Ecol Prog Ser 241:183–189

NEWMAN, SH, TAKEKAWA JY, WHITWORTH DL, BURKETT E (1999) Subcutaneous anchor attachment increases retention of radio transmitters on Xantus' and Marbled Murrelets. J Field Ornithol 70(4):520–534

NORTON J, MCLAIN D (1994) Diagnostic patterns of seasonal and interannual temperature variation off the west coast of the United States: local and remote forcing. J. Geophys Res 99:16019–16030

ODEKOVEN CS, AINLEY DG, SPEAR LB (2001) Variable responses of seabirds to change in marine climate: California Current, 1985–1994. Mar Ecol Prog Ser 212:265–281

OEY LY, WANG DP, HAYWARD T, WINANT C, HENDERSHOTT M (2001) "Upwelling" and "cyclonic" regimes of the near-surface circulation in the Santa Barbara Channel. J Geophys Res-Oceans 106 (C5):9213–9222

PETERSON WT, BRODEUR RD, PEARCY WG (1982) Food habits of juvenile salmon in the Oregon coastal zone, June 1979. Fish Bull 80:(4) 841–851

PETERSON WT, KEISTER JE (2002) The effect of a large cape on distribution patterns of coastal and oceanic copepods off Oregon and northern California during the 1998-1999 El Nino-La Nina. Prog Oceanogr 53:389–411.

PRETI, A, SMITH SE, RAMON DA (2001) Feeding habits of the common thresher shark (*Alopias vulpinus*) sampled from the California-based drift gill net fishery, 1998–1999. Calif Coop Ocean Fish Invest Rep 42:145–152

REBSTOCK GA (2001) Long-term stability of species composition in calanoid copepods off southern California. Mar Ecol Prog Ser 215:213–224

SALL J, LEHMAN A, CREIGHTON L (2001) JMP start statistics: a guide to statistics and data analysis using JMP and JMP IN software. SAS Institute Inc., Cary, North Carolina, USA.

SAS INSTITUTE, INC. (1998) StatView: StatView reference, 2nd edition. SAS Institute Inc., Cary, North Carolina, USA.

SCHOENHERR JR (1989) Blue whales feeding on high concentrations of euphausiids around Monterey Submarine Canyon. Can J Zool 69:583–594

Schwing FB, O'Farrell M, Steger J, Baltzn K (1996) Coastal Upwelling Indices, West coast of North America, 1946-1995. U.S. Dept. of Commerce, NOAA Tech. Memo. NOAA-TM-NMFS-SWFC-231, 207p.

Schwing FB, Moore CS, Ralston S, Sakuma KM (2000) Record coastal upwelling in the California Current in 1999. Calif Coop Ocean Fish Invest Rep 41:148-160

Smith SE and Adams PB. 1988. Daytime surface swarms of *Thysanoessa spinifera* (Euphausiacea) in the Gulf of the Farallones, California. Bull Mar Sci 42(1):76-84

Spear LB (1993) Dynamics and effect of western gulls feeding in a colony of guillemots and Brandt's cormorants. J Anim Ecol 62:399–414

Speich S, Manuwal DA (1974) Gular pouch developement and population structure of Cassin's Auklet. Auk 91:291–306

Stobutski IC, Bellwood DR (1997) Sustained swimming abilities of the late pelagic stages of coral reef fishes. Mar Ecol Prog Ser 149:35–41

Sydeman WJ, Hester MM, Thayer JA, Gress F, Martin P, Buffa J (2001) Climate change, reproductive performance and diet composition of marine birds in the southern California Current system, 1969–1997. Prog Ocean 49:309–329

Takahashi A, Kuroki M, Niizuma Y, Kato A, Saitoh S, Watanuki Y (2001) Importance of the Japanese anchovy (*Engraulis japonicus*) to breeding rhinoceros auklets (*Cerorhinca monocerata*) on Turi Island, Sea of Japan. Mar Bio 139:361–371

Tanasichuk RW, Cooper C (2002) A northern extension of the range of the euphausiid *Nyctiphanes simplex* into Canadian waters. J Crustacean Bio 22:206-209

Torres JJ, Childress JJ (1983) Relationship of oxygen consumption to swimming speed in Euphausia pacifica I. Effects of temperature and pressure. Mar Bio 74:79–86

Vermeer K (1981) The importance of plankton to Cassin's auklets during breeding. J Plankton Res 3:315–329

Vermeer K, Fulton JD, Sealy SG (1985) Differential use of zooplankton prey by Ancient murrelets and Cassin's auklets in the Queen Charlotte Islands. J Plankton Res 7(4):443–459

Whitaker RH (1952) A study of summer foliage insect communities in the Great Smokey Mountains. Ecol Monogr 22:1–44

Whitaker RH, Fairbanks CW (1958) A study of plankton copepod communities in the Columbia Basin, southeastern Washington. Ecology 39:46–65

Table 4.1. Cassin's Auklet diet sample effort and radio-telemetry at Prince Island during three consecutive nesting seasons (1999 – 2001) including diet sampling periods, number of diet samples collected, telemetry survey periods, number of active transmitters, and number of locations determined.

	Diet sampling			Radio telemetry			
Year Period	Start date	End date	No. samples	Start date	End date	No. active transmitters	No. locations
1999							
Early	6 March	12 May	74	7 March	20 May	30	266
Late	21 May	19 July	70	24 May	24 June	11	80
2000							
Early	11 April	15 May	38	12 April	14 May	21	287
Late	6 June	27 June	29	17 May	12 June	18	148
2001							
Both	30 April	28 June	66	5 April	22 June	24	149
Totals			277				930

Table 4.2. Summary of Cassin's Auklet chick diet composition collected on Prince Island and pooled over three consecutive years (1999–2001). Data include three relative measures of prey quantity (RMPQ): percent number (%*N*), percent wet mass (%*M*), and percent frequency occurrence (%*F*), used to calculate the geometric index of importance (GII) for individual prey groupings and broad taxonomic categories. F=female, M=Male, and juv=juvenile.

Prey Item	N	M	F	%N	%M	%F	GII
Acanthocephala	**7**	**0.176**	**5**	**0.02**	**0.00**	**1.80**	**1.05**
Chaetognatha	**1**	**0.024**	**1**	**0.00**	**0.00**	**0.36**	**0.21**
Mollusca Total	**170**	**159.329**	**65**	**0.50**	**4.38**	**23.38**	**16.32**
Cephalopoda	168	159.326	64	0.49	4.38	23.02	16.11
Loligo opalescens	139	147.458	54	0.41	4.06	19.42	13.79
Octopus spp.	29	11.869	14	0.09	0.33	5.04	3.15
Gastropoda veliger	2	0.003	1	0.01	<0.01	0.36	0.21
Crustacea Total	**31147**	**2429.626**	**255**	**91.32**	**66.83**	**91.73**	**144.26**
Class Maxillopoda							
Subclass Copepoda							
O. Calanoida Total	**1150**	**1.640**	**32**	**3.37**	**0.05**	**11.51**	**8.62**
Acartia californiensis (F)	350	0.419	8	1.03	0.01	2.88	2.26
Acartia californiensis (M)	90	0.076	4	0.26	<0.01	1.44	0.98
Acartia danae (F)	7	0.003	1	0.02	<0.01	0.36	0.22
Acartia longiremis (F)	5	0.004	1	0.01	<0.01	0.36	0.22
Aetidieus divergens (F)	8	0.009	1	0.02	<0.01	0.36	0.22
Aetidieus pacificus (F)	3	0.007	1	0.01	<0.01	0.36	0.21
Calanus marshallae (undetermined sex)	6	0.051	1	0.02	<0.01	0.36	0.22
Calanus marshallae (F)	6	0.005	2	0.02	<0.01	0.72	0.43
Calanus pacificus (F)	358	0.729	17	1.05	0.02	6.12	4.15
Calanus pacificus (M)	61	0.104	5	0.18	<0.01	1.80	1.14
Centropages bradyi (F)	1	0.001	1	<0.01	<0.01	0.36	0.21
Clausocalanus lividus (F)	16	0.016	2	0.05	<0.01	0.72	0.44
Corycaeus angelicus (M)	20	0.015	1	0.06	<0.01	0.36	0.24
Ctenocalanus vanus (M)	22	0.015	1	0.06	<0.01	0.36	0.25
Eucalanus californicus (F)	1	0.003	1	0.00	<0.01	0.36	0.21
Metridia pacifica (undetermined sex)	63	0.042	4	0.18	<0.01	1.44	0.94
Metridia pacifica (F)	31	0.019	4	0.09	<0.01	1.44	0.88
Paracalanus parvus (undetermained sex)	7	0.015	1	0.02	<0.01	0.36	0.22

Paracalanus parvus (F)	92	0.099	5	0.27	<0.01	1.80	1.20
Rhinocalanus nasatus (F)	3	0.007	1	0.01	<0.01	0.36	0.21
Class Malacostraca							
O. Mysida Total	**323**	**21.337**	**3**	**0.95**	**0.59**	**1.08**	**1.51**
Holmesimysis sculpta	1	0.027	1	<0.01	<0.01	0.36	0.21
Acanthomysis columbiae	322	21.310	2	0.94	0.59	0.72	1.30
O. Amphipoda Total	**297**	**6.779**	**32**	**0.87**	**0.19**	**11.51**	**7.26**
Suborder Hyperiidea							
Paraphronima gracilis	1	0.026	1	<0.01	<0.01	0.36	0.21
Primno brevidens	2	0.026	2	0.01	<0.01	0.72	0.42
Vibilia propinqua	259	4.976	17	0.76	0.14	6.12	4.05
Vibilia cultripes	14	1.022	6	0.04	0.03	2.16	1.29
Hyperia medusarum	16	0.628	12	0.05	0.02	4.32	2.53
Brachycelus crusculum	5	0.101	4	0.01	<0.01	1.44	0.84
O. Euphausiacea Total	**29257**	**2388.302**	**236**	**85.78**	**65.69**	**84.89**	**136.46**
F. Euphausiidae							
Euphausia pacifica	4845	534.398	99	14.20	14.70	35.61	37.25
Euphausia pacifica (juv)	72	2.397	3	0.21	0.07	1.08	0.78
Nyctiphanes simplex	2094	107.370	59	6.14	2.95	21.22	17.50
Thysanoessa spinifera	6569	789.071	153	19.26	21.70	55.04	55.43
Thysanoessa spinifera (juv)	15172	929.791	116	44.48	25.58	41.73	64.54
Thysanoessa gregaria	420	23.437	16	1.23	0.64	5.76	4.41
Thysanoessa gregaria (juv)	29	0.942	1	0.09	0.03	0.36	0.27
Nematocelis difficilis	18	0.808	2	0.05	0.02	0.72	0.46
Euphausiid protozoea	38	0.089	2	0.11	<0.01	0.72	0.48
O. Decapoda Total	**124**	**11.687**	**44**	**0.36**	**0.32**	**15.83**	**9.53**
F. Aristaeidae							
Bentheogennema burkenroadi	1	0.071	1	<0.01	<0.01	0.36	0.21
F. Penaeidae	9	0.272	7	0.03	0.01	2.52	1.47
Infraorder Caridea							
Caridea (mysis)	6	0.242	4	0.02	0.01	1.44	0.84
F. Hippolytidae	4	0.120	4	0.01	<0.01	1.44	0.84
Lysmata spp. (mysis)	14	0.894	6	0.04	0.02	2.16	1.28
Lysmata spp. (zoea)	16	0.213	4	0.05	0.01	1.44	0.86
F. Pandalidae							
Pandalid (mysis)	2	0.023	2	0.01	<0.01	0.72	0.42
Infraorder Astacidea							
Panulirus interuptus	1	0.234	1	<0.01	0.01	0.36	0.21
Infraorder Anomura (unidentified)	15	8.220	15	0.04	0.23	5.40	3.27
F. Hippidae							
Emerita analoga	8	0.221	4	0.02	0.01	1.44	0.85

Emerita analoga (zoea)	1	0.015	1	<0.01	<0.01	0.36	0.21
F. Paguridae (zoea)	3	0.057	1	0.01	<0.01	0.36	0.21
Infraorder Brachyura (unidentified)	1	0.202	1	<0.01	0.01	0.36	0.21
Brachyura (megalops)	5	0.155	4	0.01	<0.01	1.44	0.84
F. Cancridae							
Cancer spp. (megalops)	31	0.583	8	0.09	0.02	2.88	1.72
F. Grapsidae							
Hemigrapsus spp. (megalops)	7	0.164	2	0.02	<0.01	0.72	0.43
Teleostei Total	**2702**	**1042.354**	**152**	**7.92**	**28.67**	**54.68**	**52.69**
F. Pleuronectidae	1402	669.087	116	4.11	18.40	41.73	37.09
Atheresthes spp.	7	0.274	2	0.02	0.01	0.72	0.43
F. Scorpaenidae							
Sebastes spp.	230	75.447	64	0.67	2.08	23.02	14.88
F. Cottidae tot.	359	140.159	28	1.05	3.86	10.07	8.65
Cottidae (unidentified)	84	31.160	12	0.25	0.86	4.32	3.13
Scorpaenichthys marmoratus	13	5.805	5	0.04	0.16	1.80	1.15
Hemilepidotus spp.	238	100.861	7	0.70	2.77	2.52	3.46
Artideus spp.	24	2.333	7	0.07	0.06	2.52	1.53
F. Gasterosteidae							
Aulorhynchus spp.	2	0.078	2	0.01	<0.01	0.72	0.42
F. Clupeidae	654	132.575	19	1.92	3.65	6.83	7.16
F. Parapalepidae	1	0.043	1	<0.01	<0.01	0.36	0.21
Unidentified fish larvae	47	24.690	3	0.14	0.68	1.08	1.09
Unidentified							
Attached eggs	48	0.282	1	0.14	0.01	0.36	0.29
Egg cluster	16	0.088	1	0.05	<0.01	0.36	0.24
Gelatinous remains	14	3.515	7	0.04	0.10	2.52	1.53
Unidentified organic matter		230.168	169		6.33	60.79	
TOTALS	**34109**	**3635.5132***	**278**				

*total minus unidentified organic matter

Table 4.3. Mass (g, mean ± SD) of complete meal-loads, and broad prey composition (% wet mass) of Cassin's Auklet chick diet from Prince Island during 3 consecutive nesting seasons (1999–2001).

	Meal-loads		Prey composition (% wet mass)		
Year	Mass (g)	(n)	Crustaceans	Fish	Cephalopods
1999	21.2 ± 9.5	66	64.9	24.6	2.7
2000	24.4 ± 7.2	27	75.0	16.7	3.4
2001	24.1 ± 9.5	33	47.4	42.8	7.3

Table 4.4. Co-occurrence of prey items within individual Cassin's Auklet meal-loads delivered to chicks on Prince Island during 3 consecutive nesting seasons (1999 – 2001). Values above the diagonal are Fager's Index of Affinity (IA); values in bold (IA ≥0.30) indicate significant co-occurrences. Values below the diagonal are the number of co-occurrences for each item out of the total number of occurrences for each item (bottom row). Abbreviations are as follows: gelatinous material (Gel), cephalopods (Ceph), copepods (Cope), hyperiid amphipods (Hyper), *Euphausia pacifica* (Epac), *Nyctiphanes simplex* (Nsim), adult Thysanoëssa spinifera (TspinA), juvenile Thysanoëssa spinifera (TspinJ), decapod crustaceans (Deca), Pleuronectid fishes (Pleuro), rockfishes (Sebastes), (Cottidae), and clupeiform fishes (Clupe).

	Prey												
	Gel	Ceph	Cope	Hyper	Epac	Nsim	TspinA	TspinJ	Deca	Pleuro	Sebastes	Cottidae	Clupe
Gel		-0.09	0.10	**0.32**	-0.01	-0.10	0.10	-0.01	0.16	0.18	0.08	-0.01	0.11
Ceph	2		0.18	**0.31**	0.22	0.15	0.18	0.19	**0.36**	**0.40**	**0.31**	**0.33**	0.17
Cope	2	6		0.06	0.18	0.05	0.15	0.16	**0.34**	**0.35**	**0.36**	0.26	0.24
Hyper	4	9	3		0.07	-0.05	0.15	0.03	0.29	0.28	0.15	0.13	**0.31**
Epac	1	11	7	4		**0.32**	**0.48**	0.24	0.21	**0.44**	**0.38**	0.19	0.05
Nsim	0	7	3	1	14		**0.51**	0.23	0.24	**0.30**	0.26	-0.05	-0.10
TspinA	3	11	7	7	31	25		**0.59**	0.19	**0.39**	0.28	0.09	-0.03
TspinJ	1	11	7	3	16	12	43		0.11	0.20	0.07	0.07	-0.03
Deca	3	13	9	8	10	9	11	7		**0.44**	0.26	0.10	0.24
Pleuro	4	19	12	10	25	14	27	15	19		**0.47**	0.29	0.29
Sebastes	2	11	9	5	15	9	14	5	9	19		0.21	0.07
Cottidae	1	9	6	4	7	1	5	4	4	10	6		**0.32**
Clupe	2	5	5	6	3	0	1	1	6	9	3	6	
Tot. Occur.	5	31	16	16	46	27	71	62	27	52	24	15	12

Table 4.5. Breeding success (percent of parents successfully fledging a chick), chick growth rate (g d^{-1}, mean ± SE), chick peak mass (g, mean ± SE), chick wing growth rate (mm d^{-1}, mean ± SE), and percent of Cassin's Auklet pairs initiating a second clutch on Prince Island during 3 consecutive nesting seasons (1999 – 2001); sample sizes in parentheses.

Year	% Fledged	Mass gain (g d^{-1})	Peak mass	Wing growth (mm d^{-1})	% double-clutch
1999	84 (19)	3.1 ± 0.7 (12)	150 ± 6 (11)	2.9 ± 0.1 (16)	63 (16)
2000	84 (19)	4.9 ± 0.3 (2)	146 ± 3 (12)	2.9 ± 0.1 (12)	75 (16)
2001	93 (30)	3.7 ± 0.3 (11)	150 ± 3 (27)	3.0 ± 0.1 (18)	7 (29)

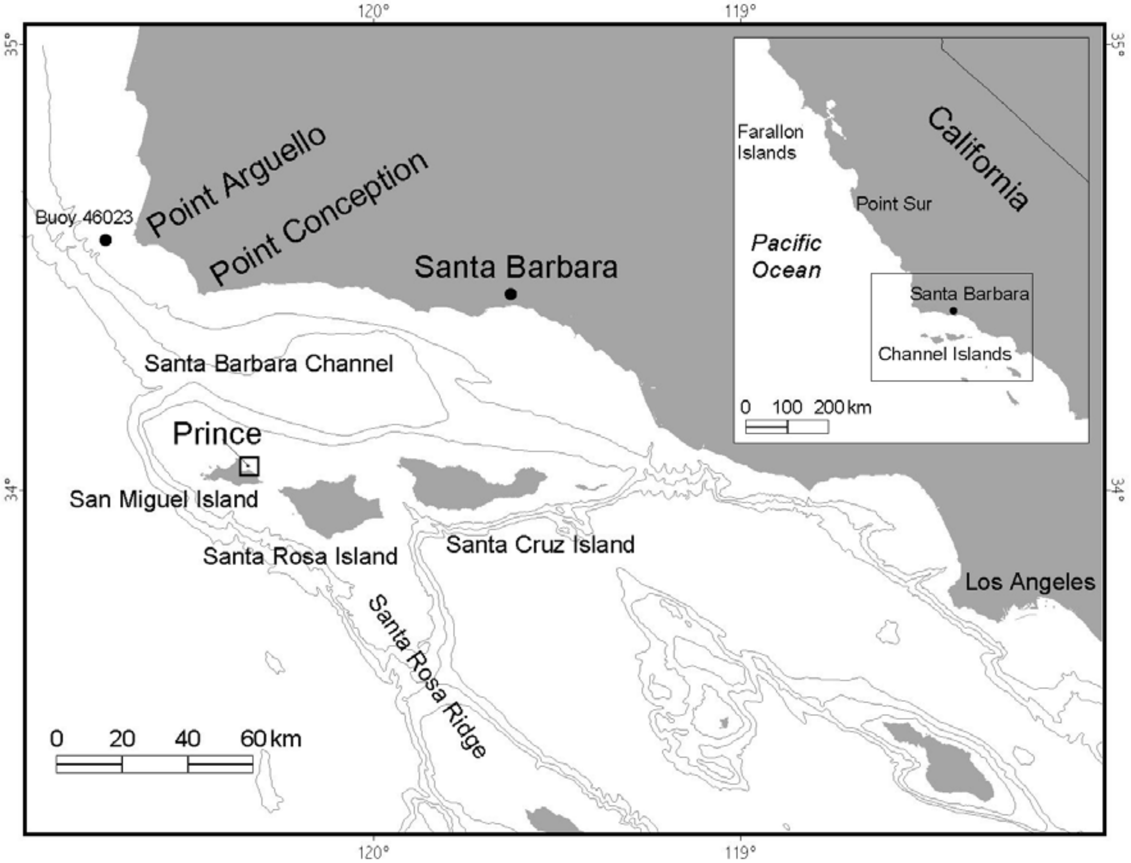

Figure 4.1. California coast (inset) and the principal study area Prince Island (located 1 km north of San Miguel Island and enclosed by a small box) in the northern Channel Islands, California, USA. Lines show bathymetric features at 200-m intervals. Data from NDBC buoy 46023, located off Point Arguello was used to calculate SST anomalies during 1999–2001 (see Methods, Oceanographic conditions).

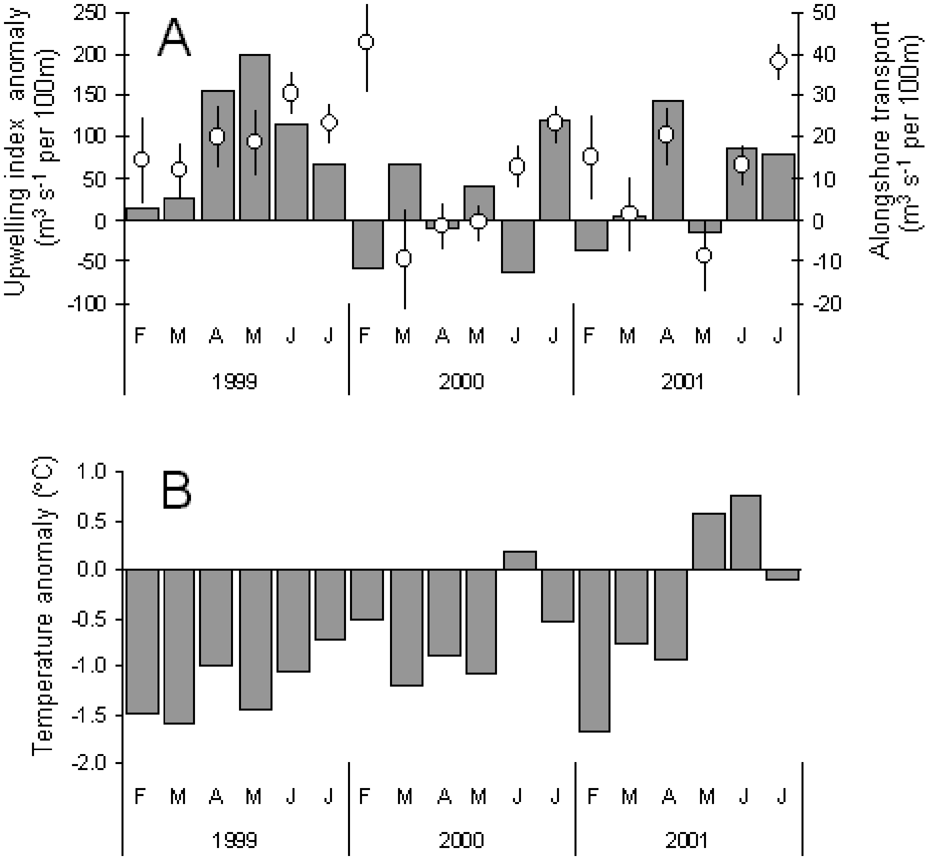

Figure 4.2. Monthly (February to July) variability in (A) upwelling index anomaly (bars: m^3 s^{-1} per 100-m coastline at 36°N) and alongshore transport (circles: m^3 s^{-1} per 100-m coastline at 36°N ± SE). Also shown (B) is the deviation from the long-term mean sea surface temperature (SST) at buoy 46023 off Point Arguello.

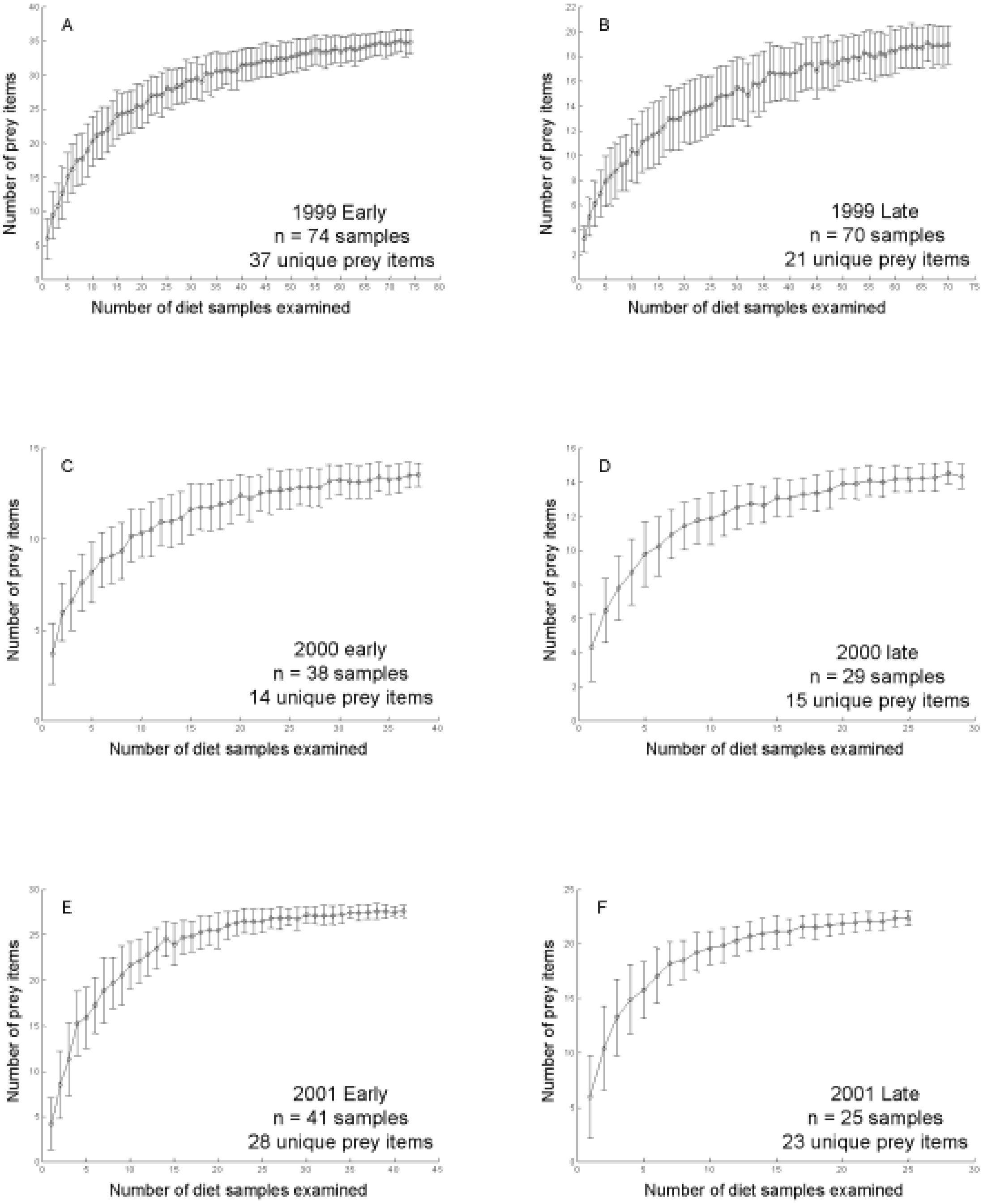

Figure 4.3. Cumulative species curves for each auklet diet sampling period during each of three consecutive years (1999–2001). Curves represent bootstrapped number of samples examined *vs.* number of unique prey items (± 1 SD).

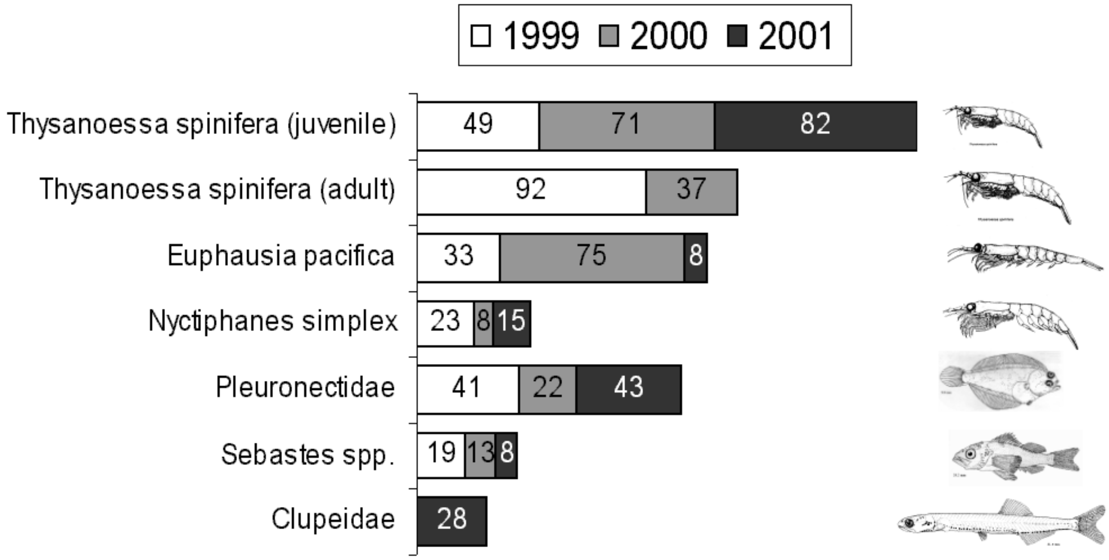

Figure 4.4. *Ptychoramphus aleuticus*. Annual variability in the geometric index of importance (GII) for the seven top ranking prey items identified in meal-load samples collected from provisioning parents on Prince Island during three consecutive years (1999–2001). Data labels on sub-bars indicate calculated GII.

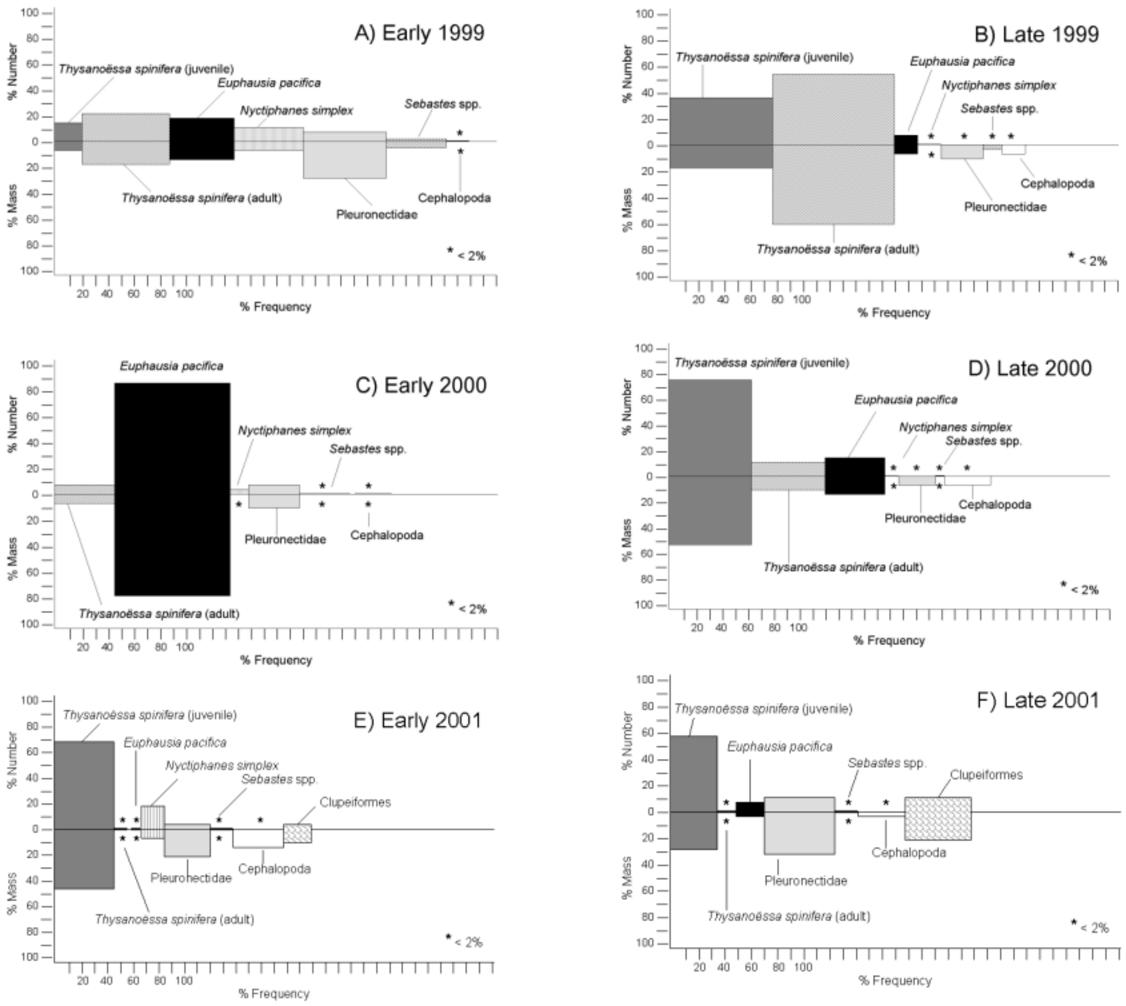

Figure 4.5. *Ptychoramphus aleuticus*. Index of relative importance representing the intra-annual variability among three relative measures of prey quantity (RMPQ): percent number (%*N*), percent mass (%*M*), and percent frequency (%*F*) for the seven top ranking prey items identified in diet samples collected from provisioning parents on Prince Island during three consecutive years (1999–2001), area of box represents relative importance.

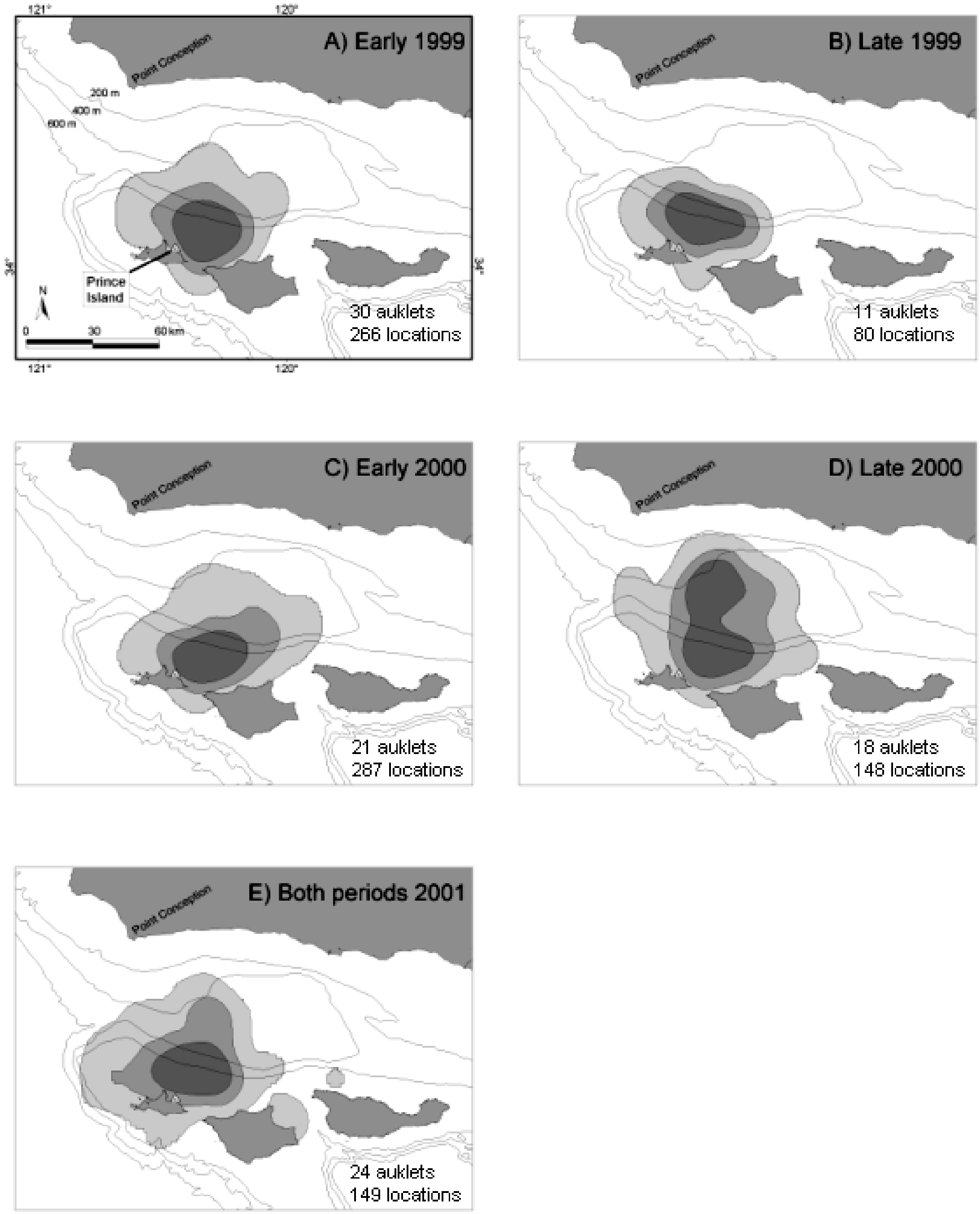

Figure 4.6. *Ptychoramphus aleuticus*. Fixed-kernel probability-density contours (50, 75, 95%) indicating the foraging areas used by provisioning auklets during early and late periods in each year: (A) early 1999, (B) late 1999, (C) early 2000, (D) , (E) 2001 (both periods combined because of few late breeding auklets). Lines show bathymetric features at 200-m intervals.

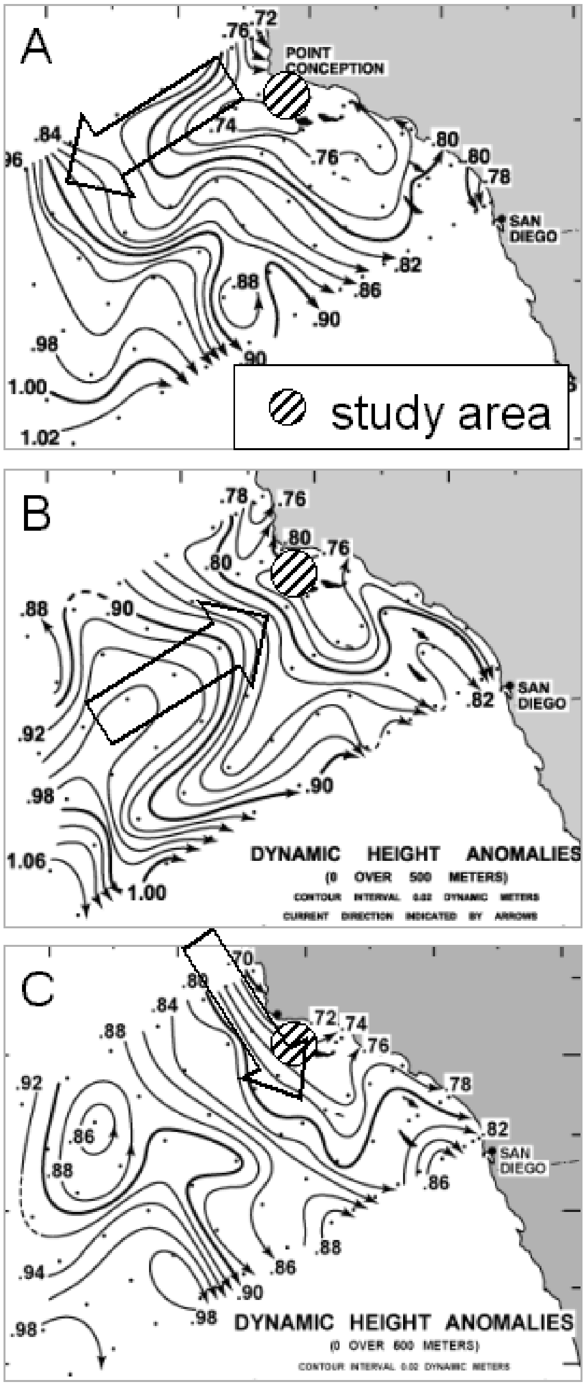

Figure 4.7. Contoured dynamic height anomalies from hydrographic data collected during annual CalCOFI oceanographic surveys off southern California. Isolines represent meso-scale patterns in the direction of current flow. The auklet foraging area is indicated by hatched circle, and arrows describe relative flow; (A) April 1999, (B) April 2000, (C) April 2001.

CHAPTER 5:

AT-SEA DISTRIBUTION AND FORAGING HABITATS OF XANTUS'S MURRELETS IN THE SOUTHERN CALIFORNIA BIGHT

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Abstract: We examined at-sea distribution and foraging habitat of Xantus's Murrelets in the Southern California Bight (SCB) during the breeding season from April to June of 2002 and 2003. Radio transmitters were attached to murrelets from Anacapa Island (n = 34 in 2002, n = 44 in 2003) and Santa Barbara Island (n = 34 in 2002). The SCB was searched to locate murrelets 4 days per week from April-June from an aircraft. We conducted 29 h of diving observations of murrelets with radio transmitters in 2003 by timing underwater dives and pause times between dives. For murrelets captured at Anacapa Island, at-sea locations were farther from Anacapa Island in 2002 compared to 2003. Similarly, home range sizes were significantly larger and murrelets left the vicinity of the nesting colony sooner in 2002 compared to 2003, indicating that conditions in the SCB may have been unfavorable in 2002. Distance to nearest shore, sea surface temperature and water depth associated with murrelet locations were significantly greater in 2003 compared to 2002. In 2003, automated telemetry systems on Anacapa Island detected frequent nocturnal attendance in the nearshore waters of the island, with a mean of 12.2 ± 1.8 nights per murrelet. Many of these murrelets were likely non-incubating. Nocturnal attendance may be a constraint to the distance that murrelets travel during the day to forage; murrelets that spent more nights in the nearshore waters of Anacapa Island were closer to the island during the day. Murrelet dives were relatively short in the 3 time periods (19, 29, and 30 s), indicating that they were foraging on prey near the surface of the water. Favorable foraging conditions until mid-May in 2003 may have allowed murrelets to forage in close proximity to the colony during the day and frequently attend nearshore colony waters at night. They were likely foraging on prey at or near the surface of the water when near Anacapa Island.

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INTRODUCTION

Xantus's Murrelets (*Synthliboramphus hypoleucus*) have a world population size of less than 10,000 individuals and a concentrated distribution when breeding (Drost and Lewis 1995, Carter et al. 2000). They only nest on islands off the west coast of Baja California and on the California Channel Islands (Drost and Lewis 1995, Carter et al. 2000, Whitworth et al. 2000). The largest known nesting colony in California (500-1250 pairs) is located on Santa Barbara Island, one of the Channel Islands (Drost and Lewis 1995, California Dept. of Fish and Game 2002). Anacapa Island, one of the northern Channel Islands, has an estimated population size of 200-600 breeding pairs (California Dept. of Fish and Game 2002, Whitworth et al. 2002).

Because of their small population size and concentrated breeding distribution, murrelets are subject to several at-sea and colony threats. These threats include oil spills and other types of pollution, as well as avian and mammalian predators (Drost and Lewis 1995, Carter et al. 2000). The long-term viability of populations of Xantus's Murrelets has been questioned (Carter et al. 1992, Sydeman et al. 1998, Wolf et al. 2000), and in October 2002, the California Department of Fish and Game Commission reviewed the population status of murrelets and adopted emergency regulations for protection of the species (California Dept. of Fish and Game 2002) while considering formal listing under the California Endangered Species Act. Further, U.S. Fish and Wildlife Service accepted a petition in June 2002 to consider federal listing of the species under the U.S. Endangered Species Act (California Dept of Fish and Game 2002).

In 1975, Hunt et al. (1979) established seven transects at points around the perimeter of Santa Barbara Island that extended from shore out to 18.5 km from the island. These transects were surveyed in 1975, 1976, and 1977. Peak murrelet densities occurred within 12.5 km from shore, leading them to believe that murrelets forage within 18 km from the island during the breeding season. In 1997, Humboldt State University (HSU) and United States Geological Survey (USGS) conducted boat surveys using the same transects as the 1975-77 surveys. Significantly fewer murrelets were found within 18 km of the island (Whitworth et al. 1997a). It is unclear whether fewer murrelets found near Santa Barbara Island in 1997 in comparison to 1975-77 indicated a decline in the population, a change in availability and location of prey, or both. In 1995-97, a study conducted by HSU and USGS to describe the home ranges of murrelets around Santa Barbara Island (using radio telemetry) found that murrelets foraged long distances from Santa Barbara Island in 1996 (62 ± 25 km; mean ± SD) and in 1997 (111 ± 44 km), and movements by individuals were highly variable within and between years (Whitworth et al. 2000).

The 1995-97 telemetry work on murrelets challenged the previous assumption based on the research conducted by Hunt et al. (1979) that they foraged relatively close to the islands during the breeding season. Murrelets exhibit several adaptations that allow for long-distance foraging from colonies, such as long incubation shifts, the ability to leave eggs unattended for a period of time, and the fact that chicks are only provisioned at sea, which enables adults to forage widely for prey occurring far from nesting colonies (Carter et al. 2000).

The foraging behaviors of murrelets may be dependent upon the variable distributions of available prey. Murrelets must have the ability to travel long distances from the breeding colony to obtain prey, and choice in at-sea foraging locations is probably a direct result of prey availability and detectability. Interannual variability in the locations of marked individuals in 1996 and 1997, and the clumping of marked individuals on some occasions (Whitworth et al. 2000) are consistent with use of patchy and mobile prey resources. The dynamic nature of the SCB, especially during the spring upwelling events that coincide with murrelet nesting, provides multiple habitat types for various prey species. Therefore, we wanted to determine if distributions of murrelets were correlated with certain oceanographic-bathymetric conditions that affect prey distributions. Ocean conditions associated with murrelet foraging, along with information about prey type and water depth, can be used to infer prey resources and identify habitat used by murrelets.

Because murrelets have a concentrated breeding distribution and a small world population size, they are susceptible to anthropogenic environmental perturbations, such as a single large oil spill, that could potentially extirpate the entire population (Baird 1993, Carter et al. 2000). Determining the distributional patterns of murrelets in the SCB during the breeding season may help to identify proper management responses to anthropogenic activities.

The objectives of this study were to: 1) describe distribution of murrelets during the breeding season in the SCB, focusing on murrelets from Anacapa Island, 2) characterize foraging habitat by comparing murrelet locations with habitat variables including sea surface temperature, water depth, distance from the breeding colony and from land, 3) make inferences on the distribution of resources (based on ocean conditions) for examination of the contrasting reports of Hunt et al. (1979) and Whitworth et al. (2000); 4) gain information on foraging and diving behavior to help determine depth of prey.

METHODS

Capture and Radio Attachment

Captures. – In 2002, we captured Xantus's Murrelets at night in the near shore waters of Santa Barbara Island and Anacapa Island using a night-lighting capture technique (Whitworth et al. 1997b). We repeated this effort in 2003 off Anacapa Island. Three-person capture crews searched near shore waters with spotlights in inflatable boats at night. The typical reaction by a murrelet to the bright light was to sit on the water a few seconds and then dive underwater. The boat quickly approached the murrelet and a person with a dip-net captured the murrelet as it dove underwater. Captured murrelets were placed in a cardboard holding box and transported to a support vessel for radio attachment.

Radio Attachment. – We attached radio transmitters to the murrelets using a subcutaneous anchor technique (Newman et al. 1999). Radio transmitters (model PD-2, Holohil Systems Ltd., Woodlawn, Ontario) weighed approximately 3g (< 2.5% of murrelet body weight), and were equipped with a 15 cm external whip antenna. Anticipated transmitter battery life was 4 months, and transmitter range was about 15 km from the air (Whitworth et al. 2000). Murrelets were weighed with an Avinet 300 g spring scale, and examined for presence of bilateral brood patches to determine incubation status. A USGS #2 stainless steel leg band was attached to the left leg of each murrelet (USGS banding permit #22911, with auxiliary marking authority for attaching radio transmitters and collecting blood samples). A 0.1 ml sample of blood was taken from the metatarsal vein. Blood samples were sent to Zoogen, Inc. (Davis, California) for DNA analysis of sex chromosomes to determine gender. Murrelets were released from the back deck of the research vessel after radio attachment and blood collection.

Locations from Aircraft

From April to June, approximately four daytime flights were conducted each week to locate murrelets with radio transmitters. Flights were conducted from a twin-engine aircraft (Partenavia P-68), and were flown at an altitude of 450-600 m at speeds of 220-260 km h^{-1}.

One 3-element Yagi antenna was mounted to each wing of the aircraft by an underwing bracket. The receiver was connected to the two antennas with coaxial cables and a left/right switch box. The frequency for each individual murrelet was scanned at 2 s intervals with a receiver (Model R-4000, Advanced Telemetry Systems, Inc., Isanti, Minnesota). We determined signal location by assessing the direction and flying towards it until a strong signal was obtained. Signal strength (classified as weak, medium, or strong) was determined in the beginning of the study at constant volume and noted for every location.

The study area was divided into 10-minute latitude (18.5 km) x 10-minute longitude (15.5 km) grid blocks (36 blocks within 1 square lat-long degree). Flights were conducted in an east-west direction using the 10-minute latitude lines. The 10-minute latitude lines were flown in consecutive order, alternating direction until the entire area was covered. The range of the radio transmitters was 15 km from the air. Grid blocks were close enough to ensure that radios in the area were not missed when the latitude lines, separated by 15.5 km, were flown in consecutive order. The "core" area was systematically searched at least 2 of the 4 days per week (Figure 6.1). To locate missing birds, areas north, west, south, and southeast of the core area were searched during the other 2 days. Locations obtained from a Garmin Global Positioning System (GPS) unit were automatically recorded onto a laptop computer every 5 s to record the flight pattern in a computer program (dLOG-R.G. Ford Consulting, Portland, Oregon).

We tested radio transmitter location accuracy by comparing transmitter locations determined from the aircraft to known locations on 26 April 2003. A transmitter was attached to a 470 ml plastic bottle filled with seawater, and the bottle was placed on the surface of the water. The transmitter was above the water, pointing up to mimic the position and angle when attached to murrelets. We tested 2 transmitters by placing them in separate locations on the water and recording those locations with GPS. An observer in the aircraft recorded the estimated locations of the test transmitters with GPS. Distance between the reported locations and the actual locations were measured in ArcView 3.3 (ESRI, Inc., Redlands, California). We determined that a "strong" signal was representative of a transmitter that was <1.5 km from the actual locations. Only locations determined from a strong signal were used in habitat analyses.

Analysis of At Sea Locations

A GIS program (Arcview v. 3.3, Animal Movement extension v 2.0 Beta; Hooge et al. 1999) was used to generate Minimum Convex Polygon 100% (MCP) estimates for home range area. The minimum amount of time between consecutive locations of any murrelet was one day (22-26 h). To determine if the time between consecutive locations was a sufficient amount of time to obtain independent observations (Swihart and Slade 1985), we compared the home range size of 8 individual murrelets using 9 consecutive locations (mean = 2 days apart) versus 9 alternate locations (mean = 4 days apart), and found that there was no difference in the estimated home range size ($p = 0.86$), regardless of sampling interval. Thus, the values for home range size did not increase when we sampled more often, and we concluded that the points were independent. Murrelets are known to fly long distances in short periods of time, and there is evidence from other studies suggesting that one day is a sufficient amount of time to obtain independent observations. Marbled Murrelets that were detected in the morning and then later in the day flew 75 ± 42 km in that time period (Whitworth et al. 2000). In one instance, a radioed Xantus's Murrelet that was detected at a nesting island was located 101 km from the island 4 hours later (Whitworth et al. 1997a).

For home range and habitat analyses, we excluded at-sea locations that were from murrelets that were considered to have moved from the area. We calculated a probability circle (mean distance from each island of all murrelet locations, pooled by individual murrelet, + 2 SD) around each island, which represented a 95% probability that all locations of murrelets from each respective island occurred within that circle (Zar 1999). We used the at-sea locations from 2002, and found that there was an absence of murrelet locations midway between the outer edge of Anacapa Island's 95% circle and the outer edge of Santa Barbara Island's 95% circle (Figure 6.2). We considered all locations that were north of this break to be representative of murrelets that left the SCB. We used the same boundary in 2003.

We determined that a minimum of seven locations were necessary to represent the home range of an individual murrelet, because adding more independent locations did not greatly increase home range size (Swihart and Slade 1985). Specifically, when we examined five randomly selected murrelets from the 2003 data, we found that there was a 75% increase in home range size between 3 and 7 locations in comparison to a 30% increase in home range size between 7 and 14 locations. However, there was a second increase in home range size later in the season when murrelets began to enlarge their home range or leave the Bight. We conducted a partitioned regression with home range size (all values pooled by day) and Julian date, and found that the home range sizes of murrelets rapidly increased after 13 May, representing the initiation of home range expansion.

Therefore, we calculated home range size using MCP for each murrelet that met the following criteria: 1) a minimum of seven locations (not at a nest) was obtained, and 2) at least one location occurred on or after 13 May. Data were examined for normality (Affifi and Clark 1997), and the mean home range size was compared between the two years using Aspin-Welch Unequal Variance two-sample t-test because the variances were unequal. Unless otherwise noted, we conducted all statistical analyses with NCSS (Hintze 2001). All mean values are presented as the mean ± 1 SE.

To determine if there was a difference in the rate that transmitters disappeared between the 2 years, we calculated total number of transmitters that were active for each flight (Golightly et al. 2002). If a murrelet was absent in a flight but detected in a subsequent flight, then it was considered active for all previous flights. We identified the date that each individual murrelet finally disappeared and built a plot of cumulative disappearance for each year. We tested for differences in the rate of murrelet disappearance between the 2 years using analysis of covariance (SAS Institute, Inc. 2001, Cary, North Carolina).

Habitat

Sea surface temperature was measured with a pyrometer (Heitronics KT 19.85, Wintronics, Inc. Millington, NJ) mounted to the underside of the aircraft. The pyrometer only measured accurate values when there was no cloud cover beneath the aircraft. All sea surface temperature readings that occurred above the marine cloud layer were excluded. Sea surface temperature readings were automatically recorded every 5 s onto the laptop computer linked with GPS locations during the flight using the computer program dLOG. The water depth (from the NOAA GEODAS cd-rom) and distance to nearest shore were calculated by the computer and recorded every 5 s with the GPS location. Sea surface temperature, water depth, and distance to nearest shore were associated with each murrelet location. We calculated the distance from the center of each island to each at-sea location for murrelets captured at that island using a GIS program (ArcView 3.3).

For analysis, we calculated the mean of each habitat variable associated with murrelet locations for each individual murrelet, and then pooled the individual means to obtain a grand mean. Datasets were examined for normality (Afifi and Clark 1997). We compared water depth and sea surface temperature between the 2 years using Aspin-Welch Unequal Variance two-sample t-test because the variances were unequal. We used a Mann-Whitney U Rank-Sum Test to compare distance to shore between the 2 years because data were not normally distributed.

Automated Monitoring at Anacapa Island

We placed two automated telemetry systems on East Anacapa Island on 15 April 2003. Each system contained two 3-element Yagi antennas attached to a receiver and data logger (model D5401, Advanced Telemetry Systems Inc., Isanti, Minnesota) powered by two 12-V deep-cycle batteries connected in parallel. Each frequency was monitored by the receiver for 10 s every 10 min and the data logger stored Julian date, time, and pulse rate of each frequency detected. The automated telemetry systems functioned continuously from 15 April to 24 June 2003.

We determined the distance from Anacapa Island that a radio transmitter could be detected by the automated telemetry systems on 28 April 2003, using the same two bottles with transmitters attached that were used to test location accuracy from the aircraft. The bottles were taken to sea by boat and placed in the water at various distances from Anacapa Island. Each time the bottles were placed on the water, the location was recorded on a GPS unit. The bottles were left on the water until the automated telemetry system scanned for both transmitter frequencies (as determined by a person on the island). The people in the boat were then directed (via radio) to place the transmitters in a new location. Afterwards, the data in the automated telemetry system were downloaded and it was determined, for each time the transmitters were placed in the water, if the automated telemetry system detected the transmitters. The GPS locations of each time the transmitters were placed in the water were imported into a GIS program (ArcView 3.3), and the distance from the transmitters to the automated telemetry systems was calculated. The transmitters were detected by the automated telemetry systems at distances <1.8 km.

Diving Behavior

On 19-20 April, 9-11 May, and 24-26 May 2003, the diving behaviors of radioed murrelets were recorded by monitoring telemetry signals that could be detected from Anacapa Island with a hand-held antenna. Transmitted signals were inaudible when birds dove, and audible when birds surfaced (Wanless et al. 1993). A frequency with a strong signal was selected and monitored for a minimum of 30 min (wind speed, sea conditions, and precipitation were noted). We attempted to obtain diving data at all times of the daylight hours during each 2-3 day session (except for 19-20 April, when monitoring was minimal). Sea surface temperature was measured on 21 April, 12 May, and 27 May during the day by the pyrometer in the aircraft.

Dives were timed with a digital watch and recorded on a tape recorder that was later transcribed. A dive was defined as a signal loss of >4 s (Strachan et al. 1995). A feeding bout was defined as three or more consecutive dives, ending when there was an interval of >3 min between successive dives (Jodice and Collopy 1999). When we were able to record a complete feeding bout, the number of dives per feeding bout was determined. Within a feeding bout, pauses between individual dives were also recorded, which was defined as an interval between successive dives where the radio transmitter could be detected for <3 min (Jodice and Collopy 1999). Percent of time spent underwater during a feeding bout was the total dive time per dive bout duration. We used analysis of variance (ANOVA) to compare the dive time, pause time, number of dives per feeding bout, and percent of time spent underwater during feeding bouts between the three different time periods. Within each of the three time periods that dive times were collected, data were pooled by individual murrelet for analysis.

We also determined the distance that a radio transmitter floating on the surface of the water could be detected with a hand-held antenna on Anacapa Island on 28 April 2003, with the same methods that were used to test the automated telemetry system. Each time transmitters were placed in the water, an observer on Anacapa Island determined if the transmitters could be detected with a hand-held antenna and receiver. The GPS locations of each time the transmitters were placed in the water were imported into a GIS program and the distance from the transmitters to the observer on the island was calculated. The transmitters could be detected at distances <5 km.

RESULTS

Capture and Radio Transmitter Attachment

We captured and attached radio transmitters to 68 Xantus's Murrelets, 33 from Anacapa Island and 35 from Santa Barbara Island on 15-19 April 2002. Seven had brood patches. There were 37 male and 30 female murrelets, and one of unknown gender. The mean mass was 167.1 ± 1.6 g. There was a significant difference between the mean mass of female (171.2 ± 2.6 g, n = 29) and male (164.5 ± 2.1 g, n = 32) murrelets caught in 2002 (t = 2.04, *P* = 0.04).

We captured and attached radio transmitters to 26 Xantus's Murrelets from Anacapa Island on 14-16 April 2003. Two had brood patches. On 28-29 April 2003, we captured and attached radio transmitters to 18 murrelets from Anacapa Island. Three had brood patches. Of the 44 murrelets captured, 30 were male and 14 were female. The mean mass was 162.2 ± 1.7 g. There was no significant difference between the mean mass of female (166.0 ± 2.4 g, n = 14) and male (160.4 ± 2.2 g, n = 30) murrelets caught in 2003 (t = 1.55, *P* = 0.13).

Locations from the Aircraft

Twenty-six flights (99.5 h of flight time) were conducted from 16 April to 1 June 2002, resulting in 193 locations of 59 murrelets (Figure 5.2). Nine murrelets were never located after capture, and an additional 26 murrelets were not located after 25 April. The mean number of locations per murrelet (excluding the nine never located) was 3.3 ± 0.3 (range 1-9). The mean number of days that murrelets were located before disappearance was 18.4 ± 2.1 d (range 1-46 d).

Thirty-six flights (117.5 h of flight time) were conducted from 16 April to 22 June 2003, resulting in 525 locations of 41 murrelets (Figure 5.3). Three murrelets were never located after capture. The mean number of locations per murrelet (excluding the three never located) was 12.7 ± 1.1 (range 3-29). The mean number of days that murrelets were located before disappearance was 34.6 ± 2.6 d (range 6-68 d).

The rate of cumulative disappearance of radio transmitters was significantly different between the 2 years (ANCOVA, *F* = 10.04; n = 68, 44; *P* = 0.002); the radio transmitters disappeared at a faster rate in 2002 in comparison to 2003 (Figure 5.4).

Home Range Size

The mean home range size was significantly greater in 2002 than 2003 (t = 3.48; n = 6,28; *P* = 0.008), although we had a much smaller sample size in 2002 (Table 5.1). Figure 5.5 shows four examples of the home ranges for individual murrelets in 2002 and Figure 5.6 shows four home ranges in 2003.

Habitat

Murrelets captured at Anacapa Island in 2002 tended to be farther from the island in comparison to murrelets captured at Anacapa Island in 2003 (Table 5.1), although this difference was not statistically significant (t = 1.58; n = 31, 41; *P* = 0.06). Mean values for distance to nearest shore, sea surface temperature, and water depth were significantly greater in 2003 in comparison to 2002 (Mann-Whitney U-test: z = 3.12, n = 50, 41, $P < 0.001$; Aspin-Welch Unequal variance t-test: t = -3.28, n = 45, 41, $P < 0.001$; t = -8.52, n = 50, 41, $P < 0.001$, respectively).

Island Attendance

In April-June 2003, 43 of 44 individual murrelets were detected with the automated telemetry system, although five were detected only on the same night that radio transmitter attachment and release occurred. The mean number of days that murrelets were detected with the monitoring system (excluding the five detected only immediately post-release) spanned 27.4 d ± 2.9 (range 2-67 d). Murrelets were frequently detected within 1.8 km of the colony at night, with a mean of 12.2 ± 1.8 nights per murrelet (excluding the one murrelet not detected at all; range 1-38 nights per murrelet). There was a negative relationship between the distance murrelets were found from Anacapa Island during the day and the number of nights detected at the island (r = 0.54, n = 33, *P* = 0.001), demonstrating that nighttime attendance presents a constraint to the distance that murrelets can travel during the day to forage (Figure 5.7). Figure 5.8 is a typical example of the nighttime attendance patterns detected for individual murrelets, showing the frequency of nighttime attendance.

Diving Behavior

On 19-20 April 2003, four murrelets were monitored for a total of 2.25 h. On 9-11 May, eight murrelets were monitored for a total of 9.75 h. On 24-26 May, five murrelets were monitored for a total of 17 h. In total, 447 individual dives and 23 complete feeding bouts were recorded for 17 individual murrelets. On 9 May, the sea conditions were a Beaufort 5, during all other observations the sea conditions were mild, with a Beaufort 1-2. We collected dive data on murrelets that were within 5 km of Anacapa Island (based on our assessment of the distance radio transmitters could be detected from the island), where water depth was 50-700 m. Sea surface temperature (SST) was different in the three time periods. Around 19-20 April, the SST in that area was 12.9 ºC, 9-11 May, the SST was 12.0-12.1 ºC, and 24-26 May, SST was 15 ºC. There were no significant differences in dive time, pause time, number of dives per feeding bout, duration of feeding bouts, and percentage of time spent underwater between the three time periods (ANOVA) (Table 5.2).

DISCUSSION

We had much better success in 2003 than 2002 in relocating murrelets with radio transmitters, with 4.5 locations/h in 2003 and 1.9 locations/h in 2002. Murrelets were located for a longer period of time in 2003 than 2002 (35.0 d vs. 18.4 d). In 2002, 40% of the murrelets were never relocated again after the first week of aerial searches. In contrast, in 2003, only 11% of the murrelets were never relocated again after the first week of aerial searches. Although it is expected that some proportion of transmitters disappear because radios fail or fall off, the faster rate of disappearance of radio transmitters in 2002 was likely because murrelets moved out of the area earlier. We do not have any evidence of a large-scale mortality, and some murrelets were relocated after a long period of disappearance, indicating that they may have been difficult to locate because they were very distant from the colony. On 6 May 2002, we started to locate murrelets north of Point Conception, and 12 murrelets were found north of Point Conception from 6 May to 29 May, with one as far as 322 km from Anacapa Island. The reason for early movements was unknown, although poor feeding conditions in the SCB may have resulted in murrelets leaving the area in search of more abundant prey.

Home range size was over three times larger in 2002 (5428 km^2 vs. 1617 km^2) and mean distance from the nesting colony was greater in 2002 in comparison to 2003, indicating that murrelets were traveling farther from the islands in 2002 to find prey. Similar results were found during a study of at-sea murrelet distribution in 1995-1997, when they obtained few locations of murrelets in 1995 in comparison to 1996 and 1997, and distance from the nesting colony and distribution of at-sea locations differed greatly between years (Whitworth et al. 2000). Home range size increased over the course of the season in both years, indicating that food resources in the SCB may have been deteriorating later in the season and murrelets were foraging farther from the nesting colony.

Habitat

It is possible that murrelets were found in warmer waters in 2003 because they stayed in the SCB longer, and ocean temperatures are known to increase over the course of the summer in the SCB. The cold sea surface temperatures associated with upwelling events that make conditions favorable for common seabird prey species (Baird 1993), may not be a habitat requirement for murrelets. Murrelets were also found in significantly deeper waters in 2003 in comparison to 2002. Approximately 80% of locations in 2003 occurred within 40 km south of Anacapa Island, where two deep-water basins occur (Dailey et al. 1993). In 2002, murrelets appeared to be scattered all over the SCB with no apparent affiliation with deep water.

Island Attendance

Most of the nesting habitat on Anacapa Island was in sea caves and inaccessible cliffs while the automated telemetry systems were located on top of Anacapa Island; consequently, incubating murrelets were not likely to be detected by the automated telemetry systems. The majority of detections by the island monitoring system were from murrelets attending the nearshore waters within 1.8 km of Anacapa Island at night (based on our assessment of the automated telemetry systems). Nighttime congregations adjacent to colonies during the breeding season are well documented, especially at Anacapa Island (Murray et al. 1983, Drost and Lewis 1995, Whitworth et al. 2003), although until now the frequency that individual murrelets attended these congregations was unknown. Attending the colony at night on a frequent basis (up to 38 nights) is a constraint to foraging murrelets; we found that murrelets that attended more frequently at night were found closer to the island during the day in comparison to murrelets that were detected less frequently at the island. Non-incubating murrelets that attend the colony at night on a frequent basis may have more of a constraint in their ability to travel from the colony during the day to forage than incubating murrelets, who are known to attend the colony for an average of 3 days, and then presumably depart the colony for 3-6 days to forage. It is possible that nightly attendance of this nature would only be possible in years where prey is available near the breeding colony on a consistent basis and murrelets are not forced to travel far to locate prey. It also illustrates the importance of the nighttime congregations to murrelets, which is presumably for social purposes such as courtship, maintenance of pair bonds, a staging area before flying to nearby nesting habitat, and for the preparation of and during chick departure (Whitworth et al. 2003).

Dive Times

Dive time, pause time, and the percent of time spent underwater during a feeding bout were similar to those values reported for Marbled Murrelets (Strachan et al. 1995, Jodice and Collopy 1999), who are reported to forage in waters 20-50 m deep (Strachan et al. 1995). The relatively short dive times (18, 29, 24 s) of Xantus's Murrelets probably indicate that they were diving at shallow depths, despite the availability of deep water in the area that they were diving (50-700 m). We previously collected 10 Xantus's Murrelets south of Anacapa Island in 2002, and the prey types found in the stomachs also suggest that they were foraging near the surface of the water on juvenile fish and euphausiids (Hamilton et al., in submission).

Conclusions

Hunt et al. (1979) found the majority of murrelets within 12.5 km of Santa Barbara Island in 1975-1977, leading them to believe that murrelets forage within close proximity of the nesting colony. However, surveys only extended to 18.5 km from the island in that study. Whitworth et al. (2000) found murrelets much farther on average from Santa Barbara Island (62 ± 25 km in 1996 and 111 ± 44 km in 1997; mean ± SD), demonstrating that murrelets have the ability to forage much farther from the nesting colony than previously thought. We found murrelets closer to the nesting islands in both years (33 ± 4 km from Anacapa Island and 53 ± 7 km from Santa Barbara Island in 2002; 25 ± 2 km from Anacapa Island in 2003; mean ± SE), however, the analysis in Whitworth et al. (2000) did not distinguish between murrelets moving out of the area and those within the area. Murrelets disperse from nesting islands after the breeding season and are thought to move offshore and north (Drost and Lewis 1995), so we wanted to exclude locations that appeared to be related to movement from the area. Our results indicate that during the time that murrelets have ties to the nesting island, whether incubating or non-incubating but attending nocturnal congregations, they forage closer to the island than Whitworth et al. (2000) recorded. Our results in 2003 also suggest that murrelets will forage in close proximity to the nesting colony in loose aggregations if conditions are favorable, if there is a reliable food source present, and that they were likely foraging on prey at or near the surface of the water when near Anacapa Island.

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LITERATURE CITED

AFIFI, A.A., AND V. CLARK. 1997. Computer-aided multivariate statistics. Chapman and Hall/ CRC, Boca Raton, Florida.

BAIRD, P.H. 1993. Birds. Pages 541-603 *in* M.D. DAILEY, D.J. REISH, AND J.W. ANDERSON (eds.), Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles, California.

CALIFORNIA DEPARTMENT OF FISH AND GAME. 2002. Evaluation of Petition: Request of the Pacific Seabird Group to list Xantus's Murrelets (*Synthliboramphus hypoleucus)* as threatened. Sacramento, California. 58pp.

CARTER, H.R., D.L. WHITWORTH, J.Y. TAKEKAWA, T.W. KEENEY, AND P.R. KELLY. 2000. At-sea threats to Xantus' Murrelets (*Synthliboramphus hypoleucus)* in the southern California Bight. *In* Browne, D., H. Chaney, and K. Mitchell (eds) Fifth Channel Islands Symposium. Camarillo, CA: Minerals Management Service.

CARTER, H.R., G.J. MCCHESNEY, D.L. JAQUES, C.S. STRONG, M.W. PARKER, J.E. TAKEKAWA, D.L. JORY, AND D.L. WHITWORTH. 1992. Breeding populations of seabirds in California, 1989-1991. Unpublished report, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California.

DAILEY, M.D, J.W. ANDERSON, D.J. REISH, AND D.S. GORSLINE. 1993. The Southern California Bight: Background and setting. Pages 1-18 *in* M.D. DAILEY, D.J. REISH, AND J.W. ANDERSON (eds.), Ecology of the Southern California Bight: A synthesis and interpretation. University of California Press, Berkeley and Los Angeles, California

DROST, C.A. AND D.B. LEWIS. 1995. Xantus' Murrelet (*Synthliboramphus hypoleucus). In* POOLE, A. AND F. GILL (eds). The Birds of North America, No. 164. Philadelphia, PA: 24. The Academy of Natural Sciences. Washington, DC: American Ornithologists' Union.

GOLIGHTLY, R.T., S.H. NEWMAN, E.N. CRAIG, H.R. CARTER, AND J.A.K. MAZET. 2002. Survival and behavior of western gulls following exposure to oil and rehabilitation. Wildlife Society Bulletin 30(2): 539-546.

HINTZE, J. 2001. NCSS and PASS. Number Cruncher Statistical Systems. Kaysville, Utah.

HOOGE, P.N., W. EICHENLAUB, AND E. SOLOMON. 1999. The animal movement program. USGS, Alaska Biological Research Center.

HUNT, G. L., JR., R. K. PITMAN, M. NAUGHTON, K. A. WINNETT, A. NEWMAN, P. R. KELLY, AND K. T. BRIGGS. 1979. Distribution, status, reproductive ecology and foraging habits of breeding seabirds. Pages 1-399 in Summary of marine mammal and seabird surveys of the Southern California Bight area, 1975-1978. U. S. Dep. Inter., Bur. Land Manage., Los Angeles. Publ. PB-81-248-205.

JODICE, P.G.R., AND M.W. COLLOPY. 1999. Diving and foraging patterns of Marbled Murrelets (*Brachyramphus marmoratus*): testing predictions from optimal-breathing models. Can. J. Zool. 77: 1409-1417.

MURRAY, K.G., K. WINNETT-MURRAY, Z.A. EPPLEY, G.L. HUNT, JR., AND D.B. SCHWARTZ. 1983. Breeding biology of the Xantus's Murrelet. Condor 85: 12-21.

NEWMAN, S.H., J.Y. TAKEKAWA, D.L. WHITWORTH, AND E.E. BURKETT. 1999. Subcutaneous anchor attachment increases retention of radio transmitters on seabirds: Xantus' and Marbled Murrelets. Journal of Field Ornithology 70:520-534.

STRACHAN G., M. MCALLISTER, AND C. J. RALPH. 1995. Marbled Murrelet at-sea and foraging behavior. United States Department of Agriculture, General Technical Report PSW-GTR-152. Pages 247-254.

SWIHART, R.K., AND N.A. SLADE. 1985. Influence of sampling interval on estimates of home-range size. Journal of Wildlife Management 49(4): 1019-1025.

SYDEMAN, W.J., N. NUR, AND P. MARTIN. 1998. Population viability analysis for endemic seabirds of the California marine ecosystem: the Ashy Storm-Petrel (*Oceanodroma homochroa*) and Xantus's Murrelet (*Synthliboramphus hypoleucus*). Unpublished report, Point Reyes Bird Observatory, Stinson Beach, California.

WANLESS, S., T. CORFIELD, M. P. HARRIS, S. T. BUCKLAND, AND J. A. MORRIS. 1993. Diving behavior of the Shag *Phalacrocorax aristotelis* (Aves: Pelecaniformes) in relation to water depth and prey size. Journal of Zoology 231:11-25.

WHITWORTH , D.L., H.R. CARTER, F. GRESS, AND S. FANGMAN. 2002. Nocturnal observations of at-sea congregations and nest monitoring of Xantus's Murrelets at Anacapa Island, California, in 2001. Pages 38-59 *in* T.E. Hamer and H.R. Carter (eds.). Population monitoring of Xantus's Murrelets (*Synthliboramphus hypoleucus)* at Anacapa Island, California; 2000 annual report. Unpubl. report, Hamer Consulting, Mount Vernon, Washington; and Humboldt State University, Department of Wildlife, Arcata, California (prepared for the American Trader Trustee Council). 64 pp.

WHITWORTH, D.L., H.R. CARTER, R.J. YOUNG, E. CREEL, W.R. MCIVER, F. GRESS, AND S. FANGMAN. 2003. Monitoring of at-sea congregations and nest success of Xantus's Murrelets (*Synthliboramphus hypoleucus)* at Anacapa Island, California, in 2000-02, prior to eradication of Black Rats (*Rattus rattus*). Unpublished report, Humboldt State University, Department of Wildlife, Arcata, California (prepared for the American Trader Trustee Council). 47 pp.

WHITWORTH, D.L., J.Y. TAKEKAWA, H.R. CARTER, AND W.R. MCIVER. 1997b. Night-lighting as a capture technique for Xantus' Murrelets in the Southern California Bight. Colonial Waterbirds 20: 525-531.

WHITWORTH, D.L., J.Y. TAKEKAWA, H.R. CARTER, S.H. NEWMAN, T.W. KEENEY, AND P.R. KELLY. 1997A. Foraging distribution and post-breeding dispersal of Xantus' Murrelets in the Southern California Bight in 1995-1997. Unpubl. Report. Vallejo, CA: US Geological Survey, Biological Resources Division.

WHITWORTH, D.L., J.Y. TAKEKAWA, H.R. CARTER, S.H. NEWMAN, T.W. KEENEY, AND P.R. KELLY. 2000. Distribution of Xantus' Murrelet (*Synthliboramphus hypoleucus)* at sea in the Southern California Bight, 1995-97. Ibis 142: 268-279.

WOLF, S., J.E. ROTH, AND W.J. SYDEMAN. 2000. Population size, phenology and productivity of seabirds on Santa Barbara Island, 1999. Unpublished report, Point Reyes Bird Observatory, Stinson Beach, California.

ZAR, J.H. 1999. Biostatistical Analysis. 4th Ed. Pearson Education, Delhi, India.

Table 5.1. Mean (± SE) of all habitat variables associated with each at-sea murrelet location (foraging and non-foraging) in 2002 and 2003: home range size (MCP), distance from the nesting colony where captured (Anacapa Island and Santa Barbara Island), distance from nearest shore, water depth, and sea surface temperature. Sample sizes are shown in parenthesis.

	Year	
	2002	2003
Home range size (MCP) (km^2)	5428 ± 1089 (*n* = 6)	1617 ± 202 (*n* = 27)
Distance from Anacapa Island (km)	33 ± 4 (*n* = 30)	25 ± 2 (*n* = 41)
Distance from Santa Barbara Island (km)	53 ± 7 (*n* = 28)	—
Distance from nearest shore (km)	11.3 ± 1.3 (*n* = 50)	13.9 ± 0.7 (*n* = 41)
Water depth (m)	371 ± 41 (*n* = 50)	804 ± 30 (*n* = 41)
Sea surface temperature (ºC)	12.8 ± 0.1 (*n* = 45)	13.2 ± 0.1 (*n* = 41)

Table 5.2. Means (± SE) of dive times, pause times, duration of feeding bouts, number of dives per feeding bout, and percent time spent underwater during feeding bouts for Xantus's Murrelets monitored from Anacapa Island, in 2003, during the three time periods. Sample sizes are shown in parenthesis. There were no significant differences between the three time periods.

	Date				
	April 19-20	May 9-11	May 24-26	*F*	*P*
Dive time (s)	19 ± 4 (*n* = 4)	29 ± 3 (*n* = 8)	30 ± 4 (*n* = 4)	2.23	0.15
Pause time (s)	15 ± 4 (*n* = 4)	23 ± 3 (*n* = 8)	29 ± 4 (*n* = 4)	3.26	0.07
Duration of feeding bout (s)	280 ± 186 (*n* = 1)	524 ± 76 (*n* = 6)	450 ± 93 (*n* = 4)	0.79	0.49
# dives per feeding bout	10 ± 6 (*n* = 1)	13 ± 3 (*n* = 6)	9 ± 3 (*n* = 4)	0.60	0.57
% time spent underwater during feeding bout	61 ± 13 (*n* = 1)	59 ± 5 (*n* = 6)	57 ± 7 (*n* = 4)	0.08	0.93

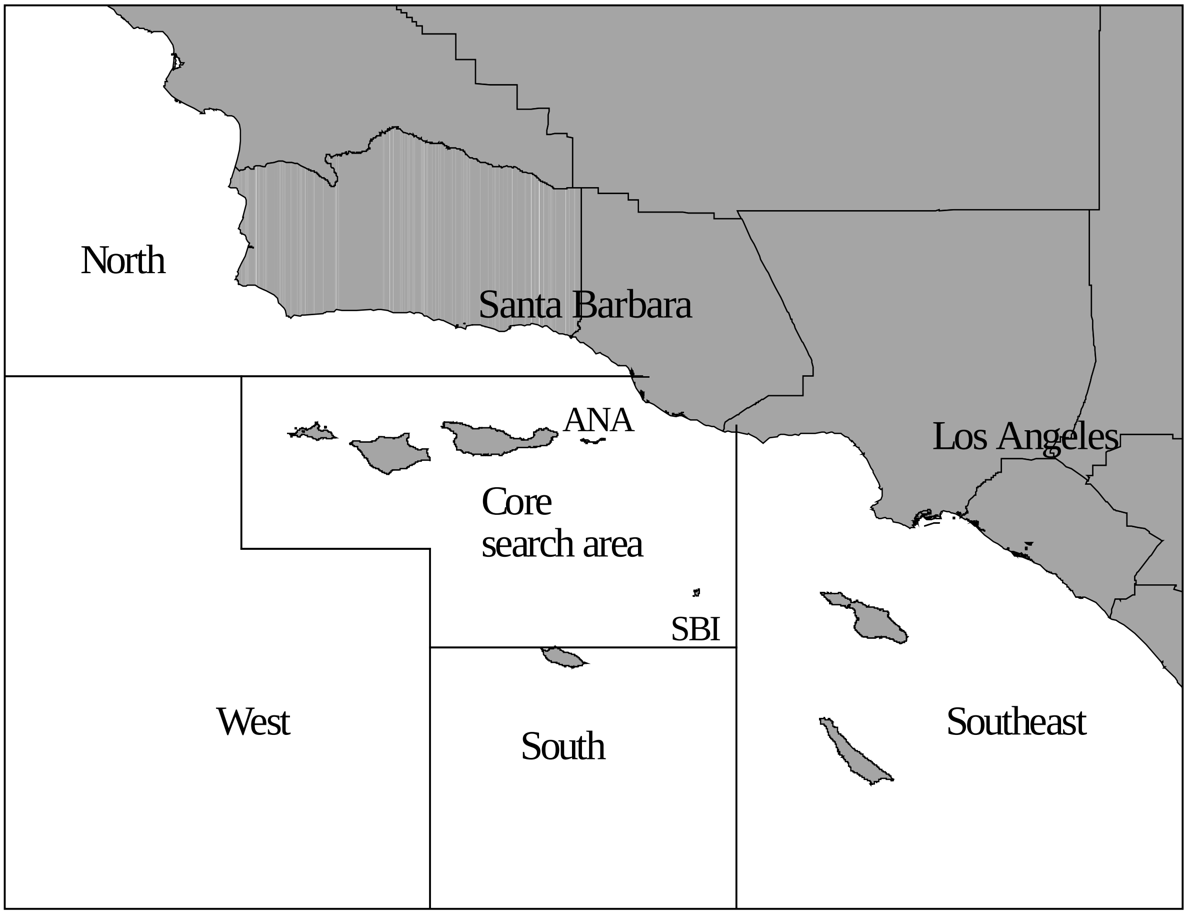

Figure 5.1. Captures and radio transmitter attachment occurred at Santa Barbara Island (SBI) and Anacapa Island (ANA) in 2002 and at ANA in 2003. The five aerial search areas (Core, North, West, South, and Southeast) were systematically searched for murrelets.

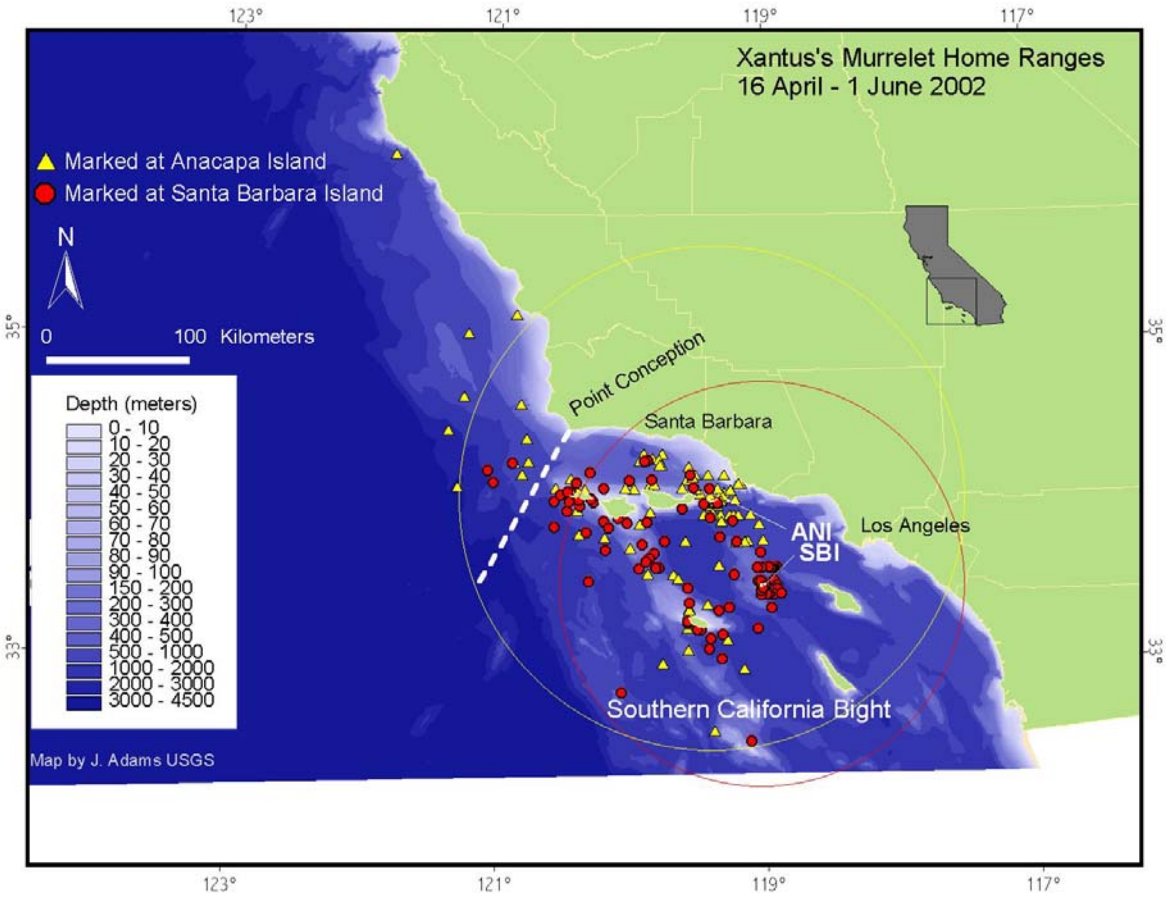

Figure 5.2. The distribution of all Xantus's Murrelet locations with radio transmitters captured at Anacapa Island (yellow) and Santa Barbara Island (red), 16 April–1 June 2002. The 95% probability circles around Anacapa Island (ANI) and Santa Barbara Island (SBI) using the murrelet locations are also shown. All murrelet locations north of the dashed line were not included in home range and habitat analyses.

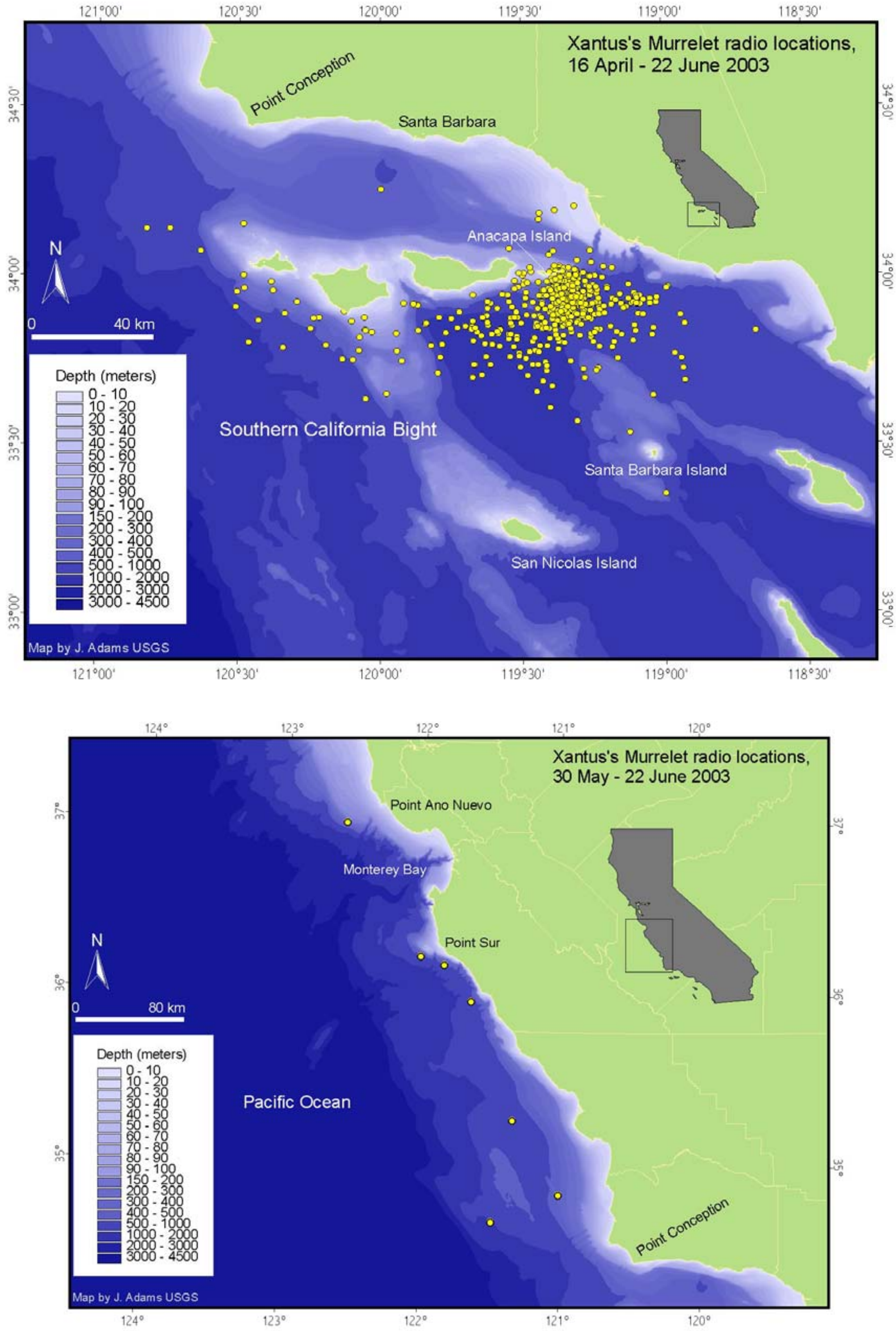

Figure 5.3. The map at the top shows the distribution of all Xantus's Murrelets with radio transmitters found south of Point Conception, 16 April–22 June 2003. The map at the bottom shows the distribution of murrelets found north of Point Conception, 30 May-22 June 2003 that were not included in home range and habitat analyses.

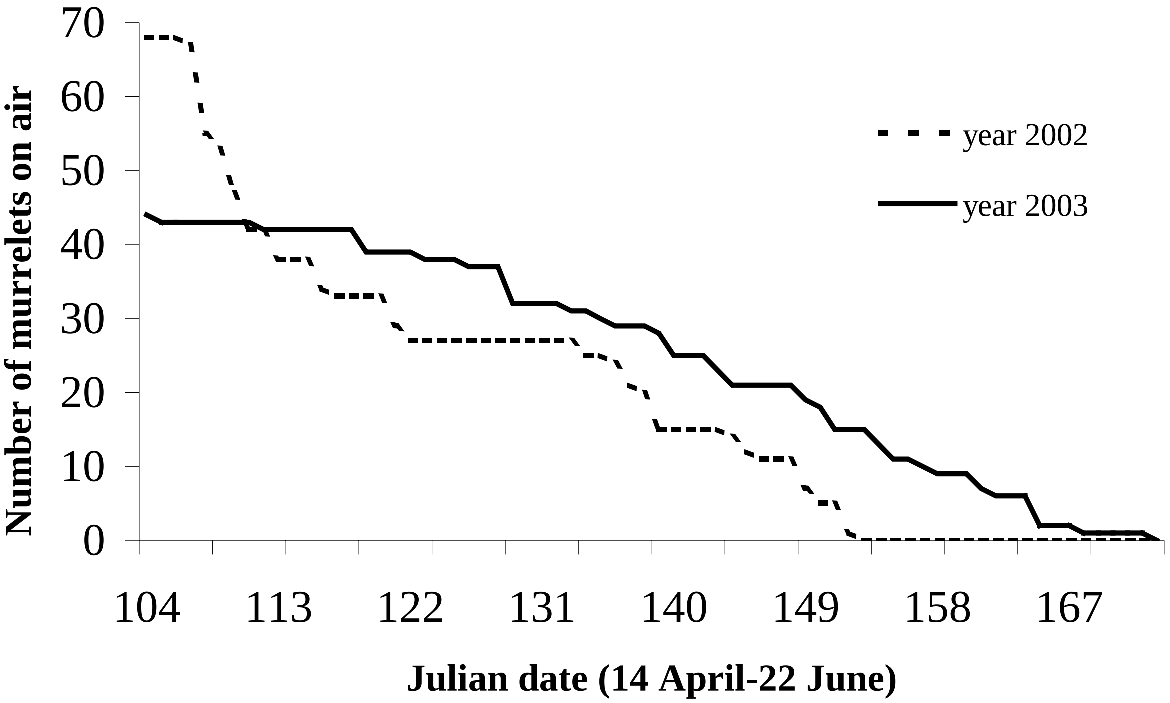

Figure 5.4. The number of Xantus's Murrelets with radio transmitters that could be located during each flight in 2002 and 2003.

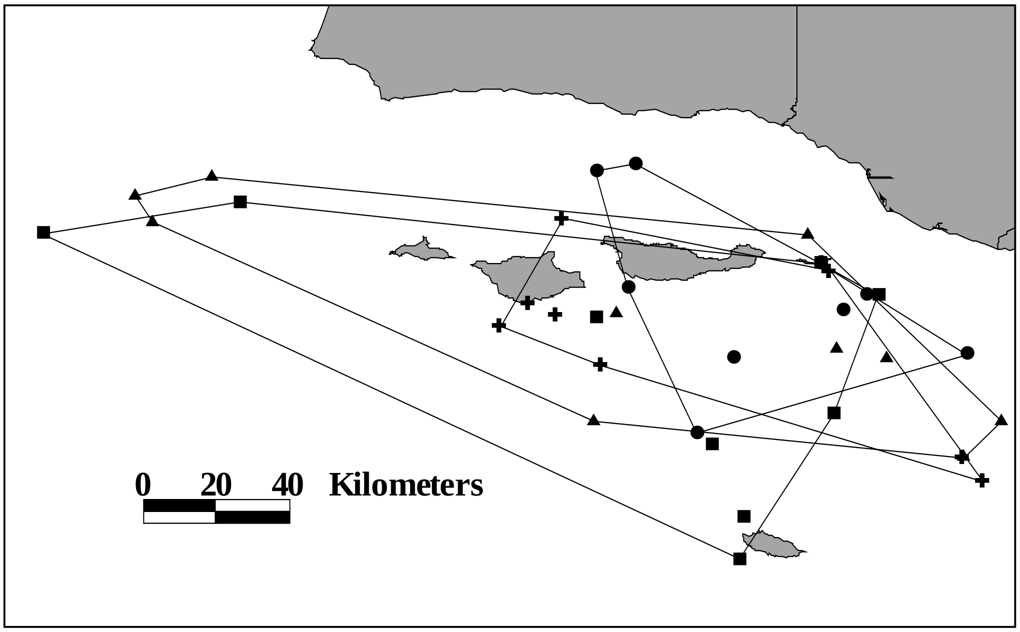

Figure 5.5. Four examples of the minimum convex polygon (MCP) home ranges for Xantus's Murrelets from Anacapa Island (circles and squares) and Santa Barbara Island (crosses and triangles) in 2002.

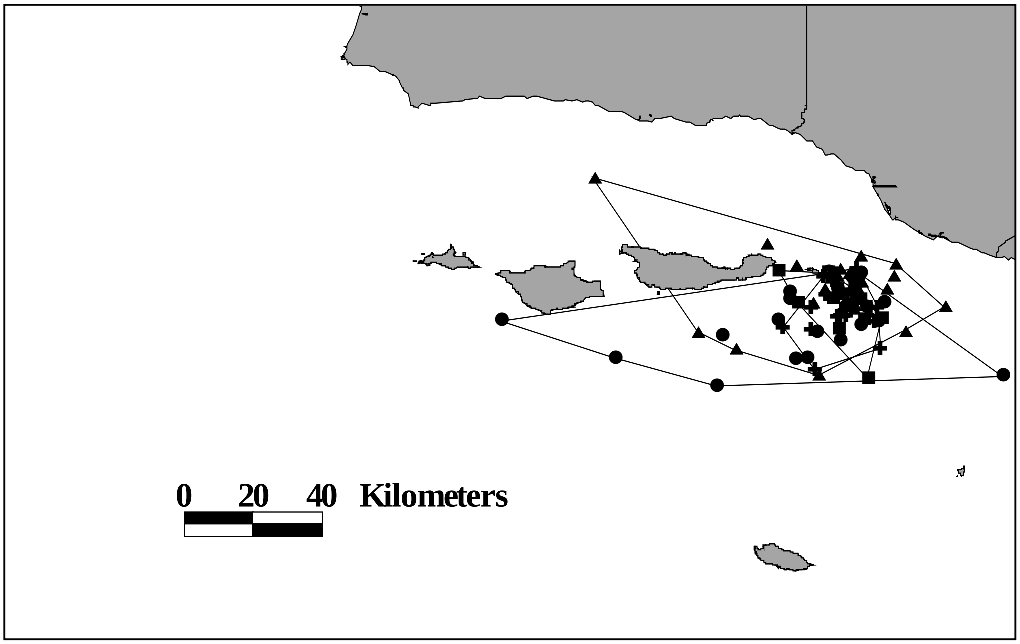

Figure 5.6. Four examples of the minimum convex polygon (MCP) home ranges for Xantus's Murrelets from Anacapa Island in 2003.

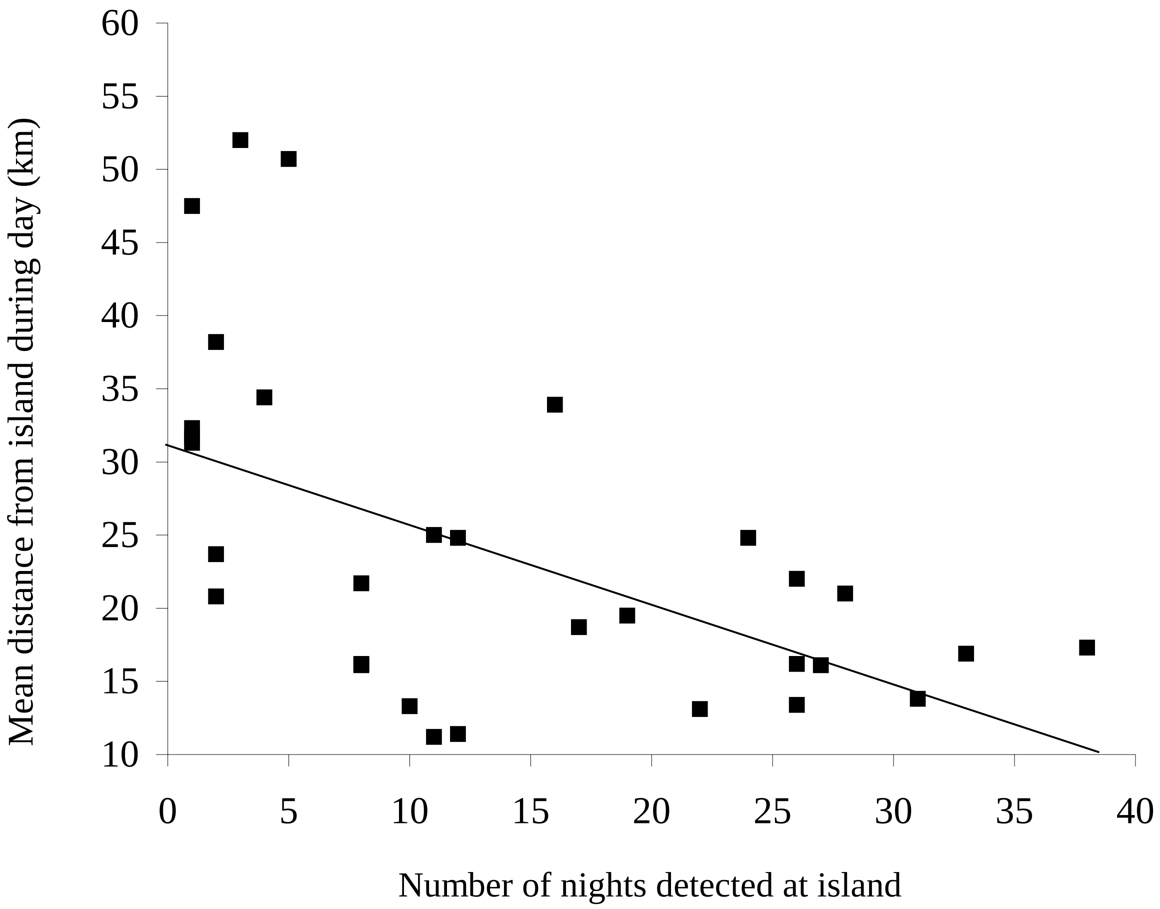

Figure 5.7. Number of nights individual murrelets were detected within 1.8 km of Anacapa Island and the mean distance from Anacapa Island individual murrelets were located during the day.

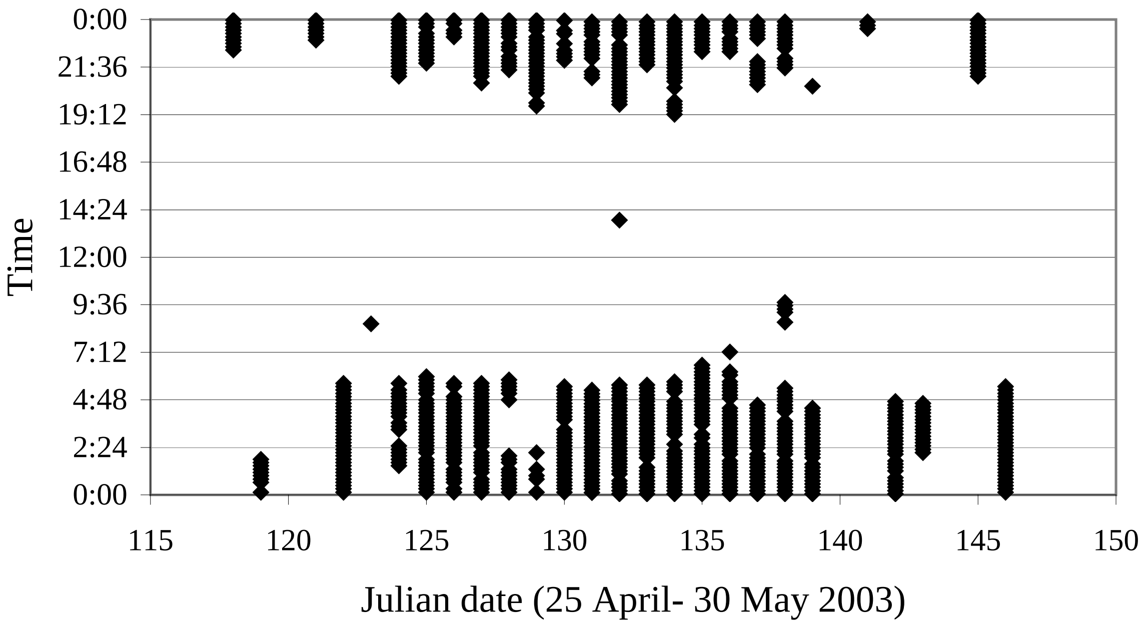

Figure 5.8. The nocturnal attendance patterns of an individual Xantus's Murrelet within 1.8 km of Anacapa Island, detected by the automated telemetry system 25 April-30 May 2003.

CHAPTER 6:

RADIO TRANSMITTER EFFECTS ON CASSIN'S AUKLETS BREEDING ON THE CALIFORNIA CHANNEL ISLANDS

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***Abstract*:** We examined whether radio transmitters adversely affected the reproductive performance of Cassin's Auklets (*Ptychoramphus aleuticus*) breeding on the California Channel Islands, USA, during 1999, 2000, and 2001. We attached external radio transmitters to one partner in 108 Cassin's Auklet pairs and to both partners in 7 pairs after nest initiation, and used 131 unmarked, but handled, pairs as controls. We statistically controlled for the potential effects of year, nest type, and hatching date. Compared to alpha chicks raised by radio-marked pairs, alpha chicks raised by unmarked pairs had faster mass growth rates (1.95 ± 0.30 g d^{-1} vs. 3.37 ± 0.53 g d^{-1}, respectively), faster wing growth rates (2.46 ± 0.10 mm d^{-1} vs. 2.85 ± 0.05 mm d^{-1}), greater peak fledging masses (118.9 ± 3.5 g vs. 148.3 ± 2.4 g), and higher fledging success (61% vs. 90%). Fledging success was reduced more when we radio-marked the male (50% fledged) than the female partner (77% fledged). Furthermore, after fledging an alpha chick, unmarked pairs were significantly more likely to initiate a second clutch (radio-marked: 7%, unmarked: 39%) and tended to hatch a second egg (radio-marked: 4%, unmarked: 25%) and fledge a second (beta) chick (radio-marked: 4%, unmarked: 18%) more often than radio-marked pairs. Radio-marked Cassin's Auklets foraged in similar areas compared to

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unmarked Cassin's Auklets that were surveyed concurrently by aircraft. We re-sighted 12 radio-marked individuals nesting during a subsequent breeding season; each bird had shed its transmitter and healed the site of attachment. We suggest caution in using radio telemetry to evaluate the reproductive performance of alcids, but it is still a valuable technique to assess their at-sea movements and foraging ranges. In addition, radio-marking females instead of males may minimize adverse effects on reproductive performance.

INTRODUCTION

Little is known about the at-sea movements and foraging ranges of breeding alcids (Alcidae), yet this information is critical for their management and conservation. Radio telemetry is a widely used tool for determining individual movements of free-ranging birds (review by Samuel and Fuller 1996), but it has been used in only a few studies of alcids in the past (Wanless et al. 1985, 1990, Duncan and Gaston 1990). The use of telemetry for studying alcids has been hindered by logistical constraints associated with at-sea tracking, the sensitivity of birds to handling, and lack of an effective method for transmitter attachment. With development of smaller transmitters and better attachment methods that increased transmitter retention times (Newman et al. 1999), several recent studies have used radio telemetry to examine at-sea movements of small alcids (e.g., Xantus's murrelets, *Synthliboramphus hypoleucus*: Whitworth et al. 2000*a*, Chapter 6; marbled murrelets, *Brachyramphus marmoratus*: Whitworth et al. 2000*b*, Lougheed et al. 2002*a*; Cassin's Auklets, *Ptychoramphus aleuticus*: Chapters 3 & 5). However, few studies have investigated the effects of radio transmitters on alcids (Wanless et al. 1988, 1989).

Breeding alcids are particularly likely to be adversely affected by externally-attached transmitters because they travel long distances from their colonies to feed and because they forage underwater. Alcids have higher wing loading (i.e., body mass-to-wing area ratio) than other seabirds, and use energetically expensive flapping flight without intermittent periods of gliding to travel between their colonies and pelagic foraging areas (Pennycuik 1987). Thus, the added mass and increased aerodynamic drag caused by an externally attached transmitter could increase the energy expended while traveling to distant foraging areas (e.g., Gessaman and Nagy 1988, Obrecht et al. 1988). Moreover, transmitters can reduce streamlining and increase hydrodynamic drag during underwater foraging, thereby reducing swimming speeds and foraging efficiency during pursuit diving (Wilson et al. 1986). Transmitters also may disrupt birds' waterproofing and thus increase thermoregulatory costs in cold ocean waters (e.g., Bakken et al. 1996).

We evaluated the effects of externally attached radio transmitters on the breeding behavior and reproductive performance of Cassin's Auklets (hereafter Auklets), a small-bodied (165 g) alcid. Because alcids are relatively long-lived and have many opportunities to breed over their lifetimes, parents are expected to reduce parental effort when breeding conditions are unfavorable to maximize their own probability of survival to a time when breeding conditions are more favorable (e.g., Stearns 1992). Auklet parents therefore might transfer any cost associated with an attached transmitter to their offspring so that they do not diminish their own prospects for survival and future reproduction. For example, other long-lived species such as Leach's Storm-petrels (*Oceanodroma leucorhoa*, Mauck and Grubb 1995) and Antarctic Petrels (*Thalassoica antarctica*, Sæther et al. 1993) have been shown to respond to a flight handicap (experimentally reduced wing span and increased mass, respectively) by feeding their chicks less frequently. Auklet chicks require feeding for a 41–50 day fledgling period during which parents feed chicks nightly (Manuwal and Thoresen 1993) following diurnal excursions to foraging areas up to 40 km away from the colony (Chapter 3). Therefore, any effects of externally-attached transmitters to Auklet parents may be expressed as reduced chick growth rates and survival to fledging.

We fitted Auklets breeding on the California Channel Islands with externally-attached radio transmitters after nest initiation and compared their reproductive performance to that of unmarked parents. Specifically, we measured the body mass and wing growth rates, peak fledging mass, and fledging success of alpha chicks raised by pairs with and without a partner carrying a transmitter. We also examined the frequency of double brooding by radio-marked pairs compared to unmarked pairs. Additionally, we evaluated whether the sex of the radio-marked partner influenced a pair's reproductive performance. To determine if transmitter effects were magnified in years with low prey availability, we compared results over a three-year period during which nesting phenology and diet varied.

METHODS

Study Area and Species

We studied Auklets nesting at two colonies 90 km apart on Prince Island (34º05'N, 120º15'W) and Scorpion Rock (34º05'N, 119º30'W) in the northern Channel Islands of California during the 1999, 2000, and 2001 breeding seasons (mid February to mid July). Prince Island, located 2 km north of San Miguel Island, has the largest colony of Auklets in the Southern California Bight. Carter et al. (1992) estimated that there were 8900 Auklets breeding on Prince Island and 100 on Scorpion Rock in 1991. The ocean around Prince Island is seasonally influenced by cool, nutrient-enriched water upwelled along the central California coast. In the spring, this highly productive water becomes entrained within the Santa Barbara Channel (Harms and Winant 1998, Oey et al. 2001). Scorpion Rock is a small islet <1 km north of Santa Cruz Island. The water around Scorpion Rock typically is warmer, more stratified, and has a more variable oceanographic influence from coastal upwelling than water around Prince Island.

Auklets are wing-propelled, pursuit-diving seabirds and are the most widely distributed of the 'true' Auklets, ranging from the Bering Sea, Alaska, to northern Baja California, Mexico (Gaston and Jones 1998). On Prince Island and Scorpion Rock, Auklets nest in shallow burrows excavated in loose, rocky soil and within rock crevices. Auklets incubate their one-egg clutch for approximately 39 days (range: 37–57 days; Manuwal 1974, Ainley et al. 1990), with partners exchanging incubation duties every 24 hr (Manuwal and Thoresen 1993, Gaston and Jones 1998). In the southern portion of their breeding range, Auklets occasionally produce a second brood during the same nesting season (i.e., double brood) when nearby waters are highly productive (Manuwal and Thoresen 1993). Breeding Auklets primarily forage within 40 km of their colony (Chapter 3), returning to the colony once per night to feed their (single) chick (Manuwal and Thoresen 1993). At the California Channel Islands, Auklet parents feed their chicks primarily with euphausiid crustaceans, particularly *Thysanoëssa spinifera*, *Euphausia pacifica*, and *Nyctiphanes simplex*, but also with pleuronectid fishes, rockfish (*Sebastes* spp.), and cephalopods (*Loligo opalescens* and *Octopus* spp.; Chapter 1). Auklets are opportunistic foragers and diet composition changes as oceanic conditions influence prey availability (Ainley et al. 1996, Hedd et al. 2002).

Treatment and Control Groups

On Prince Island, we used Auklets nesting in natural sites (i.e., burrows and rock crevices), artificial burrows, and artificial nest-boxes (Figure 6.1). Because most natural burrows are extremely fragile and susceptible to investigator damage, 50 artificial nesting boxes were placed at the Prince Island colony in 1986 to facilitate demographic monitoring (Lewis and Gress 1988). In 2000 and 2001, we added 20 and 28 new artificial burrows at the Prince Island colony one to two months before each nesting season to increase the number of accessible nest sites. Transmitters were not attached to Auklets nesting within the artificial nest-boxes on Prince Island because they are part of the long-term monitoring program by the Channel Islands National Park. Therefore, we attached transmitters only to Auklets nesting within known natural nest sites and artificial burrows on Prince Island. On Scorpion Rock, we placed 20 and 15 artificial burrows within the nesting colony two months before the 2000 and 2001 breeding seasons, respectively; there were no artificial nest-boxes available for study and we were not able to use natural nest sites at Scorpion Rock. Therefore, we attached transmitters only to Auklets nesting within artificial burrows on Scorpion Rock.

We visited Prince Island and Scorpion Rock periodically throughout the 1999–2001 breeding seasons to attach radio-transmitters. Because our goal was to study the effects of transmitters on chick growth and survival, we attached transmitters randomly to one partner of a pair whose egg was either close to hatching or had recently hatched upon our visit. We assigned the remaining artificial burrows and natural nest sites and all of the artificial nest-boxes to the control group (see Statistical analyses).

Radio Transmitter Attachment

We hand-captured breeding adults at night when the Auklets returned to previously marked nest sites on Prince Island (1999, 2000, and 2001 breeding seasons) and Scorpion Rock (2000 and 2001). We also used a nylon mist net to capture adults at Scorpion Rock (4 shelves, 38 mm mesh; Avinet Inc., Dryden, NY, USA). The birds were banded (United States Fish and Wildlife Service #3 leg bands), weighed (± 1.0 g with a 300 g Pesola® spring scale), and we measured bill depth and the length of the flattened wing chord. For radio-marked Auklets, we also collected a single drop of blood in a micro-capillary tube by pricking the bird's medial tarsal vein with a sterile needle. Blood was stored in 70% ethanol and thereafter analyzed to determine the Auklet's sex using molecular techniques (Celera AgGen, Zoogen™ sex analysis, Davis, CA, USA). We determined the sex of Auklets that we did not collect blood from (n = 9) by comparing bill depths between partners; the bird with the greater measurement was classified as a male (Nelson 1981). Iris coloration on a scale from one to four, with larger integers indicating a younger bird, was used to age Auklets (Manuwal 1978).

We attached radio-transmitters (1999 and 2000: Model BD-2G, Holohil Systems Ltd., Carp, Ontario, Canada; 2001: Model A4300, Advanced Telemetry Systems Inc., Isanti, Minnesota, USA) to the dorsal midline of Auklets with a subcutaneous anchor, single rear suture, and marine epoxy following Newman et al. (1999; Figure 6.2). All Auklets marked in 1999 and most Auklets marked in 2000 were lightly sedated with an inhalation anesthetic (isoflurane) prior to attaching transmitters. We felt that the complications potentially associated with sedation outweighed the potential benefit to the birds, so we discontinued sedating Auklets in 2001; the birds were relatively calm during transmitter attachment and we had good success. Transmitters operated at 148–149 MHz in 1999 and 164–165 MHz in 2000 and 2001, weighed 3.0–3.1 g (<2% of Auklet body mass), were either 10 mm wide × 10 mm high (Model BD-2G) or 13 mm wide × 7 mm high (Model A4300; both <5% of Auklet cross-sectional body area), and had a 15 cm external whip antenna. Immediately after attaching transmitters, we returned the birds to their nest sites. The mean ± SD time from capture to release was 29 ± 9 min. Thereafter, we monitored radio-marked Auklets at sea by fixed-wing aircraft every 1 to 8 days throughout the breeding season (Chapter 3).

Reproductive Performance

Chick Growth Rate. – We visited nest sites several times throughout each nesting season and measured chicks' body masses (± 1.0 g with 100-g or 300-g Pesola spring scales) and maximum flattened wing chords (± 1.0 mm). We used two indices of chick growth rate: (1) mass growth rate and (2) wing growth rate. We calculated mass growth rates (g d^{-1}) for individual chicks during the developmental period when body mass increases linearly (5 to 25 days of age; Manuwal 1974, Vermeer 1981, Hedd et al. 2002) using the formula: $(\text{mass}_{t2} - \text{mass}_{t1})/(\text{age}_{t2} - \text{age}_{t1})$, where *t1* was the first measurement and *t2* was the last measurement recorded during the linear growth phase. Similarly, we calculated linear wing growth rates (mm d^{-1}) for individual chicks between 5 and 35 days of age using the formula: $(\text{wing chord}_{t2} - \text{wing chord}_{t1})/(\text{age}_{t2} - \text{age}_{t1})$. We determined the chick's age at each nest visit by (1) subtracting the date we measured the chick from its observed hatching date (± 2 d), or (2), if we did not observe the hatching date, we estimated chick age using the linear relationship between wing chord and age calculated from a subset of our data that included chicks with known hatching dates {chick age = (wing chord [mm] – 14.68) ÷ 2.25; $n = 64$, $R^2 = 0.93$}. We also used this equation to estimate hatching date by subtracting the chick's estimated age from the date on which the wing chord was measured. We used only the first wing chord measurement, prior to outfitting parents with transmitters, when developing and applying the equation so that any transmitter effects on wing growth would not bias our estimates of chick age and hatching date. In the transmitter treatment group, we calculated growth rates only for chicks with parents who had carried transmitters for ≥3 days between chick measurements (during the linear growth phase) to allow sufficient time for potential transmitter effects.

Fledging Success and Peak Fledging Mass. – Because travel to Prince Island and Scorpion Rock was logistically difficult and dependent on weather, we visited nest sites sporadically throughout the breeding season and therefore did not measure exact fledging success and fledging mass. Instead, we used indices of these reproductive parameters based on expected fledging age and mass. In the southern portion of their range, Cassin's Auklet chicks typically reach peak mass at 37 days (approximate range: 35–45 days; Manuwal 1974, Ainley et al. 1990) and fledge at 41–42 days (Manuwal 1974, Ainley et al. 1990) at 147–158 g (range of annual means from 1970 to 1983 at the Farallon Islands; Ainley et al. 1990), depending on environmental conditions. For this study, we considered a chick to have fledged if it was still alive at ≥30 days of age, was mostly feathered (i.e., fully feathered except for a trace amount of down remaining on the head and neck), and weighed ≥100 g on our last visit before the chick left the nest site (following Martin and Sydeman 1998). Conversely, chicks that were found dead at the nest site, disappeared from the nest site before they were 30 days of age, or weighed <100 g after 30 days of age were considered not to have fledged (following Martin and Sydeman 1998). Chicks that did not meet these criteria were excluded from analyses of fledging success. As an index of fledging mass, we used the peak mass measured between 35 and 45 days of age. Although chicks usually reach asymptotic growth between 35 and 45 days of age, we note that peak mass is only an approximation of fledging mass because chicks can lose weight just prior to fledging (Manuwal 1974, Vermeer 1981, Ainley et al. 1990, Hedd et al. 2002). Chicks that were not measured between 35 and 45 days of age were excluded from analyses of peak mass. We used only the first nesting attempt (first egg laid and chick raised) by a pair during the breeding season (hereafter alpha chicks) for all analyses except when we specifically considered double brooding.

Double Brooding. – We also measured the frequency with which pairs initiated, hatched, and fledged second clutches after successfully fledging their alpha chick. In the treatment group, we measured the frequency of double brooding only for Auklet pairs that were radio-marked during their first breeding attempt for that season (i.e., parents were marked while raising the alpha chick). We examined whether second clutches (1) occurred less frequently among radio-marked pairs than unmarked pairs, (2) had lower hatching success among radio-marked pairs than unmarked pairs, and (3) had lower fledging success among radio-marked pairs than unmarked pairs.

Statistical Analyses

We did not randomly assign Auklet pairs to treatment groups because we could not radio-mark Auklets nesting in the artificial nest-boxes on Prince Island; hence, pairs nesting in the artificial nest-boxes were included in the control group. As a consequence, it is possible that pair quality (e.g., age, experience, pair bond duration) differed among treatment groups. Therefore, we statistically controlled for any potential differences in pairs between treatment groups by including nest type (natural nest site, artificial burrow, or artificial nest-box) as a covariate in each analysis. We also included Julian hatching date as a covariate in each analysis because fledging success and chick growth rates often decline as the nesting season progresses (Morbey and Ydenberg 1997, Ainley et al. 1990). We controlled for yearly variation in nesting phenology by using z-scores. Z-scores were calculated each year by taking the difference between a pair's Julian hatching date and the mean Julian hatching date, and dividing that quantity by the standard deviation for that year. Additionally, we included year and a year × treatment interaction in each analysis. Because the radio-marked group included pairs nesting in natural nest sites (i.e., burrows and rock crevices) and artificial nesting burrows, whereas the control group included pairs nesting in these sites and in artificial nest-boxes, we repeated each analysis after excluding the control pairs nesting in artificial nest-boxes to make sure that our results were not an artifact of nest type. Finally, we used unpaired *t*-tests to compare mean age and body mass of pairs in the radio-marked and unmarked groups to evaluate whether parents differed between treatment groups. For these analyses, we used either the mean value of a pair when both parents were measured or the value for a single parent when only one parent was measured.

To examine whether chicks raised by unmarked pairs had faster growth rates and larger peak fledging masses than chicks raised by pairs containing a radio-marked parent, we used analysis of covariance (ANCOVA) in which the factors were the treatment group (radio-marked or unmarked pairs), year (1999, 2000, or 2001), and nest type (natural nest site, artificial burrow, or artificial nest-box), and the covariate was Julian hatching date (z-score). To test whether pairs containing a partner with an attached transmitter had lower fledging success than unmarked pairs, we used multiple logistic regression in which the nominal dependent variable was fledge or fail and the explanatory variables were treatment group, year, nest type, and Julian hatching date (z-score). We also used multiple logistic regression to analyze the probability that a pair would initiate a second clutch, hatch a second egg, and fledge a second (beta) chick after successfully fledging their alpha chick. We included treatment group, year, nest type, and Julian hatching date (z-score) as explanatory variables in each model.

We also tested whether the sex of the radio-marked parent influenced reproductive performance. For these analyses we statistically controlled for the effect of year, but not for hatching date or nest type (as in the other analyses) because transmitters were assigned randomly to a partner within a nest site. We tested the effect of the radio-marked partner's sex on chick growth rates and peak fledging masses using ANCOVA in which the factors were the sex of the radio-marked parent, year, and a sex × year interaction. We tested the effect of the radio-marked partner's sex on fledging success using multiple logistic regression, in which the nominal dependent variable was fledge or fail and the explanatory variables were the sex of the radio-marked partner, year, and a sex × year interaction. We also tested whether the radio-marked partner's sex influenced the probability that a pair would initiate a second clutch, hatch a second egg, and fledge a second chick after successfully fledging their alpha chick using multiple logistic regression, in which the explanatory variables were the sex of the radio-marked parent, year, and a sex × year interaction. We conducted statistical analyses with JMP® (version 4.0.4; SAS Institute Inc., Sall et al. 2001) or StatView® (version 5.0.1; SAS Institute Inc. 1998), and tests were considered statistically significant when $P < 0.05$. All tests were two-tailed. We report means ± SE unless otherwise noted.

RESULTS

We attached radio-transmitters to both partners in 7 pairs and to one partner in 108 Auklet pairs during the 1999, 2000, or 2001 breeding seasons. We used 131 unmarked pairs as controls. There was no difference in the mean iris (age) score (unmarked: 1.37 ± 0.07, radio-marked: 1.44 ± 0.07; $t_{138} = -0.64$, $P = 0.52$) or mean body mass (unmarked: 165.2 ± 1.5 g, radio-marked: 163.4 ± 1.1 g; $t_{121} = 0.96$, $P = 0.34$) of pairs in the radio-marked and unmarked groups. Eighty-four transmitters were attached when parents had young chicks and 31 were attached when parents were in the late stages of incubation. Of the parents that were radio-marked during the egg stage, 13 of 31 eggs hatched (42%). Egg failure was primarily due to nest desertion (15 of 18 egg failures), but five of these pairs renested during the same breeding season. Of those parents marked during the chick rearing stage, none immediately deserted their chick.

Radio transmitter failure was especially common in 1999 when 12 of 35 transmitters were confirmed to have failed within 2 to 90 days. These radio-marked Auklets were observed at their nest sites with their transmitters still attached, but the transmitters were not functioning. Fourteen other transmitters were suspected to have failed in 1999 on the basis of poor signal quality and strength. In 2000 and 2001, radio-failure was less common and we observed only 5 radio-marked Auklets at their nesting sites with attached transmitters that were not functioning.

There were marked differences in nesting phenology among years. The median Julian hatching dates of the first egg laid were 49 (range: 31–156), 84 (range: 64–170), and 110 (range: 90–177) during 1999, 2000, and 2001, respectively. However, we detected no interaction effect between year and treatment on any of the indices of reproductive performance (all $P > 0.10$), while statistically controlling for year, treatment, nest type, and Julian hatching date. We also detected no interaction effect between year and sex of the radio-marked parent on any of the indices of reproductive performance (all $P > 0.10$), while statistically controlling for year and sex. Therefore, we dropped all interaction terms from further analyses.

Chick Growth and Survival

Mass Growth Rate. – While statistically controlling for year, nest type, and hatching date, the only factor that affected a chick's mass growth rate was whether a parent was radio-marked (ANCOVA: treatment: $F_{1,37} = 4.28$, $P = 0.046$; year: $F_{2,37} = 1.21$, $P = 0.31$; nest type: $F_{2,37} = 0.60$, $P = 0.56$; z-score Julian hatch date: $F_{1,37} = 0.49$, $P = 0.49$). Chicks raised by unmarked pairs had faster mass growth rates than chicks raised by radio-marked pairs during each year of the study (Figure 6.3a). We obtained similar results after excluding pairs nesting in the artificial nest boxes (some of the controls) from the analysis (ANCOVA: treatment: $F_{1,24} = 4.67$, $P = 0.04$; year: $F_{2,24} = 3.13$, $P = 0.06$; nest type: $F_{1,24} = 0.01$, $P = 0.91$; z-score Julian hatch date: $F_{1,24} = 0.66$, $P = 0.42$). Chicks raised by unmarked parents were consistently heavier throughout the chick-rearing period and tended to reach peak fledging mass at earlier ages than chicks raised by a radio-marked parent (Figure 6.4).

Wing Growth Rate. – Chicks raised by unmarked pairs also tended to have faster wing growth rates than chicks raised by radio-marked pairs during each year of the study (Figure 6.3b), but these results were not statistically significant when we controlled for year, nest type, and hatching date (ANCOVA: treatment: $F_{1,73} = 3.27$, $P = 0.075$; year: $F_{2,73} = 0.50$, $P = 0.61$; nest type: $F_{2,73} = 0.15$, $P = 0.86$; z-score Julian hatch date: $F_{1,73} = 8.31$, $P < 0.01$). We obtained similar results after excluding pairs nesting in the artificial nest boxes from the analysis (ANCOVA: treatment: $F_{1,47} = 2.13$, $P = 0.15$; year: $F_{2,47} = 0.46$, $P = 0.64$; nest type: $F_{1,47} = 0.01$, $P = 0.92$; z-score Julian hatch date: $F_{1,47} = 4.77$, $P = 0.03$).

Peak Fledging Mass. – While statistically controlling for year, nest type, and hatching date, peak fledging mass was significantly influenced by whether a parent was radio-marked (ANCOVA: treatment: $F_{1,87} = 13.64$, $P < 0.001$; year: $F_{2,87} = 0.31$, $P = 0.73$; nest type: $F_{2,87} = 2.08$, $P = 0.13$; z-score Julian hatch date: $F_{1,87} = 6.60$, $P = 0.01$). Chicks raised by unmarked pairs had higher peak fledging masses than chicks raised by radio-marked pairs during each year of the study (Figure 6.3c). We obtained similar results after excluding pairs nesting in the artificial nest boxes from the analysis (ANCOVA: treatment: $F_{1,55} = 10.46$, $P < 0.01$; year: $F_{2,55} = 0.25$, $P = 0.78$; nest type: $F_{1,55} = 2.93$, $P = 0.09$; z-score Julian hatch date: $F_{1,55} = 1.89$, $P = 0.18$).

Fledging Success. – While statistically controlling for year, nest type, and hatching date, the probability of fledging a chick depended on whether the pair contained a radio-marked partner (multiple logistic regression, $n = 143$ pairs: treatment: Wald $\chi^2_1 = 4.13$, $P = 0.04$; year: Wald $\chi^2_2 = 0.73$, $P = 0.70$; nest type: Wald $\chi^2_2 = 0.17$, $P = 0.92$; z-score Julian hatch date: Wald $\chi^2_1 = 9.94$, $P < 0.01$). Radio-marked pairs fledged fewer chicks than unmarked pairs during each year of the study (Figure 6.3d). We obtained similar results after excluding pairs nesting in the artificial nest boxes from the analysis (multiple logistic regression, $n = 93$ pairs: treatment: Wald $\chi^2_1 = 5.22$, $P = 0.02$; year: Wald $\chi^2_2 = 3.75$, $P = 0.15$; nest type: Wald $\chi^2_1 = 0.19$, $P = 0.66$; z-score Julian hatch date: Wald $\chi^2_1 = 10.11$, $P < 0.01$).

Both Parents Radio-Marked

Of the 7 pairs to which we attached radio-transmitters to both partners, two alpha chicks successfully fledged with normal peak masses and growth rates (2001: 123 g at 36 days of age, 4.22 g d^{-1} mass growth rate, and 3.33 mm d^{-1} wing growth rate; 2000: 130 g at 45 days of age), three eggs were abandoned (all in 1999; one partner renested with a new mate), one chick failed to fledge, and the seventh chick did not meet the criteria to estimate fledging success.

Double Brooding

Altogether, 61 unmarked pairs and 46 radio-marked pairs successfully fledged their alpha chick. Of these, unmarked pairs were more likely to initiate a second clutch than radio-marked pairs (multiple logistic regression, $n = 107$ pairs: treatment: Wald $\chi^2_1 = 7.05$, $P < 0.01$; year: Wald $\chi^2_2 = 17.80$, $P = 0.0001$; nest type: Wald $\chi^2_2 = 0.78$, $P = 0.68$; z-score Julian hatch date of first clutch: Wald $\chi^2_1 = 7.99$, $P < 0.01$; Table 6.1, Figure 6.5). Similarly, unmarked pairs tended to hatch a second egg (multiple logistic regression, $n = 107$ pairs: treatment: Wald $\chi^2_1 = 1.14$, $P = 0.29$; year: Wald $\chi^2_2 = 0.85$, $P = 0.65$; nest type: Wald $\chi^2_2 = 0.13$, $P = 0.94$; z-score Julian hatch date of first clutch: Wald $\chi^2_1 = 3.22$, $P = 0.07$) and fledge a second chick (multiple logistic regression, $n = 107$ pairs: treatment: Wald $\chi^2_1 = 0.01$, $P = 0.97$; year: Wald $\chi^2_2 = 0.16$, $P = 0.92$; nest type: Wald $\chi^2_2 = 0.01$, $P = 0.99$; z-score Julian hatch date of first clutch: Wald $\chi^2_1 = 3.06$, $P = 0.08$) more often then radio-marked pairs (Table 6.1, Figure 6.5), but these results were not statistically significant.

Sex of Radio-Marked Parent

The probability of fledging an alpha chick depended on the sex of the radio-marked parent (multiple logistic regression, $n = 63$ pairs: sex: Wald $\chi^2_1 = 3.86$, $P = 0.049$; year: Wald $\chi^2_2 = 0.46$, $P = 0.80$; Figure 6.6). Pairs containing a radio-marked female fledged 77% of their chicks whereas pairs containing a radio-marked male fledged only 50% of their chicks. However, we detected no difference in mass growth rate (ANCOVA: sex: $F_{1,20} = 0.92$, $P = 0.35$; year: $F_{2,20} = 4.11$, $P = 0.03$), wing growth rate (ANCOVA: sex: $F_{1,35} = 1.89$, $P = 0.18$; year: $F_{2,35} = 0.10$, $P = 0.90$), or peak fledging mass (ANCOVA: sex: $F_{1,38} = 0.01$, $P = 0.97$; year: $F_{2,38} = 0.40$, $P = 0.68$) between chicks raised by pairs containing a radio-marked male or female (Figure 6.6). Additionally, the sex of the radio-marked partner did not influence the likelihood that a pair would initiate a second clutch (multiple logistic regression, $n = 40$ pairs: sex: Wald $\chi^2_1 = 0.01$, $P = 0.97$; year: Wald $\chi^2_2 = 0.01$, $P = 0.99$), hatch a second egg (multiple logistic regression, $n = 40$ pairs: sex: Wald $\chi^2_1 = 0.01$, $P = 0.98$; year: Wald $\chi^2_2 = 0.01$, $P = 0.99$) or fledge a second chick (multiple logistic regression, $n = 40$ pairs: sex: Wald $\chi^2_1 = 0.01$, $P = 0.98$; year: Wald $\chi^2_2 = 0.01$, $P = 0.99$).

Long-Term Effects

We re-sighted 12 of 74 (16%) individuals nesting during a subsequent breeding season after they had been radio-marked in 1999 or 2000. Of these re-sighted individuals, all had shed their transmitter, healed their attachment sites, and normally molted their feathers around the attachment site. We re-sighted 37 of 115 (32%) individuals nesting during a subsequent breeding season that were not marked with transmitters in 1999 or 2000. Fifty percent of the 12 re-sighted individuals in the radio-marked group and 46% of the 37 re-sighted individuals in the unmarked group nested in the same site they used in the prior year.

DISCUSSION

We found that the reproductive performance of Cassin's Auklet parents was reduced by externally attached radio transmitters. Chicks raised by unmarked pairs had faster body mass and wing growth rates, larger peak fledging masses, and higher fledging success than chicks raised by radio-marked pairs during each year of the study (Figure 6.3). Overall, radio-marking one partner in a pair reduced chick mass growth rates by 1.42 g d^{-1}, wing growth rates by 0.39 mm d^{-1}, peak fledging mass by 29.4 g, and fledging success by 29% compared to unmarked pairs. Furthermore, of those pairs that successfully fledged their alpha chick, unmarked pairs were significantly more likely to initiate a second clutch and tended to hatch a second egg and fledge a second chick more often than radio-marked pairs (Table 6.1, Figure 6.5).

We radio-marked Auklets nesting in natural sites (i.e., burrows and rock crevices) and artificial burrows, whereas unmarked pairs were nesting in these sites and in artificial nest-boxes. As a consequence, it is possible that pair quality (e.g., age, experience, pair bond duration) differed between the unmarked and radio-marked groups. For example, the artificial nest-boxes were placed on Prince Island in 1986 (Lewis and Gress 1988), allowing long-term pairs ample time to become established residents, whereas the artificial burrows were placed on the islands one to two months before the 1999 and 2000 breeding seasons. Thus, the unmarked group could have contained a higher proportion of older and more experienced pairs that had been breeding together for a longer period of time than the radio-marked group. If so, then unmarked pairs may have had higher reproductive success than radio-marked pairs, regardless of any transmitter effects, because breeding performance often improves with age, breeding experience, and the length of the pair bond in Cassin's Auklets (Emslie et al. 1992, Pyle et al. 2001).

However, five lines of evidence suggest that the reduction in breeding performance observed in radio-marked pairs was due to transmitter effects rather than to a difference in inherent parental quality between treatment groups. First, the mean ages of pairs did not differ between the unmarked and radio-marked groups. Second, we used only pairs that had successfully hatched their eggs in our study, and hatching success often improves with breeding experience in Cassin's Auklets (Emslie et al. 1992). Hence, both radio-marked and unmarked pairs were similarly successful in their breeding attempts to the chick stage and probably were similar in parental quality and experience as well. Third, we statistically controlled for any potential differences in parental quality between treatment groups by including nest type (natural site, artificial burrow, or artificial nest-box) and Julian hatching date (z-scores) as co-variables in our analyses. For example, higher quality Cassin's Auklet parents are thought to initiate nesting, and therefore hatch their eggs, earlier in the breeding season (Morbey and Ydenberg 2000). Although hatching date (but not nest type) influenced chick wing growth rates, peak fledging mass, fledging success, and double brooding attempts, radio-marking nevertheless had an independent and significant negative effect on the reproductive performance of Cassin's Auklets. Fourth, we found similar results after excluding all of the pairs nesting in the artificial nest-boxes (used in the control group) from analyses. Finally, mass growth rates of chicks raised by pairs with a radio-marked parent (1999: 2.40 ± 0.46 g d^{-1}, 2000: 3.20 ± 0.53 g d^{-1}, 2001: 1.22 ± 0.41 g d^{-1}) were well below typical growth rates reported for Cassin's Auklets (e.g., 3.9 g d^{-1}, Manuwal 1974; 4.49 g d^{-1}, Morbey and Ydenberg 1997). Wing growth rates of chicks raised by pairs with a radio-marked parent (1999: 2.41 ± 0.15 g d^{-1}, 2000: 2.57 ± 0.27 g d^{-1}, 2001: 2.45 ± 0.13 g d^{-1}) were below normal as well (e.g., 2.82 mm d^{-1}, Morbey and Ydenberg 1997). Together, these results indicate that transmitter effects were responsible for the reduced reproductive performance observed in the radio-marked pairs.

Few studies have examined radio transmitter effects on alcids, but each has found some adverse effects on breeding behavior and reproductive performance. Using tail-mounted radio transmitters, Wanless et al. (1989) found that radio-marked common murres (*Uria aalge*) and razorbills (*Alca torda*) tended to make fewer foraging trips per day, were away for longer periods, and returned more often without food for their chicks than unmarked birds. In a similar study using back-mounted radio transmitters, Wanless et al. (1988) found that common murres fitted with transmitters that had external antennas spent less time attending the breeding colony, were absent for longer periods, and delivered food to chicks less frequently than murres fitted with transmitters that had internal antennas or unmarked murres. However, this change in parental behavior did not reduce fledging success because the mates of radio-marked partners compensated by increasing the amount of food delivered to chicks (Wanless et al. 1988). Similarly, thick-billed murre (*Uria lomnia*) parents that were fitted with time-depth recorders lost weight at a faster rate, attended nests less often, and fed their chicks less frequently than unmarked birds (R. Paredes et al., Memorial University of Newfoundland, unpublished data). Yet, again, fledging success was not influenced because the partners of marked birds increased their feeding rates to compensate for their mates' reduction in parental care (R. Paredes et al., Memorial University of Newfoundland, unpublished data). Unlike common murres and thick-billed murres, partners of radio-marked Cassin's Auklets were either unable or unwilling to compensate for their partners' reduced chick provisioning, and chick growth and survival were negatively affected.

In addition to a reduction in chick growth and survival, pairs with a radio-marked partner also initiated fewer second clutches (7%) than unmarked pairs (39%) after successfully fledging their alpha chick (Table 6.1, Figure 6.5). Raising a second chick during the same breeding season is unique to Cassin's Auklets breeding in the southern portion of their range (Manuwal and Thoresen 1993). Because the cost of initiating and successfully rearing a second chick is substantial (Ainley et al. 1990), the occurrence of double brooding typically indicates that parents are in good physical condition and that environmental conditions are particularly favorable for breeding. Thus, although we did not measure parental condition directly, the 32%, 21%, and 14% reduction in the number of radio-marked pairs initiating, hatching, and successfully fledging a second chick, respectively, suggests that transmitters reduced parents' body condition. In accordance, several studies have documented mass loss after attaching external recording devices to alcids (Croll et al. 1992; Falk et al. 2000; R. Paredes et al., Memorial University of Newfoundland, unpublished data; but see Tremblay et al. 2003).

The mechanism by which externally attached transmitters reduced the reproductive performance of Cassin's Auklets is unclear. Cassin's Auklets have relatively high metabolic rates, probably due to the high costs of flapping flight and pursuit diving, and must consume about 67% of their body mass equivalent in euphausiids daily to meet their energy expenditure during chick rearing (Hodum et al. 1998). We speculate that radio-marked birds expended more energy and foraged less efficiently than unmarked parents due to an increase in aerodynamic and hydrodynamic drag during long-distance flights to foraging areas (mean distance = 18 km; Chapter 3) and underwater pursuit diving for prey (average maximum diving depth = 28 m; Burger and Powell 1990). For instance, although fitting common murres with transmitters that had external antennas reduced parental care, fitting common murres with transmitters that had internal antennas had no adverse effects on parental care despite the heavier mass of the internal transmitter package (Wanless et al. 1988). Wilson et al. (1986) found that swimming speeds of African penguins (*Spheniscus demersus*) were inversely related to the size of an externally attached data-recording device and concluded that while attachments should have as little mass as possible, it is more important that the stream-lining of marine animals be altered as little as possible. Similarly, the foraging trip durations of chinstrap penguins (*Pygoscelis antartica*; Croll et al. 1991; but see Croll et al. 1996), adélie penguins (*Pygoscelis adeliae*; Watanuki et al. 1992; but see Ballard et al. 2001), royal penguins (*Eudyptes schlegeli*; Hull 1997), and Humboldt penguins (*Spheniscus humboldti*; Taylor et al. 2001) were lengthened by attaching external recording devices. These results suggest that an increase in hydrodynamic drag caused by externally attached radio transmitters had an important influence on the energy expenditure and foraging ability of Cassin's Auklets.

An increase in mass and aerodynamic drag might also have contributed to reduced reproductive performance of Cassin's Auklets, especially since alcids have a high wing loading and use energetically expensive flapping flight (Pennycuik 1987). Cassin's Auklets commonly carry meal loads to chicks that weigh (22.9 ± 9.1 g, mean ± SD; Chapter 4) far more than the radio transmitters we used (3 g). Therefore, it is unlikely that the mass of the transmitter per se adversely affected Auklets, but aerodynamic drag may have contributed. For instance, the flight speed of pigeons (*Columba livia*) was reduced more by the aerodynamic drag associated with an externally attached transmitter than by the added mass, and drag caused a substantial increase in energy expenditure (Gessaman and Nagy 1988, Gessaman et al. 1991). In sum, the increased hydrodynamic and aerodynamic drag associated with an externally attached radio transmitter probably increased the energy expenditure and reduced the foraging efficiency of radio-marked parents, causing a reduction in the amount of energy available to provision chicks. Since Cassin's Auklets are relatively long-lived, it is likely that radio-marked parents transferred the cost of carrying a transmitter to their offspring by reducing their chick provisioning rates (e.g., Sæther et al. 1993, Mauck and Grubb 1995) or deserting the reproductive attempt, such that they did not diminish their own prospects for survival and future reproduction (e.g., Stearns 1992).

Interestingly, we found that fledging success was reduced more when we attached transmitters to the male parent (50% fledged) than when we radio-marked female Cassin's Auklets (77% fledged; Figure 6.6). It is possible that male parental care during chick rearing is more important to fledging success than female care, and that radio-marking males disproportionately reduced the amount of parental care received by the chick. Sex differences in parental care are not well known for Cassin's Auklets, but, using long-term data, Pyle et al. (2001) concluded that the reproductive success of Cassin's Auklets may be optimized by the behavior of the male, rather than the female. Additionally, there have been several studies on alcids that have shown male-biased parental care during chick rearing. For example, male little auks (*Alle alle*) fed chicks more often and spent more time at the colony than females during the late chick-rearing period (A. M. A. Harding et al., Polish Academy of Sciences, unpublished data). Similarly, male marbled murrelets visited nests, and presumably fed chicks, more often than females during the latter half of chick rearing (Bradley et al. 2002). In addition, sex differences in the types of prey delivered to chicks have been observed in razorbills (*Alca torda*; Wagner 1997) and crested Auklets (*Aethia cristatella*; Fraser et al. 2002). Thus, male parental care may also be more important to chick survival than female parental care in Cassin's Auklets. However, it is unclear why fledging success was influenced by the sex of the radio-marked parent, but chick growth rates and peak fledging masses were not.

Although we could not directly examine the effects of radio transmitters on adult survival or at-sea distribution, we found little evidence of adverse effects. Of the 136 Cassin's Auklets we radio-marked, only 9 (7%) individuals were not subsequently found. Because radio-failure was common, especially in 1999, these results indicate that (immediate) transmitter-associated mortalities were rare. Furthermore, of the 12 previously radio-marked individuals we re-sighted nesting during a subsequent breeding season, each individual had shed the transmitter, the attachment site was healed, and the feathers around the attachment site had molted normally. In contrast, proportionately larger implanted satellite transmitters caused high mortality rates in common murres, thick-billed murres, and tufted puffins (*Fratercula cirrhata*; Meyers et al. 1998, Hatch et al. 2000). We also found no evidence that radio-marking reduced nest-site fidelity; 50% of the 12 re-sighted individuals in the radio-marked group and 46% of the 37 re-sighted individuals in the unmarked group nested in the same site they had used in the prior year. Finally, radio-marked Cassin's Auklets foraged in similar areas (Chapter 3, Figure 6.7) compared to unmarked Cassin's Auklets that were surveyed concurrently by aircraft (Chapter 1, Figure 6.7) and previously by ship (Hunt et al. 1979). Additionally, Whitworth et al. (2000*a*) found that radio-marked Xantus's murrelets foraged at similar or greater distances from their colony during the breeding season than had been previously reported for (unmarked) Xantus's murrelets by Hunt et al. (1979) and Briggs et al. (1987). These results indicate that the at-sea movements and distribution of alcids were relatively unaffected by radio transmitters.

Management Implications

Despite the negative effects of externally attached radio transmitters on the breeding performance of Cassin's Auklets, telemetry remains an essential tool for studying alcids and other seabirds. For example, radio telemetry is currently one of the only reliable techniques for finding nests and assessing the breeding phenology of marbled murrelets (Lougheed et al. 2002*b*), a species of critical conservation concern. However, biologists should be aware of the potential effects telemetry has on their study animal so that management decisions are not biased by research techniques. The results of our study on Cassin's Auklets and those on larger alcids such as common murres, thick-billed murres, and razorbills (Wanless et al. 1988, 1989; R. Paredes et al., Memorial University of Newfoundland, unpublished data) indicate that externally attached devices negatively affect the breeding performance of several alcids. We suggest that telemetry should be used with caution when evaluating the reproductive performance of alcids, but probably is still a valuable technique to assess their at-sea movements, foraging ranges, and risks at sea. In addition, our results suggest that radio-marking females, rather than males, may partially mitigate some of the adverse effects on reproductive performance.

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LITERATURE CITED

AINLEY, D. G., L. B. SPEAR, AND S. G. ALLEN. 1996. Variation in the diet of Cassin's Auklet reveals spatial, seasonal, and decadal occurrence patterns of euphausiids off California, USA. Marine Ecology Progress Series 137:1–10.

AINLEY, D. G., R. J. BOEKELHEIDE, S. H. MORRELL, AND C. S. STRONG. 1990. Cassin's Auklet. Pages 307–338 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling–system community. Stanford University Press, Stanford, California, USA.

BAKKEN, G. S., P. S. REYNOLDS, K. P. KENOW, C. E. KORSCHGEN, AND A. F. BOYSEN. 1996. Thermoregulatory effects of radio telemetry transmitters on mallard ducklings. Journal of Wildlife Management 60:669–678.

BALLARD, G., D. G. AINLEY, C. A. RIBIC, AND K. R. BARTON. 2001. Effect of instrument attachment and other factors on foraging trip duration and nesting success of adélie penguins. Condor 103:481–490.

BRADLEY, R. W., L. A. MCFARLANE TRANQUILLA, B. A. VANDERKIST, AND F. COOKE. 2002. Sex differences in nest visitation by chick-rearing marbled murrelets. Condor 104:178–183.

BRIGGS, K. T., W. B. TYLER, D. B. LEWIS, AND D. R. CARLSON. 1987. Bird communities at sea off California: 1975 to 1983. Studies in Avian Biology 11:1–74.

BURGER, A. E., AND D. POWELL. 1990. Diving depths and diets of Cassin's Auklet at Reef Island, British Columbia. Canadian Journal of Zoology 68:1572–1577.

CARTER, H. R., G. J. MCCHESNEY, D. L. JAQUES, C. S. STRONG, M. W. PARKER, J. E. TAKEKAWA, D. L. JORY, AND D. L. WHITWORTH. 1992. Breeding populations of seabirds in California, 1989–1991. Unpublished Draft Final Report, United States Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California, USA.

CROLL, D. A., A. J. GASTON, A. E. BURGER, AND D. KONNOFF. 1992. Foraging behavior and physiological adaptation for diving in thick-billed murres. Ecology 73:344–356.

CROLL, D. A., J. K. JANSEN, M. E. GOEBEL, P. L. BOVENG, AND J. L. BENGTSON. 1996. Foraging behavior and reproductive success in chinstrap penguins: the effects of transmitter attachement. Journal of Field Ornithology 67:1–9.

CROLL, D. A., S. D. OSMEK, AND J. L. BENGTSON. 1991. An effect of instrument attachment on foraging trip duration in chinstrap penguins. Condor 93:777–779.

DUNCAN, D. C., AND A. J. GASTON. 1990. Movements of ancient murrelet broods away from a colony. Studies in Avian Biology 14:109–113.

EMSLIE, S. D., W. J. SYDEMAN, AND P. PYLE. 1992. The importance of mate retention and experience on breeding success in Cassin's Auklet (*Ptychoramphus aleuticus*). Behavioral Ecology 3:189–195.

FALK, K., S. BENVENUTI, L. DALL'ANTONIA, K. KAMPP, AND A. RIBOLINI. 2000. Time allocation and foraging behaviour of Brünnich's guillemots *Uria lomvia* in high-arctic Greenland. Ibis 142:82–92.

FRASER, G. S., I. L. JONES, AND F. M. HUNTER. 2002. Male-female differences in parental care in monogamous crested Auklets. Condor 104:413–423.

GASTON A. J., AND I. L. JONES. 1998. The auks: Alcidae. Oxford University Press Inc., New York, New York, USA.

GESSAMAN, J. A., AND K. A. NAGY. 1988. Transmitter loads affect the flight speed and metabolism of homing pigeons. Condor 90:662–668.

GESSAMAN, J. A., G. W. WORKMAN, AND M. R. FULLER. 1991. Flight performance, energetics and water turnover of tippler pigeons with a harness and dorsal load. Condor 93:546–554.

HARMS, S., AND C. D. WINANT. 1998. Characteristic patterns of the circulation in the Santa Barbara Channel. Journal of Geophysical Research 103:3041–3065.

HATCH, S. A., P. M. MEYERS, D. M. MULCAHY, AND D. C. DOUGLAS. 2000. Performance of implantable satellite transmitters in diving seabirds. Waterbirds 23:84–94.

HEDD A., J. L. RYDER, L. L. COWEN, AND D. F. BERTRAM. 2002. Inter-annual variation in the diet, provisioning and growth of Cassin's Auklet at Triangle Island, British Columbia: responses to variation in ocean climate. Marine Ecology Progress Series 229:221–232.

HODUM, P. J., W. J. SYDEMAN, G. H. VISSER, AND W. W. WEATHERS. 1998. Energy expenditure and food requirements of Cassin's Auklets provisioning nestlings. Condor 100:546–550.

HULL, C. L. 1997. The effect of carrying devices on breeding royal penguins. Condor 99:530–534.

HUNT, G. L. JR., R. L. PITMAN, M. NAUGHTON, K. WINNETT, A. NEWMAN, P. R. KELLY, AND K. T. BRIGGS. 1979. Reproductive ecology and foraging habits of breeding seabirds. In Summary of marine mammal and seabird surveys of the Southern California Bight area 1975–1978, Vol. 3, Investigator's Reports, Part 3, Seabirds, Book II, Final Report: 399. Washington, D. C., Bureau of Land Management, United States Department of the Interior, USA.

LEWIS, D. B., AND F. GRESS. 1988. Seabird monitoring in the Channel Islands National Park, 1986. United States National Park Service, Channel Islands National Park Natural Science Report 88–002.

LOUGHEED, C., L. W. LOUGHEED, F. COOKE, AND S. BOYD. 2002*a*. Local survival of adult and juvenile marbled murrelets and their importance for estimating reproductive success. Condor 104:309–318.

LOUGHEED, C., B. A. VANDERKIST, L. W. LOUGHEED, AND F. COOKE. 2002*b*. Techniques for investigating breeding chronology in marbled murrelets, Desolation Sound, British Columbia. Condor 104:319–330.

MANUWAL, D. A. 1974. The natural history of Cassin's Auklet (*Ptychoramphus aleuticus*). Condor 76:421–431.

MANUWAL, D. A. 1978. Criteria for aging Cassin's Auklets. Bird Banding 49:157–161.

MANUWAL, D. A., AND A. C. THORESEN. 1993. Cassin's Auklet (*Ptychoramphus aleuticus*). *In* A. Poole and F. Gill, editors. The Birds of North America, No. 50. 16 p.

MARTIN, P. L., AND W. J. SYDEMAN. 1998. Seabird monitoring Channel Islands National Park. United States National Park Service, Channel Islands National Park, Technical Report 98–03.

MAUCK, R. A., AND T. C. GRUBB. 1995. Petrel parents shunt all experimentally increased reproductive costs to their offspring. Animal Behaviour 49:999–1008.

MEYERS, P. M., S. A. HATCH, AND D. M. MULCAHY. 1998. Effect of implanted satellite transmitters on the nesting behavior of murres. Condor 100:172–174.

MORBEY, Y. E., AND R. C. YDENBERG. 1997. Intraspecific variability in nestling growth and fledging behavior of Cassin's Auklets at Triangle Island, British Columbia. Condor 99:361–371.

MORBEY, Y. E., AND R. C. YDENBERG. 2000. Seasonal decline in nestling growth: support for the parental-quality hypothesis in Cassin's Auklets. Auk 117:1065–1068.

NELSON, D. A. 1981. Sexual differences in measurements of Cassin's Auklet. Journal of Field Ornithology 52:233–234.

NEWMAN, S. H., J. Y. TAKEKAWA, D. L. WHITWORTH, AND E. BURKETT. 1999. Subcutaneous anchor attachment increases retention of radio transmitters on Xantus' and marbled murrelets. Journal of Field Ornithology 70:520–534.

OBRECHT, H. H., C. J. PENNYCUICK, AND M. R. FULLER. 1988. Wind tunnel experiments to assess the effect of back-mounted radio transmitters on bird body drag. Journal of Experimental Biology 135:265–273.

OEY, L-Y., D. P. WANG, T. HAYWARD, C. WINANT, AND M. HENDERSHOTT. 2001. "Upwelling" and "cyclonic" regimes of the near-surface circulation in the Santa Barbara Channel. Journal of Geophysical Research 106:9213–9222.

PENNYCUIK, C. J. 1987. Flight of auks (Alcidae) and other northern seabirds compared with southern Procellariiformes: ornithodolite observations. Journal of Experimental Biology 128: 335–348.

PYLE, P., W. J. SYDEMAN, AND M. HESTER. 2001. Effects of age, breeding experience, mate fidelity and site fidelity on breeding performance in a declining population of Cassin's Auklets. Journal of Animal Ecology 70:1088–1097.

SÆTHER, B. E., R. ANDERSEN, AND H. C. PEDERSEN. 1993. Regulation of parental effort in a long-lived seabird: an experimental manipulation of the cost of reproduction in the Antarctic petrel, *Thalassoica antarctica*. Behavioral Ecology and Sociobiology 33:147–150.

SALL, J., A. LEHMAN, AND L. CREIGHTON. 2001. JMP start statistics: a guide to statistics and data analysis using JMP and JMP IN software. SAS Institute Inc., Cary, North Carolina, USA.

SAMUEL, M. D., AND M. R. FULLER. 1996. Wildlife radio telemetry. Pages 370–418 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth ed., rev. The Wildlife Society, Bethesda, Maryland, USA.

SAS INSTITUTE INC. 1998. StatView: StatView reference, 2nd edition. SAS Institute Inc., Cary, North Carolina, USA.

STEARNS, S. C. 1992. The evolution of life histories. Oxford University Press, Oxford.

SYDEMAN, W. J., M. M. HESTER, J. A. THAYER, F. GRESS, P. MARTIN, AND J. BUFFA. 2001. Climate change, reproductive performance and diet composition of marine birds in the southern California Current system, 1969–1997. Progress in Oceanography 49:309–329.

TAYLOR, S. S., D. J. BONESS, AND P. MAJLUF. 2001. Foraging trip duration increases for Humboldt penguins tagged with recording devices. Journal of Avian Biology 32:369–372.

TREMBLAY, Y., Y. CHEREL, M. OREMUS, T. TVERAA, AND O. CHASTEL. 2003. Unconventional ventral attachment of time-depth recorders as a new method for investigating time budget and diving behaviour of seabirds. Journal of Experimental Biology 206:1929–1940.

VERMEER, K. 1981. The importance of plankton to Cassin's Auklets during breeding. Journal of Plankton Research 3:315–329.

WAGNER, R. 1997. Differences in prey species delivered to nestlings by male and female razorbills *Alca torda*. Seabird 19:58–59.

WANLESS, S., M. P. HARRIS, AND J. A. MORRIS. 1985. Radio-monitoring as a method for estimating time budgets of guillemots *Uria aalge*. Bird Study 32:170–175.

WANLESS, S., M. P. HARRIS, AND J. A. MORRIS. 1988. The effect of radio transmitters on the behavior of common murres and razorbills during chick rearing. Condor 90:816–823.

WANLESS, S., M. P. HARRIS, AND J. A. MORRIS. 1989. Behavior of alcids with tail-mounted radio transmitters. Colonial Waterbirds 12:158–163.

WANLESS, S., M. P. HARRIS, AND J. A. MORRIS. 1990. A comparison of feeding areas used by individual common murres (*Uria aalge*), razorbills (*Alca torda*) and an Atlantic puffin (*Fratercula arctica*) during the breeding season. Colonial Waterbirds 13:16–24.

WATANUKI, Y., Y. MORI, AND Y. NAITO. 1992. Adélie penguin parental activities and reproduction: effects of device size and timing of its attachment during chick rearing period. Polar Biology 12:539–544.

WHITWORTH, D. L., J. Y. TAKEKAWA, H. R. CARTER, S. H. NEWMAN, T. W. KEENEY, AND P. R. KELLY. 2000*a*. Distribution of Xantus' murrelet *Synthliboramphus hypoleucus* at sea in the Southern California Bight, 1995–97. Ibis 142:268–279.

WHITWORTH, D. L., S. K. NELSON, S. H. NEWMAN, G. B. VAN VLIET, AND W. P. SMITH. 2000*b*. Foraging distances of radio-marked marbled murrelets from inland areas in southeast Alaska. Condor 102:452–456.

WILSON, R. P., W. S. GRANT, AND D. C. DUFFY. 1986. Recording devices on free-ranging marine animals: does measurement affect foraging performance? Ecology 67:1091–1093.

Table 6.1. The frequency of unmarked and radio-marked Cassin's auklet pairs that initiated a second clutch, hatched a second egg, and fledged a second chick after successfully fledging their alpha chick during the 1999, 2000, and 2001 breeding seasons at the Northern Channel Islands, California, USA. Sample sizes are indicated in parentheses.

Year	Pairs Initiating a Second Clutch		Pairs Hatching a Second Egg		Pairs Fledging a Second Chick	
	Unmarked	Radio-marked	Unmarked	Radio-marked	Unmarked	Radio-marked
1999	63% (16)	18% (11)	3% (16)	18% (11)	25% (16)	18% (11)
2000	75% (16)	7% (14)	63% (16)	0% (14)	44% (16)	0% (14)
2001	7% (29)	0% (21)	0% (29)	0% (21)	0% (29)	0% (21)
Total	39% (61)	7% (46)	25% (61)	4% (46)	18% (61)	4% (46)

Figure 6.1. For the control group, we used unmarked Auklet pairs nesting within artificial nest-boxes (placed on Prince Island in 1956), artificial burrows (inset), and natural nest sites. For the radio-marked group, we used Auklet pairs nesting within artificial burrows and natural nest sites. Artificial burrows were placed on Prince Island and Scorpion rock 1–2 months before the 2000 and 2001 breeding seasons. Photos by Josh Adams.

Figure 6.2. An adult Cassin's Auklet with an externally-attached radio transmitter. Photo by Josh Adams.

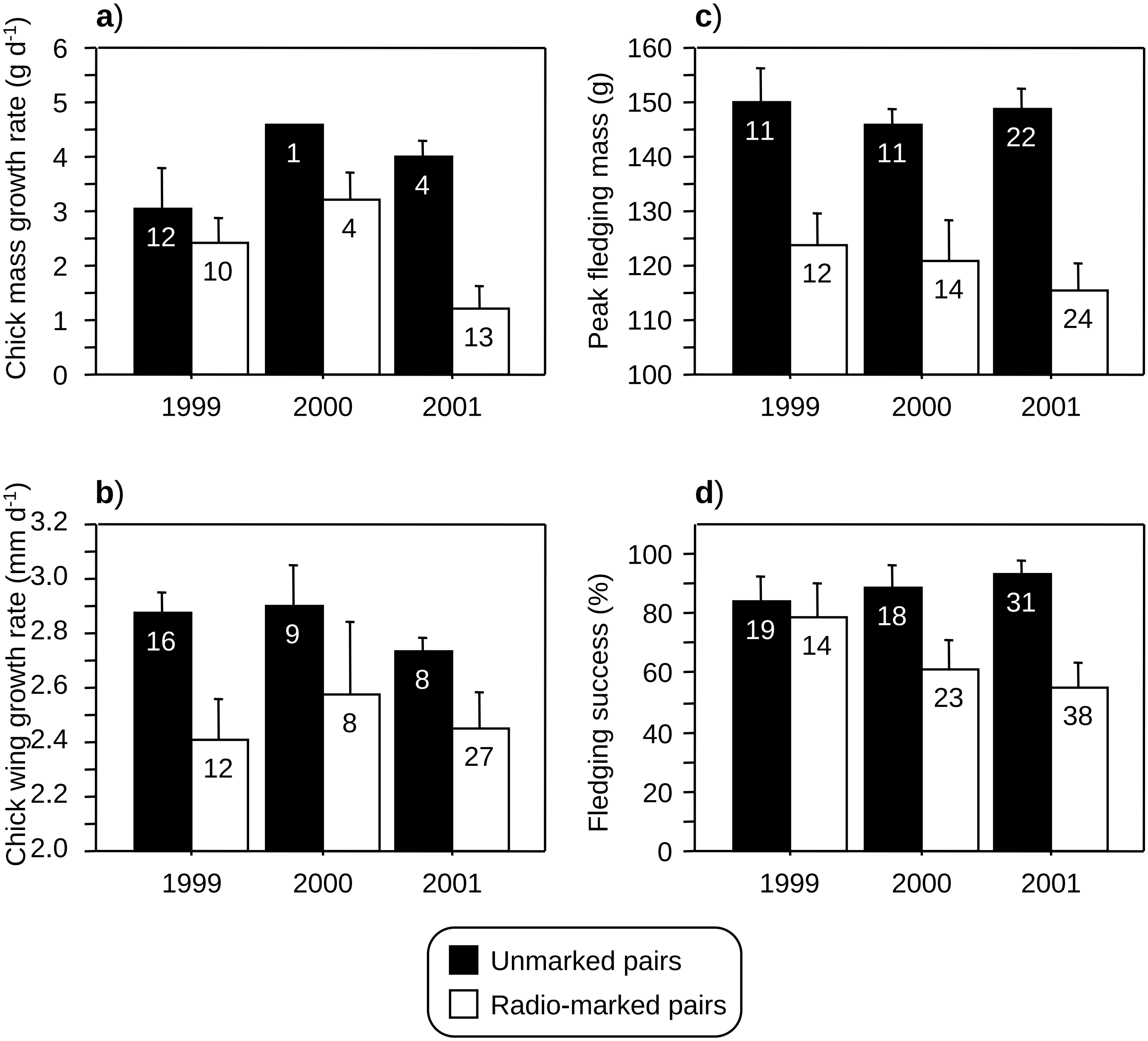

Figure 6.3. Alpha chicks raised by unmarked pairs (filled bars) had (**a**) faster body mass growth rates, (**b**) faster wing growth rates, (**c**) larger peak fledging masses, and (**d**) higher fledging success than alpha chicks raised by pairs with one radio-marked partner (unfilled bars) during each year of the study in the California Channel Islands, USA (mean ± SE). Numbers within bars indicate sample sizes.

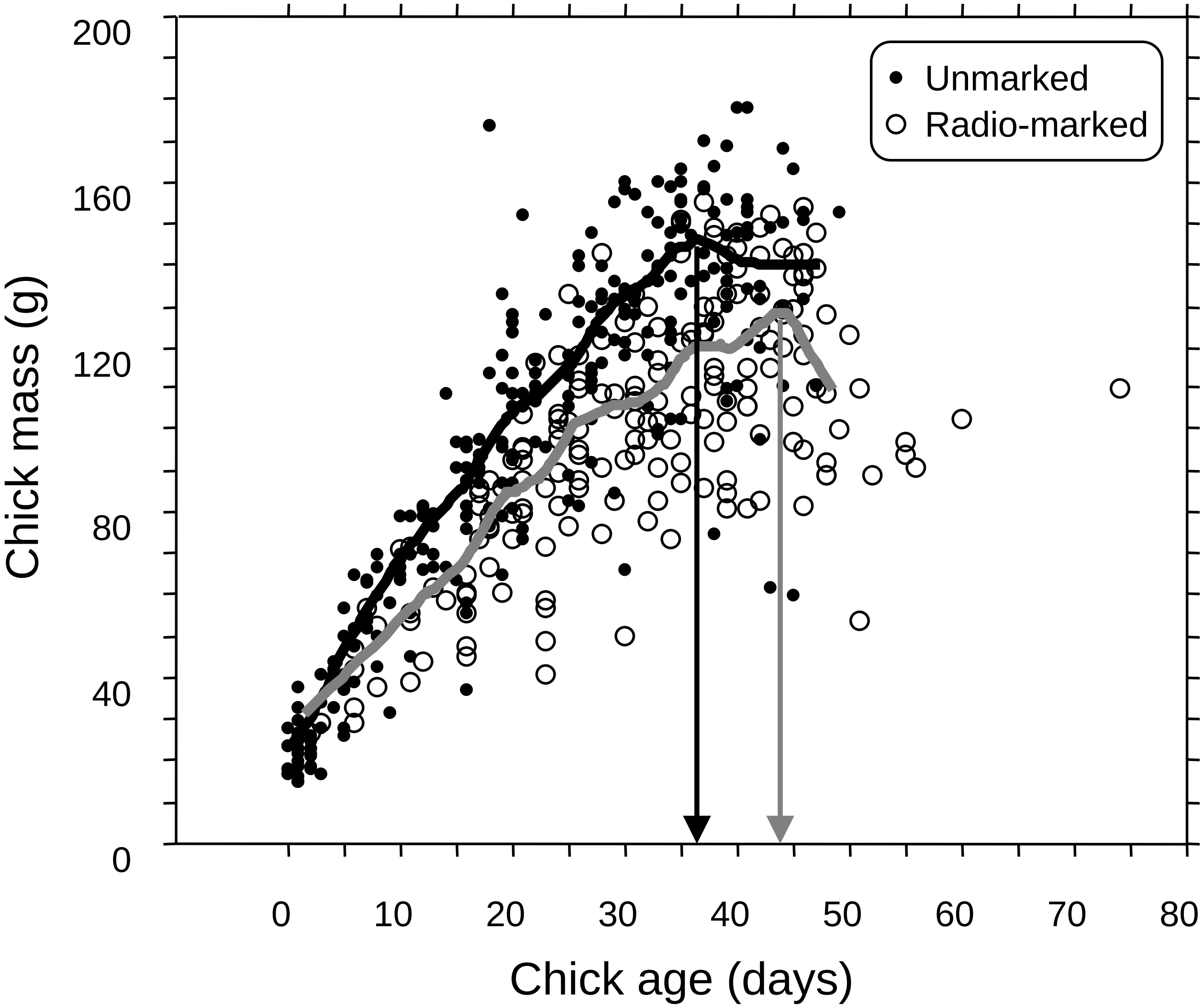

Figure 6.4. Chicks raised by unmarked parents (filled circles, dark line, *n* = 299) were heavier than chicks provisioned by a pair with a currently radio-marked parent (unfilled circles, gray line, *n* = 199) throughout the chick-rearing period at the California Channel Islands, USA. Arrows indicate the average age of chicks when they reached their peak fledging mass; chicks raised by pairs with a radio-marked parent took 8 days longer to reach peak fledging mass compared to chicks raised by unmarked pairs. The figure includes multiple measurements on individual chicks, and all years (1999–2001) are pooled. Each data point represents a single alpha chick's measurement and the corresponding status of the parents. Chicks in the radio-marked group that were measured before the parent was actually radio-marked were considered to have unmarked parents until after the transmitter was attached to the parent. Lines were fitted with a LOWESS function through the fiftieth day of age.

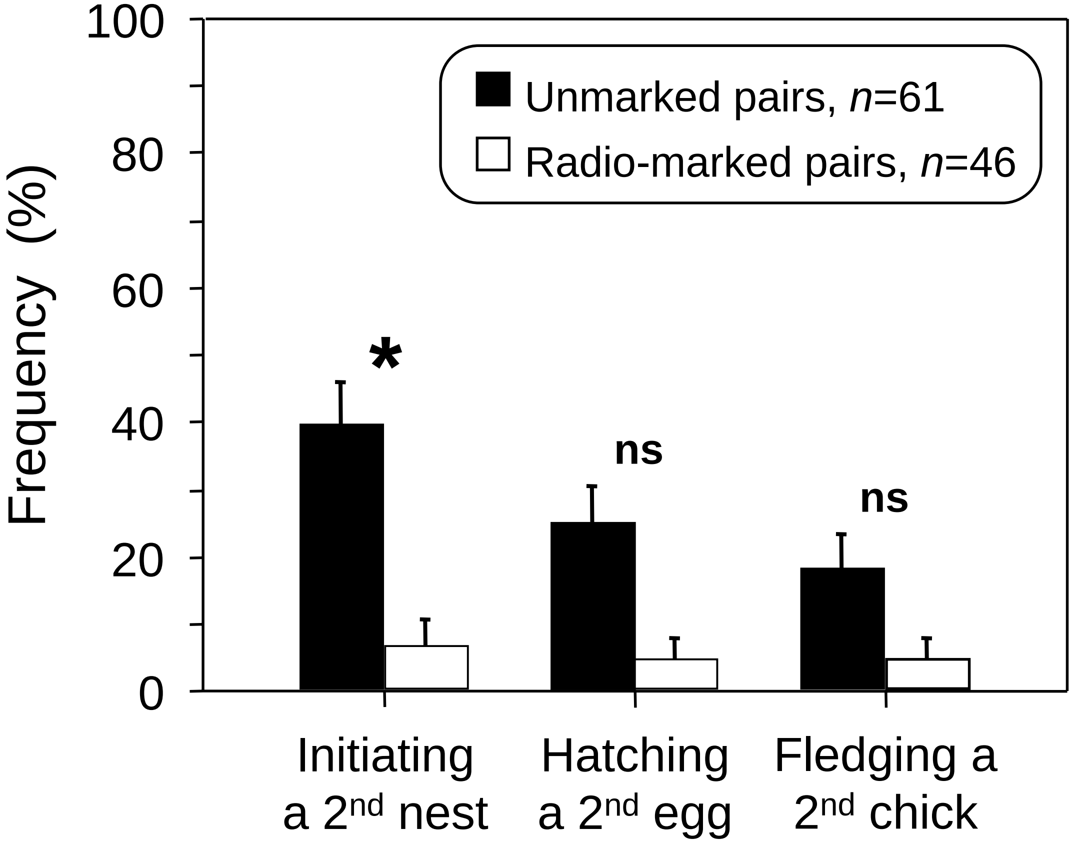

Figure 6.5. Unmarked pairs (filled bars) initiated a second nest, hatched a second egg, and fledged a second chick after successfully fledging their first (alpha) chick more often than pairs with one radio-marked partner (unfilled bars) during 1999–2001 at the California Channel Islands, USA (mean ± SE).

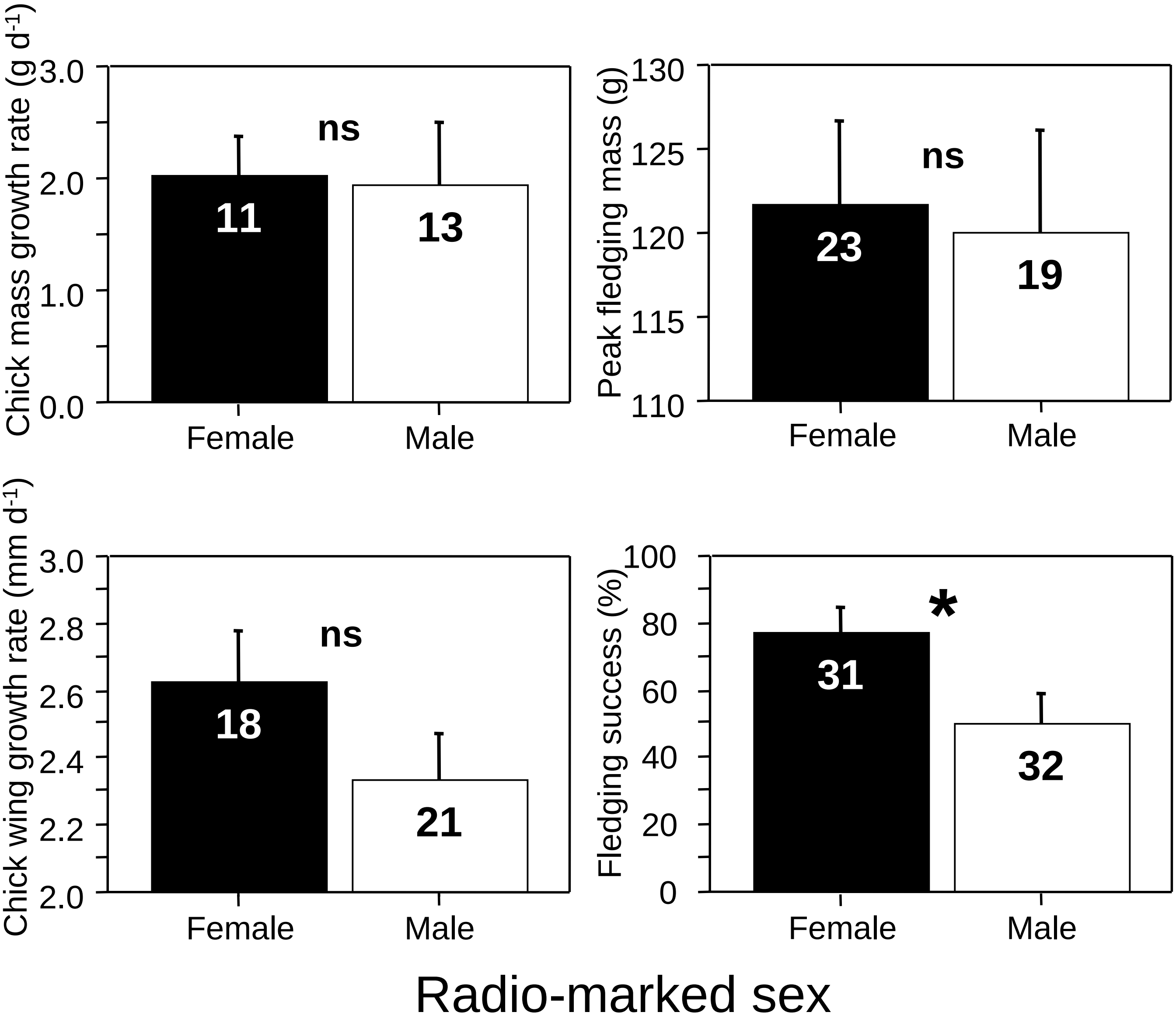

Figure 6.6. Chick fledging success was higher when we radio-marked the female partner (filled bars) than when we radio-marked the male parent (unfilled bars; mean ± SE). Chick wing growth rates and peak fledging mass also tended to be higher when we radio-marked the female parent, rather than the male parent, but these results were not statistically significant. Numbers within bars indicate sample size. Data were collected during 1999–2001 from Cassin's Auklets nesting on the California Channel Islands, USA.

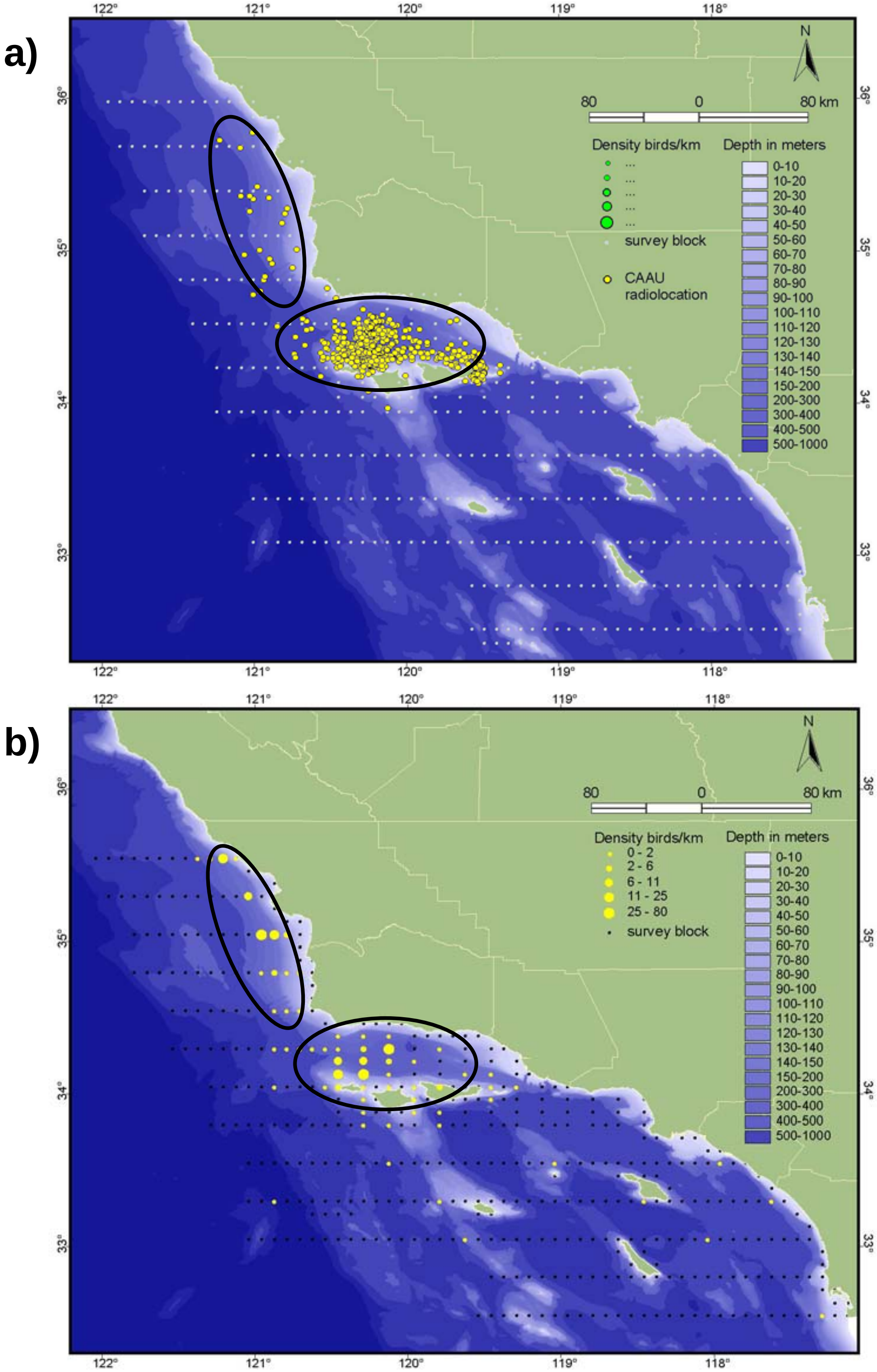

Figure 6.7. **(a)** Telemetry locations of all radio-marked Cassin's Auklets nesting on the California Channel Islands during the 1999, 2000, and 2001 breeding seasons (Chapter 3). **(b)** Average densities of (unmarked) Cassin's Auklets during aerial surveys in May of 1999, 2000, and 2001 (Chapter 1). Radio-marked Auklets foraged in similar areas and at similar rates as unmarked Auklets, mainly within the Santa Barbara Channel and to a lesser extent north of Point Conception.

APPENDIX 1:

U. S. GEOLOGICAL SURVEY--MMS PACIFIC OCS REGION SEABIRD PROGRAM PRODUCTS: 1999–2004

PUBLICATIONS

Ackerman, J. T., J. Adams, J. Y. Takekawa, H. R. Carter, D. L. Whitworth, S. H. Newman, R. T. Golightly, and D. L. Orthmeyer. 2004. Effects of radio transmitters on the reproductive performance of Cassin's Auklets. *Wildlife Society Bulletin*, in press.

Schwemm, C. A., J. T. Ackerman, P. L. Martin, and W. M. Perry. Nest occupancy and hatching success of Xantus's murrelets breeding on Santa Barbara Island, California, during a twenty-year period. *Proceedings of the Sixth California Islands Symposium*, in press.

Adams, J., J. Y. Takekawa, and H. R. Carter. 2005. Cassin's Auklet (*Ptychoramphus aleuticus*) foraging during variable ocean conditions suggests transport mediated changes in zoo- and ichthyoplankton availability off California. *Canadian Journal of Zoology*, in press.

Adams, J., J. Y. Takekawa, and H. R. Carter. 2004. Foraging distance and home range of Cassin's Auklets nesting at two colonies in the California Channel Islands. *Condor* 106:618-637.

Adams, J. 2004. Foraging ecology and reproductive biology of Cassin's Auklet *Ptychoramphus a. aleuticus* in the California Channel Islands. M.Sc. thesis, Moss Landing Marine Laboratories and San Francisco State University, San Francisco.

Hamilton, C. D., H. R. Carter, and R. T. Golightly. 2004. Diet of Xantus's Murrelets in the Southern California Bight. *Wilson Bulletin* 116:152-157.

Carter, H. R., D. L. Whitworth, J. Y. Takekawa, T. W. Keeney, and P. R. Kelly. 2000. At-sea threats to Xantus's murrelets (*Synthliboramphus hypoleucus*) in the Southern California Bight. Pp. 435-447 *in* D. R. Browne, K. L. Mitchell, and H. W. Chaney (eds.). Proceedings of the fifth California Islands symposium, 29 March to 1 April 1999. U. S. Department of the Interior, Minerals Management Services, Pacific OCS Region, Camarillo, California.

McChesney, G. J., H. R. Carter, F. Gress, W. R. McIver, J. W. Mason, T. W. Keeney, and P. R. Kelly. 2000. Effects of El Niño events on cormorant breeding populations in the Southern California Bight. *Pacific Seabirds* 27: 42-43.

Whitworth, D. L., J. Y. Takekawa, H. R. Carter, S. H. Newman, T. W. Keeney, and P. R. Kelly. 2000. At-sea distribution of Xantus's murrelets (*Synthliboramphus hypoleucus*) in the Southern California Bight. *Ibis* 142: 268-279.

Mason, J. W., G. J. McChesney, W. R. McIver, H. R. Carter, J. Y. Takekawa, R. T. Golightly, J. T. Ackerman, D. L. Orthmeyer, W. Perry, J. L. Yee, M. O. Pierson, and M. D. McCrary. Distribution and abundance of seabirds off southern California. Studies in Avian Biology, in prep.

Hamilton, C. D. *In prep*. At-sea distribution, habitat, and foraging behavior of Xantus's Murrelets during the breeding season in the Southern California Bight. M.Sc. thesis. Humboldt State University.

Hamilton, C. D., R. T. Golightly, and J. Y. Takekawa. *In prep*. Daytime foraging locations and nocturnal colony attendance of Xantus's Murrelets.

Hamilton, C. D., R. T. Golightly, and J. Y. Takekawa. *In prep*. At-sea distribution and foraging habitat of Xantus's Murrelets in the Southern California Bight.

REPORTS FOR CLIENT AGENCIES

Capitolo, P. J., H. R. Carter, R. J. Young, G. J. McChesney, W. R. McIver, R. T. Golightly, and F. Gress. 2004. Changes in breeding population size of Brandt's and double-crested cormorants in California, 1975-2003. Unpublished report, Department of Wildlife, Humboldt State University, Arcata, California.

Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Mason, J. W., G. J. McChesney, W. R. McIver, H. R. Carter, J. Y. Takekawa, R. T. Golightly, J. T. Ackerman, D. L. Orthmeyer, W. M. Perry, J. L. Yee, M. O. Pierson, and M. D. McCrary. 2004. At-sea Aerial Surveys of Seabirds in the Southern California Bight: 1999–2002. Pages 11–109 *in* Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Pierson, M. O., J. W. Mason, M. D. McCrary, G. J. McChesney, W. R. McIver, H. R. Carter, R. T. Golightly, D. L. Orthmeyer, J. Y. Takekawa, W. Perry, and J. L. Yee. 2004. At-sea aerial surveys of marine mammals in the Southern California Bight: 1999–2002. Pages 109–196 in Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Adams, J., J. Y. Takekawa, and H. R. Carter. Foraging distance and home range of Cassin's Auklets nesting at two colonies in the California Channel Islands. 2004. Pages 197–222 in Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Adams, J., J. Y. Takekawa, and H. R. Carter. Stable foraging areas and variable chick diets: insight to ocean variability and reproductive success of Cassin's Auklets in the California Channel Islands. 2004. Pages 223–255 in Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R.

McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Hamilton, C.H., R.T. Golightly, and J. Y. Takekawa. 2004. At-sea distribution and foraging habitat of Xantus's Murrelets in the Southern California Bight. Pages 256–276 in Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Ackerman, J. T., J. Adams, J. Y. Takekawa, H. R. Carter, D. L. Whitworth, S. H. Newman, R. T. Golightly, and D. L. Orthmeyer. 2004. Radio transmitter effects on Cassin's Auklets breeding on the California Channel Islands. Pages 277–301 *in* Takekawa, J. Y., H. R. Carter, J. T. Ackerman, G. J. McChesney, J. W. Mason, J. Adams, D. L. Orthmeyer, R. T. Golightly, W. R. McIver, M. O. Pierson, and C. D. Hamilton. 2004. At-sea distribution and abundance of seabirds and marine mammals in the Southern California Bight: 1999–2003. Unpublished summary report, U. S. Geological Survey, Western Ecological Research Center, Vallejo, CA; and Humboldt State University, Department of Wildlife, Arcata, CA 301 pp.

Whitworth, D. L., H. R. Carter, R. J. Young, E. M. Creel, W. R. McIver, and J. W. Mason. 2003. Status and trends of the Xantus's Murrelet (*Synthliboramphus hypoleucus*) at Islas Los Coronados, Baja California, Mexico. Unpublished report, Humboldt State University, Arcata, California. 36 pp.

Capitolo, P. J., R. J. Young, H. R. Carter, W. R. McIver, and T. W. Keeney. 2003. Roosting patterns of Brown Pelicans at Mugu Lagoon, California and other nearby roosts in 2002. Unpublished report, Humboldt State University, Arcata, California; and Naval Base Ventura County, Natural Resources Management Office, Point Mugu, California.

Palacios, Eduardo C., Franklin Gress, Daniel W. Anderson, Lucia Alfaro, Laurie Harvey and Eduardo Gonzalez. 2003. Seabird status in the Mexican portion of the Southern California Bight. 2002 progress report, California Institute of Environmental Studies, Davis, CA. (prepared for U.S. Geological Survey, Sacramento, CA). 24 pp.

Whitworth, D. L., B. S. Keitt, H. R. Carter, G. J. McChesney, J. W. Mason, W. R. McIver, and A. J. Hebshi. 2003. Preliminary assessment of the status of Xantus's Murrelets (*Synthliboramphus hypoleucus*) at the San Benito Islands, Baja California, Mexico, in March 2002. Unpubl. Rep., Humboldt State Univ., Dep. of Wildlife, Arcata, CA; and Island Conservation and Ecology Group, Univ. of California, Santa Cruz, CA. 21pp.

Adams, J. 2001. Foraging distribution and movement patterns of Cassin's Auklets nesting at Prince Island, California. Pages *In* D. L. Orthmeyer, H. R. Carter, J. Y. Takekawa, and R. T. Golightly (eds.). At-sea distribution of seabirds and marine mammals in the Southern California Bight: 2000 progress report. U. S. Geological Survey, Western Ecological Research Center, Dixon and Vallejo, California; and Humboldt State University, Arcata, California.

Orthmeyer, D. L., H. R. Carter, J. Y. Takekawa, and R. T. Golightly (eds.). 2001. At-sea distribution of seabirds and marine mammals in the Southern California Bight: 2000 Progress Report. U. S. Geological Survey, Western Ecological Research Center, Dixon and Vallejo, California; and Humboldt State University, Department of Wildlife, Arcata, California, 117pp.

Adams, J., J. Y. Takekawa, and H. R. Carter. 2000. Foraging distribution and movement patterns of Cassin's auklets nesting at Prince Island, California, in 1999. Pages 45-73 *In* D. L. Orthmeyer, H. R. Carter, J. Y. Takekawa, and R. T. Golightly (eds.). At-sea distribution of seabirds and marine mammals in the Southern California Bight: 1999 progress report. U. S. Geological Survey, Western Ecological Research Center, Dixon and Vallejo, California; and Humboldt State University, Arcata, California.

McChesney, G. J., J. W. Mason, W. R. McIver, M. D. McCrary, M. O. Pierson, and H. R. Carter. 2000. Aerial at-sea and photographic surveys of seabirds and marine mammals in the Southern California Bight and adjacent areas, May-June 1999. Pages 5-44 *In* D. L. Orthmeyer, H. R. Carter, J. Y. Takekawa, and R. T. Golightly (eds.). At-sea distribution of seabirds and marine mammals in the Southern California Bight: 1999 progress report. U. S. Geological Survey, Western Ecological Research Center, Dixon and Vallejo, California; and Humboldt State University, Department of Wildlife, Arcata, California.

Orthmeyer, D. L., H. R. Carter, J. Y. Takekawa, and R. T. Golightly (eds.). 2000. At-sea distribution of seabirds and marine mammals in the Southern California Bight: 1999 Progress Report. U. S. Geological Survey, Western Ecological Research Center, Dixon and Vallejo, California; and Humboldt State University, Department of Wildlife, Arcata, California.

SCIENTIFIC PRESENTATIONS

Ackerman, J. T., J. Adams, J. Y. Takekawa, H. R. Carter, D. L. Whitworth, S. H. Newman, R. T. Golightly, and D. L. Orthmeyer. 2004. Radio transmitter effects on breeding Cassin's auklets at the California Channel Islands. Pacific Seabird Group, 31st Annual Meeting, La Paz, Mexico, scheduled January 21–25. (poster)

Adams, J., J. Y. Takekawa, and H. R. Carter. 2004. Ocean habitat of Cassin's Auklets: integrating locations at sea with environmental variables off Southern California. Pacific Seabird Group, 31st Annual Meeting, La Paz, Mexico, scheduled January 21–25.

Mason, J. W., G. J. McChesney, W. R. McIver, H. R. Carter, J. Y. Takekawa, R. T. Golightly, J. T. Ackerman, D. L. Orthmeyer, W. M. Perry, J. L. Yee, M. O. Pierson, and M. D. McCrary. 2004. Distribution and abundance of seabirds off southern California: a twenty-year comparison. Pacific Seabird Group, 31st Annual Meeting, La Paz, Mexico, scheduled January 21–25. (poster)

Hamilton, C., R. T. Golightly, and J. Y. Takekawa,. 2004. Daytime foraging locations and nocturnal colony attendance of Xantus's Murrelets. Pacific Seabird Group, 31st Annual Meeting, La Paz, Mexico, scheduled January 21–25.

Capitolo, P. J., H. R. Carter, R. J. Young, M. W. Parker, G. J. McChesney, J. Yee, and R. T. Golightly. 2004. Humboldt Bay area Double-crested Cormorant population, 1993-2003. Pacific Seabird Group, 31st Annual Meeting, La Paz, Mexico, scheduled January 21–25.

Mason, J. W., G. J. McChesney, W. R. McIver, H. R. Carter, J. Y. Takekawa. 2003. At-sea distribution of seabirds near three California Channel Islands in 1999–2002, based on aerial radial transects. Sixth California Islands Symposium, Ventura, California, December 1–3, 2003. (poster)

Adams, J., E. Beckenbach, J. Y. Takekawa, and H. R. Carter. 2003. Affiliation of Cassin's Auklets and zooplankton prey with oceanographic features in the Santa Barbara Channel. Sixth California Islands Symposium, Ventura, California, December 1–3, 2003.

Martin, PL, CA Schwemm, W Perry, and JT Ackerman. 2003. Nest occupancy and hatching success of Xantus's murrelets breeding on Santa Barbara Island, California, during a twenty-year period. Sixth California Islands Symposium, Ventura, California, December 1–3, 2003.

Adams, J. 2003. Using GIS and satellite oceanography to investigate the dynamic habitats of marine predators of the California Current. Marine and Coastal GIS Workshop, California State University Monterey Bay, November 13, 2003.

Takekawa, J. Y. 2003. Seabird surveys in Baja, California. Minerals Management Service, Camarillo, California, September 9, 2003.

Takekawa, J. Y. 2003. Introduction to the seabird and marine mammal research program. Minerals Management Service, Camarillo, California, September 9, 2003.

Takekawa, J. Y. 2003. Continued USGS seabird research in the Southern California. Minerals Management Service, Camarillo, California, September 9, 2003.

Mason, J. W., G. J. McChesney, W. R. McIver, H. R. Carter, R. T. Golightly, D. L. Orthmeyer, J. Y. Takekawa, J. T. Ackerman, W. Perry, J. L. Yee, M. O. Pierson, and M. D. McCrary. 2003. Distribution, abundance, and colony counts of seabirds off Southern California. Minerals Management Service, Camarillo, California, September 9, 2003.

Ackerman, J. T., J. Adams, J. Y. Takekawa, H. R. Carter, D. L. Whitworth, S. H. Newman, R. T. Golightly, and D. L. Orthmeyer. 2003. Effects of radio transmitters on breeding Cassin's auklets. Minerals Management Service, Camarillo, California, September 9, 2003.

Adams, J., J. Y. Takekawa, and H. R. Carter. 2003. At-sea distribution and diet of Cassin's auklets. Minerals Management Service, Camarillo, California, September 9, 2003.

Adams, J., J. W. Mason, G. J. McChesney, W. R. McIver, H. R. Carter, R. T. Golightly, D. L. Orthmeyer, J. Y. Takekawa, J. T. Ackerman, W. Perry, and J. L. Yee. 2003. Integrating seabird use and ocean features: an example with Cassin's auklets. Minerals Management Service, Camarillo, California, September 9, 2003.

Pierson, M. O., J. W. Mason, M. D. McCrary, G. J. McChesney, W. R. McIver, H. R. Carter, R. T. Golightly, D. L. Orthmeyer, J. Y. Takekawa, W. Perry, and J. L. Yee. 2003. At-sea surveys of marine mammals off Southern California. Minerals Management Service, Camarillo, California, September 9, 2003.

Perry, W. 2003. GIS database of seabirds and marine mammals. Minerals Management Service, Camarillo, California, September 9, 2003.

Hamilton, C., J. Y. Takekawa, and R. T. Golightly. 2003. At-sea distribution of Xantus's murrelets. Minerals Management Service, Camarillo, California, September 9, 2003.

Adams, J., J. Y. Takekawa, and H. R. Carter. 2003. Food habits of chick-rearing Cassin's auklets nesting on Prince Island and foraging in the Santa Barbara Channel, California during a prolonged La Niña event. 30th Annual Meeting of the Pacific Seabird Group, Parksville, British Columbia, Canada, February 19-22, 2003.

Hamilton, C., R. T. Golightly, H. R. Carter, and D. L. Orthmeyer. 2003. Diet of Xantus's murrelet in southern California. 30th Annual Meeting of the Pacific Seabird Group, Parksville, British Columbia, Canada, February 19-22, 2003. (poster)

Adams, J., J. Y. Takekawa, and H. R. Carter 2002. At-sea distribution and central-place foraging of Cassin's Auklets in the California Channel Islands. 29th Annual Meeting of the Pacific Seabird Group, Santa Barbara, California, February 20-23, 2002.

Capitolo, P. J., H. R. Carter, T. W. Keeney, W. R. McIver, G. J. McChesney, J. W. Mason, R. T. Golightly, and D. L. Orthmeyer. 2002. Roosting patterns of brown pelicans at Mugu Lagoon, California, June-October 2001. 29th Annual Meeting of the Pacific Seabird Group, Santa Barbara, California, February 20-23, 2002.

McChesney, G. J., W. M. Perry, J. L. Yee, J. W. Mason, and W. R. McIver. 2002. Comparison of habitat availability measures to examine seabird at-sea habitat use. 29th Annual Meeting of the Pacific Seabird Group, Santa Barbara, California, February 20-23, 2002. (poster)

Adams, J., J. Y. Takekawa, and H. R. Carter 2001. At-sea distribution of breeding Cassin's Auklets off the northern Channel Islands in 1999-2000. 8th Annual Conference of The Wildlife Society Reno, Nevada, September 25-29, 2001.

Adams, J., J. Y. Takekawa, and H. R. Carter 2001. At-sea distribution of breeding Cassin's Auklets off the northern Channel Islands in 1999-2000. Annual Meeting of the Western Section of The Wildlife Society, Sacramento, California, February 22 - 24, 2001.

Adams, J., J. Y. Takekawa, and H. R. Carter 2001. At-sea distribution of breeding Cassin's Auklets off the northern Channel Islands in 1999-2000. 28th Annual Meeting of the Pacific Seabird Group, Lihue, Kauai, Hawaii, February 7-11, 2001.

McChesney, G. J., W. R. McIver, H. R. Carter, D. L. Orthmeyer, and R. T. Golightly. 2001. At-sea distribution and abundance of seabirds in Southern California. Annual Meeting of the Western Section of The Wildlife Society, Sacramento, California, February 22 - 24, 2001.

Adams, J., J. Y. Takekawa, H. R. Carter, D. L. Whitworth, and G. J. McChesney. 2000. At-sea distribution of radio-marked Cassin’s Auklets, breeding at Prince Island, California in 1999. 27th Annual Meeting of the Pacific Seabird Group, Napa, California, February 23-26, 2000. (poster)

McChesney, G. J., H. R. Carter, F. Gress, W. R. McIver, J. W. Mason, T. W. Keeney, and P. R. Kelly. 2000. Effects of El Niño events on cormorant breeding populations in the Southern California Bight. 29th Annual Meeting of the Pacific Seabird Group, Napa, California, February 23-26, 2000.