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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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BREEDING SEASON DISTRIBUTION AND POPULATION GROWTH OF CALIFORNIA SEA LIONS, *Zalophus californianus*, IN THE UNITED STATES DURING 1964-2014

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ABSTRACT

Breeding-season distribution and population growth rate of California sea lions (*Zalophus californianus*) in the U.S. population are estimated from counts of pups and non-pups collected during 1964 to 2014. Pup and non-pup count data were compiled from published and unpublished sources. These data showed that during this period the U.S. count of live-pups increased at an average annual rate of 4.7% per year (L95% CI=4.2%, U95% CI=5.2%). Average annual growth rates of live-pup counts at the four main island-rookeries in southern California (Santa Barbara Island, San Clemente Island, San Nicolas Island, and San Miguel Island; hence fore referred to as the Main Channel Islands) ranged from 4.2% to 5.5% from 1964 to 2014. The Channel Islands count of non-pups (non-pup counts were unavailable for the entire U.S. population prior to 2003) increased at an average annual growth rate of 2.8% per year (L95% CI=2.4%, U95% CI=3.4%). San Nicolas Island and San Miguel Island were the largest rookeries in the U.S. population, both having the most pups and non-pups. Prior to 1990, 59.2% of live pups counted in the Channel Islands were on San Miguel Island, and 32.4% were on San Nicolas Island. After 1990, these islands constituted 44.9% and 45.6% of Channel Island pups, respectively. California-wide surveys conducted during 2003-2005, 2007, and 2011-2013 indicated that the Main Channel Islands rookeries accounted for 99.71% of live pups counted in California and 77.35% of hauled-out non-pups in California during the breeding season. Sea lion counts were modeled (using generalized linear modeling) as a function of sea level height at Los Angeles, California (SLH-LA), Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), and Multivariate El Niño Index (MEI). This model indicated that more pups were produced during cold-water conditions and fewer pups were produced during warm-water conditions, and that fewer non-pups were present at southern California rookeries during warm-water conditions and more were present during cold-water conditions.

INTRODUCTION

California sea lions (*Zalophus californianus*) are distributed from central Mexico to Alaska. The primary California sea lion (CSL) rookeries in the United States (U.S.) are located at the Channel Islands in southern California (Figure 1) and are separated by approximately 600 km from the primary rookeries of western Baja California, Mexico. The U.S. and Mexico populations are genetically distinct (Schramm et al., 2009). Although mixing of individuals occurs within their range, it is hypothesized that philopatric behavior, physical oceanography, and foraging behavior are responsible for creating five genetically distinct stocks of the species (Schramm et al., 2009). Schramm et al. (2009) called the U.S. population the Pacific Temperate population, but here CSLs found in the U.S. during the breeding season will be referred as the U.S. population.

The number of CSLs in southern California expands and contracts during various times of the year as individuals from Mexico enter and leave the area and as individuals from the Channel Islands in southern California migrate southward into Mexico or northward as far as British Columbia, Canada (Bartholomew, 1967; Mate, 1975; Bonnell et al., 1980, 1983; Bigg, 1988; Huber, 1991) and Alaska (Maniscalco et al., 2004). Sexually mature CSLs return to a rookery in the summer for pupping and breeding. Rookeries on four of the Channel Islands (Santa Barbara Island [SBI], San Clemente Island [SCI], San Nicolas Island [SNI], and San Miguel Island [SMI]; Figure 1) are the reproductive center of the U.S. population (Lowry and Maravilla-Chavez, 2005). Although a few births occur at Anacapa Island, Santa Catalina Island, Año Nuevo Island, and the Farallon Islands (Figure 1) or various other sites in central California (Pierotti, et al., 1977; Keith, et al., 1984; Lowry and Maravilla-Chavez, 2005), these sites did not qualify as rookeries previously because fewer than 50 pups were produced at those sites. Since 2007, the accepted definition of a pinniped rookery is one where >50 pups are born annually (Pitcher et al., 2007).

The CSL breeding season at rookeries in the U.S. begins in mid-to-late-May when full-term pups are born, and sub-adult and adult males arrive at the rookery. Adult females are generally year-round residents at the rookeries. Juveniles are present at rookeries year round, as well as at other haulouts throughout California. The number of newborn pups and adult males present at southern California rookeries reaches maximum on or about July 2 (Heath and Francis, 1983, 1984; Stewart and Yochem, 1984, 1986). Soon after that date, the numbers of pups

decrease due to mortality and sub-adult and adult males begin to depart the rookery, leaving adult females at the rookery to forage in local waters and raise their pups. Many sub-adult males and adult males remain at the rookeries until late July, but most migrate north by early-to-mid-August.

Records of historic exploitation and distribution were compiled from the literature and personal communications by Helling (1984), Cass (1985), and Seagars et al. (1985). Extensive hunting of CSLs for their oil and hides took place in the middle 1800's resulting in population declines (Bonnot, 1928). Sea lions were protected by California laws passed in 1909 and 1927, but only in certain regions of the state (Bonnot, 1928). Until the Marine Mammal Protection Act (MMPA) became law in 1972, CSLs continued to be hunted for pet food, hides, trimmings, display (public and scientific), sport, and bounty; and also were killed to reduce fishery depredation and for target practice. It is assumed that when the MMPA was passed in 1972, the population size was below pre-exploitation levels, but to what extent cannot be determined from historical records.

The first documented counts of CSLs in California were made in 1927 and were continued intermittently until the mid-1970s, after which annual counts were made for most years (Bonnot, 1928, 1931, 1937, 1938; Bureau of Marine Fisheries, 1938; Bonnot and Ripley, 1948; Bartholomew and Boolootian, 1960; Ripley et al., 1962; Carlisle and Aplin, 1966, 1970, 1971; Frey and Aplin, 1966, 1970; Bonnell et al., 1980; Lowry and Maravilla-Chavez, 2005). Pups at all four major Channel Island rookeries were first counted during the breeding-season in 1964 (Odell, 1971). The counts were made by biologists on the ground or in small boats and from black-and-white or color photographs taken with small-format and large-format aerial cameras which were either hand-held for oblique photography or mounted vertically inside the aircraft (Table 1).

A complete census of CSLs using counts of hauled-out individuals is not possible because not all age classes are ashore at the same time. In the 1980's counts of pups became the principal age class used for monitoring the CSL population in the U.S. because it is the only age class available for a complete census (DeMaster et al., 1982; Boveng, 1988; Lowry et al., 1992; Lowry and Maravilla-Chavez, 2005). Newborn pup counts have been used to estimate total population size (using a life table model to extrapolate abundance for the other age classes) and to estimate population growth rates (Boveng, 1988; Lowry et al., 1992; Lowry and Maravilla-

Chavez, 2005). Although pups were sometimes surveyed in June before all were born, most surveys were conducted in July, and sometimes in August, after virtually all births had occurred. The slightly inconsistent timing of surveys adds measurement error to the time series in the sense that the fluctuations in the annual count data are in part due to variation in the survey timing rather than true variation in pup production.

In the 1980's ground counts of CSL pups was the primary method used for estimating pup abundance, but large groups of them could not be counted accurately and either a large workforce would be required or a long time-period would be needed to count them over a wide geographical area. In 1987, researchers at the Southwest Fisheries Science Center (SWFSC) developed aerial photographic survey methods using a 126-mm-format surplus military recognizance camera mounted inside a low flying aircraft to census northern elephant seals (*Mirounga angustirostris*), Steller sea lions (*Eumetopias jubatus*), and CSLs (Lowry et al., 1996; Westlake et al., 1997; Lowry, 1999). Counts of CSL pups at San Nicolas Island during 1992-1994 from aerial color photographs taken with this camera were shown to be as accurate (and in some cases more accurate) than ground counts (Lowry, 1999). Subsequently, aerial photographic surveys became the primary method used to census CSLs and other pinniped species in the U.S.

Here, counts of CSLs in the U.S. population during the CSL breeding season are summarized for 1964 to 2014. Pup and non-pup count data from published sources were compiled with previously unpublished data collected by the NOAA Southwest Fisheries Science Center and Alaska Fisheries Science Center (AFSC). A method is presented for correcting live-pup counts that were made prior to the maximum or peak count to obtain annual pup estimates that are more comparable through time. This paper provides estimates of U.S. CSL population growth rates from counts of live pups and non-pups during 1964-2014 and describes geographical distribution of CSLs in California during the breeding season.

METHODS

Survey methods

CSL surveys were first designed to count every pup, and later included other age/sex classes present on land. Surveys were conducted primarily via ground counts through the mid-

1980s. A mix of ground counts and aerial photographic survey methods were used through the 1990s and 2000s. Ground count data was used in the analysis when aerial photographic count data was not obtained.

For ground counts, CSLs were tallied by biologists on the ground using mechanical hand-counters; animals were observed directly or through a hand-held binocular or tripod-mounted spotting scope. Ground counts were made by one or more biologists over several days, depending on the size of the island. Because the counts were conducted when pups were too young to swim, double counting on subsequent days was not a concern for pups. However, movement of non-pups does occur, so we assume that their rate of movement during the survey period is constant within a rookery, between islands, and between wide geographical areas. At SBI, sea lions were also counted from a small boat 20-30 meters offshore. Ground and boat-based counts at SBI, SCI, and SNI were made in a manner that would minimize disturbance to sea lions. Disturbance counts of CSL pups were required at SMI in some areas that were not countable from a distance. In these areas, biologists herded pups into small groups and counted them as the pups streamed out of the herd.

For aerial photographic counts, CSLs were counted from vertical aerial photographs taken with a high-resolution aerial film camera during 1987-2009 or with a digital single lens reflex (DSLR) camera during 2011-2014. Aerial photographic surveys were conducted with a twin-engine, high-winged Aero Commander Twin 500B (1991-1994 aerial photo surveys of Año Nuevo Island) or with a Partenavia P-68 (1992-1993) or Partenavia P-68 Observer model aircraft (1987-1990 and 1994-2014). The glass nose of the Partenavia P-68 Observer model aircraft provided the pilot with excellent forward and downward views for aligning the aircraft over beaches or rocks and became the preferred aircraft for aerial photographic surveys of CSLs. Aircraft were flown at a ground speed of 185 km/h (100 knots) and at an altitude of approximately 213 m (700 ft) during 1987 to 2009 or approximately 244 m (800 ft) during 2011 to 2014, except at the Farallon Islands and SBI where the aircraft was flown at approximately 396 m (1300 ft) to prevent disturbance to nesting seabirds. The low altitude and lens configuration (see below) ensured that CSLs could be detected on rocky substrates (especially when animals were wet and consequently darkly colored), aided in identification of different pinniped species and CSL age/sex classes, and enabled accurate counts from aerial photographs. All CSLs onshore were photographed. The aircraft was flown directly over the coastline or

slightly offshore or inshore to locate and photograph sea lions onshore. Multiple overlapping photographic passes were made over large rocks or portions of coastlines and beaches to ensure that all hauled-out CSLs were photographed. Surveys were made without regard to tidal conditions and at any time of day between approximately 2 hours after sunrise and 2 hours before sunset. Aerial photographic surveys of CSLs in California took one to two weeks to complete.

Prior to the use of digital cameras in 2011, sea lions were photographed with a 126-mm-format Chicago Aerial Industries, Inc. KA-45A or KA-76 military recognizance camera equipped with forward motion compensation and operated at a cycle rate that achieved 67% overlap between adjacent frames. The location of each photograph was recorded by linking the camera to a laptop computer and Global Positioning System (GPS) receiver. The camera was attached to a gimbal camera-mount placed vertically over a camera port inside the aircraft and was manually leveled with a bubble level to obtain a vertical image. A 152-mm-focal-length lens was used for low altitude photography (i.e., altitude of approximately 213 m [700 ft]) and a 305-mm-focal–length lens was used for higher altitude photography (i.e., altitude of approximately 396 m [1300 ft]). The camera was set at an aperture of f/5.6 with a shutter speed between 1/400 second and 1/3000 second. Three types of film were used: (1) Kodak Aerochrome MS Film 2448, a very fine-grained, medium-speed, color transparency, film was used during 1987-1999, (2) Aerochrome HS Film SO-359, a very fine-grained, high-speed, color transparency film was used during 1997-2005, and (3) KODAK Aerochrome III MS Film 2427, a very fine grained, medium-speed color-reversal aerial film was used during 2003-2009.

Two different DSLR cameras were used during 2011-2014. During 2011through 2013, CSLs were photographed with a Canon EOS 1Ds Mark III, full-frame 21.1-megapixel DSLR camera having a Zeiss 85-mm-focal-length lens for photographing at an altitude of approximately 244 m (800 ft) or a Canon 135-mm-focal-length lens for photographing at an altitude of approximately 396 m (1300 ft) altitude. In 2014, CSLs were photographed with a Canon EOS 5D Mark III, full-frame 22.3-megapixel DSLR having a Zeiss 85-mm-focal-length lens for photographing at an altitude of approximately 244 m or a Zeiss 135-mm-focal-length lens to photograph CSLs from 396 m altitude. Image motion compensation was achieved using a custom-made rocking mechanism in the camera mount (manufactured by Aerial Imaging

Solutions[1]). The focus ring of the 85mm lens was immobilized with tape when focused at approximately 244 m and the 135 mm lens was taped when focused at approximately 396 m. A laptop computer was connected to the camera, a GPS receiver, radar altimeter, and controlled the camera's forward motion compensation mechanism. A video camera and monitor provided a view through the camera's viewfinder which allowed the operator to see what was being photographed. For each photograph, the computer recorded the geographical position, date and time the photograph was taken, altitude from the GPS and radar altimeter, lens being used, and ground speed of the aircraft in a comma separated variable (csv) text file. The DSLR camera was attached to a gimbal camera-mount placed vertically over a camera port inside the aircraft and the camera was manually leveled at the vertical position with a bubble level. The computer controlled all camera functions. Camera aperture was set at f/5.6 in aperture priority shooting mode and shutter speed was set at or above 1/800 second by changing the ISO image sensor setting between 100 and 1000. Photographs were overexposed by +1/3 f-stop (for sunny condition) or +2/3 f-stop (for overcast condition). White balance in the camera was set on automatic, and all photographs were taken in JPEG image file format set at fine image quality and at 3:2 aspect ratio. The camera was operated at a cycle rate that achieved 40% overlap between adjacent photographs, and occasionally at 60% overlap for short photographic passes.

CSLs in 126-mm-format transparencies were counted through a 7-70X zoom binocular microscope as the photographs were back-illuminated on a light table. Images of animals were counted and marked on a clear acetate overlay with a different colored pen for each age/sex class category (see "Age-sex classes counted" below). Marks on the acetate were compared and verified with overlapping photographs. If all animals could not be counted in one photograph, the overlay was placed on another photograph at the exact location where the count ended previously and the count continued on the uncounted portion. Sea lions swimming in the water within approximately 30 meters of land were included in the count.

CSLs in digital photographs were counted in a two-step process: creation of mosaics from merged photographs and counting CSLs in the mosaics. Adobe Bridge CS5 was used to review and select digital photographs, and to initiate the photo-merging process. Adobe Photoshop CS5 Extended, version 12.1 x64 on Windows 7 64-bit operating system, received photographs from Adobe Bridge CS5 and was subsequently used to create photographic mosaics

[1] Aerial Imaging Solutions, LLC, 5 Myrica Way, Old Lyme, CT 06371. info@aerialimagingsolutions.com

from multiple overlapping digital photographs of a beach-section or rock within the Adobe Photoshop software screen on a 24-inch or 27-inch Dell ultra-sharp computer monitor. Photographs were merged together manually using the move tool and transpose tools. Under-exposed or over-exposed images were brightened or darkened with image tools in Adobe Photoshop. The brush tool was used to draw a line to separate and mark animals and to code areas on the mosaic that would be counted. Adjacent mosaic files of photographs were compared, and a brush-line was inserted onto the mosaic to separate counted animals from uncounted ones, or to mark areas where animals should be, or not be, counted. Age/sex class categories for counting were manually entered into the count tool of Adobe Photoshop Extended, each animal was marked with a unique colored dot and number using the computer mouse, and the software maintained a running total of each age/sex class category.

The number counted for each age/sex class category were entered into a Microsoft Excel spreadsheet along with other metadata for the counts (e.g., date, time photo was taken location, area codes) and then converted into a Microsoft Access data-table in a database.

Two types of surveys were conducted over the study period: pup counts and total population counts. Surveys focused on counting pups covered all areas where pups were born and covered a smaller area than surveys focused on counting all animals in the population which included breeding and haulout areas. California-wide surveys for total population counts (excluding the continental coastline of southern California) were conducted in 2003-2005 and 2011-2013 to document breeding season distribution of CSLs within the state and estimate total numbers of CSL for seven age-sex classes.

Age-sex classes counted

When the AFSC census of CSLs began in 1971 and by SWFSC in 1981, the primary objective was to census live-pups because pup counts were to be used for estimating population growth rate, population abundance, and to determine population status. While SWFSC biologists counted live-pups, counts were also made of all "non-pups" which included all age/sex classes except pups. The category "adult males" was first included in counts in 1986. Starting in 1992, CSL counts at all breeding areas and non-breeding haulout areas were expanded to include seven age-sex class categories:

1) Live-pup: Newborns, very small compared to other age/sex classes, dark to lite brown in color when dry, black when wet, short neck and muzzle.
2) Dead pup: Pups that are decomposing, are bloated, partially covered with sand, have a western gull (*Larus occidentalis)* eating it, or which are lying on their side with the head bent back toward the spine as a result of rigor mortis.
3) Juvenile: Larger than live-pups, about one-fourth to two-thirds the length of an adult female with brown or lite brown hair, elongated neck and muzzle. Sometimes found suckling on adult female or lying next to one.
4) Adult female: When dry, most often pelage will be blond in color, but sometimes are dark brown. They are dark grey when wet. Cranial sagittal crest is not present.
5) Young male: They are approximately the same size as an adult female. Cranial crest has not begun to develop, dark brown or charcoal color. During breeding season rarely if ever found within groups of breeding adult females but will be found at the periphery of adult female groups or will be within groups of "bachelor" males or juveniles. When in tide pools they will bark like an adult male and will play-fight with similar sized sea lions.
6) Sub-adult male: Sagittal crest is present and may or may not be fully formed; tuft of white hair on sagittal crest may or may not be present. Pelage is dark brown to grey in color. They do not have a wide chest and neck, and are larger than an adult female.
7) Adult male: Sagittal crest is fully formed and has tuft of white hair. Pelage is dark brown to grey in color. Has a wide chest and neck. Will often be patrolling a territory when in water or on land during the breeding season. When stationary or near vertical in the water, the tuft of white hair on the sagittal crest will be visible.

Study areas, 1971 - 2014

A posteriori geographic strata were created (Figure 1A) for summarizing counts. The California coast was divided into three sections: (1) southern California, which includes the continental coast and all Channel Islands (the Coronado Islands, which are in Mexico, were not included); (2) central California, which includes the continental coastline, offshore rocks, and islands between Point Conception (34° 26.8' N, 120° 28.0' W) and Point Reyes (38°00.0' N, 123°00.0' W) and San Francisco Bay estuary; and (3) northern California, which includes the

continental coastline, offshore rocks, and islands between Point Reyes and the California-Oregon border (42° 0' N, 124° 12.7 W). Secondary, smaller strata within each California section were created as follows: (1) Central and northern California were stratified into 7 zones (zones A, B, and C in northern California; zones D, E, F, and G in central California; see Lowry and Forney, 2005); and (2) southern California was stratified into two zones with one zone consisting of the four principal CSL Channel Island rookeries (referred to as the Main Channel Islands and include SBI, SCI, SMI, and SNI) and the other zone having the remaining islands and rocks (referred to as the Other Channel Islands). The continental coast within the southern California section was not surveyed due to too extremely low abundance of CSLs in that area and safety concerns of flying at low level in a large metropolitan coastal area. Counts were also summarized separately for each Channel Island. The Farallon Islands were divided into South Farallon Islands and North Farallon Islands. Within San Francisco Bay Estuary, only CSLs at Pier 39 in San Francisco (37° 48.6' N, 122° 25.2' W) were surveyed during central California surveys.

CSL ground surveys at SMI by AFSC began in 1971 and aerial photographic surveys at SMI by SWFSC began in 1987 (Table 1; Figure 1B). In most years, AFSC ground surveys were also conducted at Castle Rock, a sub-island located 1 km offshore of SMI. Although aerial surveys at SMI by SWFSC began in 1987, ground counts by AFSC continued to be conducted annually to ensure uninterrupted data collection. When aerial survey data were available they were used for estimates of CSLs at SMI to provide consistency in analysis among areas. While AFSC ground counts were only made of pups, SWFSC aerial photographic counts also included other age/sex classes.

CSL ground and aerial photographic surveys at the Channel Islands in southern California by SWFC began at SCI in 1981and were later expanded to include other islands in southern California and the continental coastline of central and northern California (Table 1; Figure 1B). Año Nuevo Island and the Farallon Islands, in central California, were included in aerial photographic surveys in 1992 and 1995, respectively (Table 1; Figure 1C). The continental coastline in central California and northern California between Point Conception, California and the California/Oregon border was included in aerial photographic surveys in 1998 (Table 1; Figure 1A). At SCI, CSL ground surveys were conducted along the western shoreline between Seal Cove (32° 54.5’ N, 118° 32.3’ W) and 2.2 km south of Mail Point (32° 52.1’ N,

118° 30.4’ W) where all CSL pups at that island are born; aerial photographic surveys included the entire island (however, sometimes the entire island was not accessible due to naval operations). Aerial photographic surveys of SNI covered the entire island and ground surveys covered the southern shoreline between Point Vizcaino (33° 16.7’ N, 119° 34.6’ W) and East End Sand Spit (33° 17.8’ N, 119° 25.9’ W) where CSLs occurred. At SBI, ground surveys and small-boat surveys were conducted during 1983-1998 and aerial photographic surveys were conducted during 1997-2014.

Population Growth Rates and Trends

Population growth rates and trends were examined by combining data collected by AFSC and SWFSC during 1971-2014 (Lowry et al., 1987; Oliver and Lowry, 1987; Oliver et al., 1988; Wexler and Oliver, 1988; Oliver, 1991a, 1991b; Oliver and Wexler, 1991; Lowry, 1999; Carretta et al., 2000; Lowry and Maravilla-Chavez, 2005; M. Lowry and S. Melin, unpublished data; Table 2, 3, and 4) with published data collected by other biologists during 1964-1987 (Carlisle and Aplin, 1966; Peterson and Bartholomew, 1967; Odell, 1971, 1972; Bonnell et al., 1980, 1983; Heath and Francis, 1983, 1984; Stewart and Yochem, 1984, 1986; Francis and Heath, 1991; Stewart et al., 1993; Table 5). Two corrections to live-pup count data were made:

1. Castle Rock correction at SMI: CSL live-pups at Castle Rock, a small sub-island just off SMI, were not counted in every year, but Castle Rock is considered part of the SMI CSL colony. When both Castle Rock and SMI were censused, SMI represented an average of 0.962 of the total for the two sites. The inverse of 0.962 (1/0.962=1.04) provided a multiplier that was applied to the years when Castle Rock was not censused to estimate total live-pups for the combined rookery during 1971, 1972, 1978, and 1981-1984.
2. Correction to counts of live-pups made prior to the peak count date of July 2: Heath and Francis (1983, 1984) and Stewart and Yochem (1984, 1986) provide a series of CSL live-pup counts made during the May-July breeding season (Table 6). The proportion of the maximum-live-pup-count was calculated for each count, year, and source. Logistic regression analysis (Figure 2) was used to obtain the following model describing the relationship between Julian date (x) and relative pup count levels (as a proportion of the maximum counts expected around July 2):

$$y = \frac{1}{1 + e^{-\left(\frac{x-165.1168}{4.8434}\right)}}$$

Multiplying the number of live-pups counted prior to July 2 by the inverse of *y* (i.e., 1/*y*) yields an estimate of the July 2 maximum-live-pup-count, which is the metric used for growth rate and trend analysis in the study. The model fit to the data (Figure 2) was extremely precise (Adjusted R^2=0.972), so error in *y* is ignored. Counts of dead-pups were not added to the count of live-pups because they were not always counted, and they underestimate pre-census mortality due to decomposition, being covered by sand or washed out to sea.

CSL growth rates were computed from counts of live pups and, separately, from counts of non-pups. For counts of live pups, growth rates were estimated for the following: (1) each CSL rookery (SBI, SCI, SMI, SCI, Año Nuevo Island, and South Farallon Islands), (2) the Main Channel Islands rookeries group (which comprise nearly all pups produced in the U.S. [Lowry and Maravilla-Chavez, 2005]), and (3) the U.S. population (includes counts of pups from all available count data). For counts of non-pups, growth rates were estimated for the following: (1) each CSL rookery (SBI, SCI, SMI, SCI, Año Nuevo Island, and South Farallon Islands), (2) the Main Channel Islands rookeries group, (3) Other Channel Islands group, (4) southern California (includes all Channel Islands combined), (5) central and northern California separately and combined, and (6) Año Nuevo Island and South Farallon Islands combined. The initial analysis year was 1964 because that was the first year that pups were counted at all Main Channel Islands rookeries in the same year during the breeding season (prior to 1964, pups were either not counted or were not counted at all rookeries). Not all rookeries and haulout sites were surveyed every year, therefore, there is some sampling variation due to missing data or due to the use of estimated pup count data. A variety of methods were employed by various researchers to count CSLs (Table 1). Very few pups were produced at non-rookery areas. Any pups produced and not censused at non-rookeries were deemed insignificant and were assumed to have no significant effect on calculations for the U.S. population growth rate estimate.

CSL pup production dropped during 1983, 1992-1993, 1998, and 2009-2010 when El Niño conditions existed in the Pacific Ocean (Lowry and Maravilla-Chavez, 2005). To understand the influence of variability in marine environmental conditions on CSL pup production, four environmental indices were used as covariates in the analysis of CSL population

growth rate: (1) the Pacific Decadal Oscillation (PDO), a large-scale ocean-atmospheric cycle that affects productivity in the Pacific ocean (Mantua et al., 1997), (2) North Pacific Gyre Oscillation (NPGO), a basin-scale ocean-atmospheric cycle that affect the north Pacific ocean and is out of phase with the PDO (Di Lorenzo et al., 2008), (3) Multivariate El Niño Index (MEI), a measure of the El Niño Southern Oscillation cycle at the equator (Wolter and Timlin, 1993), and (4) sea level height at Los Angeles, California harbor (SLH-LA) with its seasonal and linear trends removed so as to index anomalies, as a local measure of environmental conditions (Zervas, 2009). PDO values were obtained from The Pacific Decadal Oscillation website (http://research.jisao.washington.edu/pdo/data; accessed on May 25, 2016). NPGO values were obtained from the North Pacific Gyre Oscillation website (http://www.o3d.org/npgo/; accessed on 20 May 2016). MEI values were obtained from NOAA Earth System Research Laboratory, Physical Science Division website (http://www.esrl.noaa.gov/psd/enso/mei/index.html#Home, last accessed February 22, 2016). SLH-LA values were obtained from NOAA Center for Operational Oceanographic Products and Services website (http://tidesandcurrents.noaa.gov/sltrends/sltrends.html; last accessed March 21, 2016). The October-to-May mean was calculated for each covariate because those months corresponded to the gestation period of CSLs and environmental conditions that affect prey available to pregnant females during this period would affect the annual birth rates. Log-transformed live-pup counts and (separately) non-pup counts were modeled as functions of year, PDO, NPGO, MEI, and SLH-LA, using a backward-stepwise Generalized Linear Model (GLM) with a normal/Gaussian error assumption in Systat 13.00.05 64-bit for Windows software. Rookeries having zero values had a 1 added, as per Sokal and Rolf (1995), to all values before being log transformed to prevent zero data from being eliminated in the analysis. The stepwise GLM model removed insignificant covariates ($p>0.05$). The annual rate of increase (λ) was calculated as e^r where r is the year coefficient of the GLM analysis (Eberhardt and Simmons, 1992). The 95% confidence interval for the year coefficient was used to estimate the 95% CI for λ. The average annual growth rate was calculated separately for counts of live pups and counts of non-pups. Average percentage annual growth rate is computed as $\%= (\lambda-1)*100$.

RESULTS

From 1964 to 2014, counts of CSL live-pups in the U.S. population increased from 6,113 to a high of 67,398 in 2012 and counts of non-pups in southern California increased from 29,875 to a high of 95,814 in 2013 (Figure 3). The California wide total count of non-pups was between 91,772 (in 2003) and 113,141 (in 2013; Figure 3). In 2012 there were 169,813 CSLs (pups + non-pups) counted in California (excluding the continental coastline of southern California; Figure 4). This does not represent the full CSL population size because many non-pups were at sea and, thus, unavailable for counting. During the CSL breeding season, southern California had the most CSLs by age/sex class categories, followed by central California and northern California (Tables 2, 3, and 4; Figure 5). SNI and SMI were the largest rookeries in the U.S. population, having the most pups and non-pups (Tables 2, 3, 4, and 5; Figure 6A and 6B). Prior to 1990, 59.2% of live pups counted in the Main Channel Islands rookeries were at SMI and 32.4% were at SNI (Figure 7A). After 1990, 44.9% of live pups were at SMI and 45.6% were at SNI. The percentage distribution of non-pups amongst the Main Channel Islands rookeries and the Other Channel Islands did not change over the years with SMI having the highest proportion (~50%; Figure 7B).

In years when all the California study areas were surveyed, 99.71% (SD=0.239) of pups counted were at the Main Channel Islands rookeries; 0.29% (SD=0.197) were in central California; 0.05% (SD=0.044) were at Other Channel Islands; none were in northern California (Table 7). Counts of non-pups at the Main Channel Islands rookeries averaged 77.35% (SD=5.040) of the California totals, with 2.40% (SD=1.378) found at Other Channel Islands, 18.96% (SD=3.675) in central California, and 1.29% (SD=1.770) in northern California. Those surveys also showed that San Miguel Island and San Nicolas Island had the greatest percentage of each age/sex class within the state (Table 8).

CSLs were not uniformly distributed in central and northern California (Table 3, Figure 5). More pups were produced at Año Nuevo Island (mean=35; SD=35) and South Farallon Islands (mean=53; SD=60), located within zones D and E, respectively, than at other zones (Tables 3 and 4). Beginning in 2009, more than 50 pups were counted at Año Nuevo Island and South Farallon Islands, qualifying them as new rookeries. Zone E had the most non-pups (mean=7,539; SD=3,121), followed by zone G (mean=6,066; SD=2,866) and D (mean=5,027; SD=2,816). Northern California zones A, B, and C had very few CSLs compared to central

California zones (D through G).

From 1964 to 2014, the U.S. count of live-pups and the count of live pups at the Main Channel Islands rookeries, increased at an average annual growth rate of 4.6% per year (L95% CI=4.1%, U95% CI=5.1%; Table 9). For the same period, the southern California count of non-pups increased at an average annual growth rate of 2.8% per year (L95% CI=2.4%, U95% CI=3.4%) and that of the Main Channel Islands rookeries increased at 2.9% per year (L95% CI=2.5%, U95% CI=3.4%); Table 9). Average annual growth rates from live-pup counts were higher at San Nicolas Island (5.7%) and Santa Barbara Island (5.3%) than at San Clemente Island (4.7%) and San Miguel Island (4.1%). However, average annual growth rates from counts of non-pups at each of the Main Channel Islands rookeries were lower (ranged 2.2% to 3.5% for individual rookeries) than was estimated from counts of live-pups at the same rookeries (Table 9).

Stepwise GLM analysis indicated that the environmental covariates SLH-LA and NPGO were negatively related to the count of live pups at the Channel Islands (i.e., the negative slope of the coefficient indicates that fewer pups were produced as SLH-LA and NPGO increased), and that they were positively related to SLH-LA at the central California rookeries at Año Nuevo Island and the South Farallon Islands (i.e., the positive slope of the coefficient indicates that more pups were produced as SLH-LA increased; Table 9). Likewise, SLH-LA was negatively related to counts of non-pups at San Miguel Island, San Nicolas Island, and the combined Main Channel Islands rookeries group (Table 9). Non-pup counts at the South Farallon Islands increased as MEI increased (i.e., as conditions went from cold-water La Niña to warm-water El Niño) and non-pup counts at Año Nuevo Island increased as NPGO increased. None of the environmental covariates improved the model of non-pup counts for central and northern California (Table 9).

DISCUSSION

During the 1980s and 1990s, CSL pup surveys were emphasized to estimate population status and only the Main Channel Islands rookeries were surveyed regularly; non-pups were not counted regularly and not counted at all the rookeries. With time, other age/sex class categories were counted and SWFSC surveys expanded geographically. Eventually, surveys covered all the

California Channel Islands and the continental coastline of California from Point Conception to the California/Oregon border. These surveys along with published data made it possible to examine statewide CSL population growth rates from counts of pups and non-pups over a fifty-year period, and allowed examination of the geographical distribution within California of various age/sex classes during the July breeding season.

The first estimates of average annual growth rates of the U.S. population of CSLs were based on counts of pups at San Miguel Island and San Nicolas Island between 1970 and 1986 (Boveng, 1988). The estimates were variable depending on the time period included in the estimate: 3.4% (1971-1986), 6.4% (1970-1982), and 11.9% (1983-1986). The variability in the rates was attributed to effects of El Niño on pup production (Boveng, 1988). Lowry et al. (1992) then estimated a population growth at 4.6% from pup counts between 1975 and 1990 from the Main Channel Islands rookeries. From 1975 to 2000, the mean annual growth rate was estimated at 6.1% (Lowry and Maravilla-Chavez, 2005), and five years later in 2005 it declined to 5.6% (Carretta et al., 2007). However, analyses generating these two estimates omitted pup counts obtained during 1983-1984, 1992-1993, and 1998 when El Niño conditions resulted in low pup production. The growth rates in this report incorporate more years (1964-2014) and did not omit pup count data but rather used four environmental condition indices as covariates (MEI, SLH-LA, PDO and NPGO) to model the effect of the environmental conditions on pup count data, of which SLH-LA and NPGO were identified as being the most influential. These two environmental indices are positively correlated with ENSO and their negative relationships with pup counts, indicating that elevated temperature reflected by thermal expansion derived from sea level data and NPGO values resulted in fewer pups born.

Counts of non-pups were also used to estimate population growth. The 4.7% average annual growth rate obtained from counts of pups at the Main Channel Islands rookeries during 1964-2014 is probably more representative of California-wide population growth than the 2.9% growth rate obtained from non-pup data because it is unclear whether trends in non-pup counts (number of hauled-out animals) would be linearly 1:1 related to growth of the full population.

For generating stock assessment reports (SARs) under the Marine Mammal Protection Act, a default of 12% is assumed to be the maximum annual rate of increase for pinnipeds (Wade, 1998). The growth rates in this report are much lower. Possibly this reflects some density-dependence in the time series, noting that the population would only be expected to grow

at its intrinsic rate when population size is very low relative to available resources (i.e., in the earliest part of the time series). It is also possible it indicates that CSL maximum growth is less than 12%. One factor likely affecting population growth rate estimates early in the time series was bycatch of non-pups in gillnet-fisheries. Mortality from U.S. west coast gillnet fisheries prior to a gillnet ban in southern California coastal waters in 1994 was on the order of a few thousand animals per year (Barlow et al., 1994), which would have corresponded to several percent of the total population size at the time and thus reduced the population growth rate. This fishery bycatch mortality on non-pups could also partially explain the difference in growth rate estimates between pups and non-pups.

The western coast of the contiguous U.S. periodically experiences above average warm-water periods associated with the El Niño Southern Oscillation (ENSO) cycle that occurs in equatorial waters off South America (Fahrbach et al., 1991). The ENSO cycle is composed of the warm-water El Niño period, the cold-water La Niña period, and a neutral phase. The El Niño periods decrease primary productivity and abundance and availability of CSL forage along the California coast (Arntz et al., 1991). El Niño periods have been observed to have short and long-term effects on the CSL population in the U.S. Short-term effects were apparent in drops in CSL pup production during 1983, 1992-1993, 1998, and 2009-2010 and were the most noticeable effect of recent El Niño periods on population growth (Fig. 3). The decline in pup births reflects an inability of pregnant females to find sufficient food to support the energetic demands of pregnancy. Lower numbers of pup births in the El Niño years resulted in fewer adults in later years for the affected cohorts resulting a long-term population affect. After an El Niño period, pup production sometimes rebounds in the following year to pre-El Niño levels (as was observed in 1994, 1999, and 2011), usually when the event is weak or mild or of short duration. The immediate rebound in pup production will not occur when adult females die during an El Niño event, as probably occurred during the very strong and prolonged 1982-1983 El Niño period (DeLong et al., 1991) due to fewer adult females of reproductive age in the population than were present prior to the El Niño event. Pup production took about five years to reach the level it was at prior to the 1982-1983 El Niño. Other characteristics of El Niño's are higher pup and juvenile mortality rates (DeLong et al., 1991), that also affect future recruitment into the adult population for the affected cohorts, and delayed recruitment into the breeding population of females that are born during El Niño conditions or experience El Niño conditions while they are juveniles (Melin

et al., 2012). These responses also slow population growth as was observed (in the form of reduced pup production) five to six years after the 1992-1993 El Niño (there was a drop in births in 1997 and 1998, with the 1998 also affected by the 1997-1998 El Niño) and in 2002 and 2003 after the 1997-1998 El Niño (Figs. 1 and 6). Other factors that have affected population growth rates are domoic acid poisoning from an environmental toxin that results in adult female and juvenile mortality and reproductive failure, and hookworm infections that result in elevated pup mortality rates (Scholin et al., 2000; Lefebvre et al., 2000; Lyons et al., 2001; Bejarano et al., 2008).

Four environmental covariate indices (MEI, SLH-LA, PDO and NPGO) were examined to determine whether and how they affected the U.S. population growth rate estimates of CSLs. Each of the four indices reflects different environmental conditions. NPGO measures sea surface height in the Northeast Pacific and has been found to correlate with fluctuations in salinity, nitrates, and chlorophyll-a in the southern portion of the California Current (Di Lorenzo et al., 2008). PDO is an El Niño like pattern that measures variability in North Pacific sea surface temperatures (Mantua et al., 1997) over multiple decades (20-30 years). MEI is an ENSO index derived from tropical measurements of sea level pressure, surface wind, and sea surface temperature at the equator (Wolter and Timlin, 1993). SLH-LA is the sea level height at Los Angeles, California harbor with its seasonal variation and long-term trend removed (Zervas, 2009), resulting in a measure of the thermal expansion and contraction of the water mass. The SLH-LA index used here, however, should not be confused with sea level rise due to climate change (e.g., melting glaciers) because seasonal and long-term trend were removed from the observed data.

Population growth rate analysis of CSLs at California rookeries indicated that SLH-LA and NPGO explained the rise and fall of pup production and SLH-LA explained presence/absence of non-pups. The relationship between CSL pup production and distribution of non-pups within California with SLH-LA and NPGO (which both represent heat content in oceanic water) may indicate how CSLs will respond to climate change. If oceanic water temperature increases in the Pacific Ocean (Overland and Wang, 2007) and the Southern California Bight (Auad et al., 2006) due to climate change, it is possible that fewer CSL pups will be produced at southern California rookeries and more CSLs may occur in central and northern California in the future.

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Table 1. Locations that CSLs were censused by observers on the ground (Gr), or by counts made from aerial color photographs taken with a 35mm-format (35Ph), 126mm-format (Ph), or 9inch-format (9Ph) film cameras, a digital SLR camera (DPh), or by aerial observation (AO) during 1964-2014.

Year	San Clemente Island	Santa Barbara Island	San Nicolas Island	San Miguel Island	Richardson Rock	Santa Rosa Island	Santa Crus Island	Anacapa Island	Santa Catalina Island	Año Nuevo Island	Farallon Islands	Central California	Northern California
1964	9Ph	9Ph	9Ph	9Ph		9Ph	9Ph	9Ph	9Ph				
1965	9Ph	9Ph	Gr	9Ph		9Ph	9Ph	9Ph	9Ph				
1971				Gr									
1972				Gr									
1975	35Ph	35Ph	35Ph	Gr, 35Ph	35Ph	35Ph	35Ph	35Ph	35Ph				
1976	35Ph	35Ph	35Ph	Gr, 35Ph	35Ph	35Ph	35Ph	35Ph	35Ph				
1977	35Ph	35Ph	35Ph	Gr, 35Ph	35Ph	35Ph	35Ph	35Ph	35Ph				
1978		Gr		Gr									
1979		Gr		Gr									
1980			Gr	Gr									
1981	Gr	Gr	Gr	Gr							Gr		
1982	Gr	Gr	Gr	Gr									
1983	Gr	Gr	Gr	Gr							Gr		
1984	Gr	Gr	Gr	Gr							Gr		
1985	Gr	Gr	Gr	Gr									
1986	Gr	Gr	Gr	Gr									
1987	Gr	Gr	Gr	Ph									
1988	Gr	Gr		Ph									
1989	Gr	Gr		Ph									
1990	Gr	Gr	Ph	Ph									
1991	Gr	Gr	Gr	Gr									
1992	Gr	Gr	Gr, Ph	Ph	Ph		Ph			Ph			
1993	Gr	Gr	Gr, Ph	Ph						Ph			
1994	Gr	Gr	Gr, Ph	Ph	Ph					Ph			
1995	Gr, Ph	Gr	Ph	Ph						Ph	Ph		
1996	Gr, Ph	Gr	Ph	Ph						Ph			
1997	Gr, Ph	Gr, Ph	Ph	Ph						Ph	Ph		
1998	Gr, Ph	Gr, Ph	Ph	Ph						Ph	Ph	Ph	Ph
1999	Gr, Ph	Ph	Ph	Ph	Ph					Ph	Ph	Ph	Ph
2000	Gr, Ph	Ph	Ph	Ph	Ph					Ph	Ph	Ph	Ph
2001	Gr, Ph	Ph	Ph	Ph	Ph					Ph	Ph	Ph	Ph
2002	Gr, Ph	Ph	Ph	Ph		AO	Ph		Ph	Ph	Ph	Ph	Ph
2003	Gr, Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph
2004	Gr, Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph		Ph	Ph	Ph	Ph
2005	Gr, Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph
2006	Gr, Ph	Ph	Ph	Ph									
2007	Gr	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	
2008	Gr, Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph	Ph				
2009	Gr			Gr						Ph	Ph	Ph	Ph
2010	Gr			Gr									
2011	Gr, DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh
2012	Gr, DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh
2013	Gr, DPh	DPh	DPh	DPh		DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh
2014	Gr, DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh	DPh				

Table 2. The number of California sea lions counted by age/sex class at each of the Channel Islands in southern California from surveys conducted during 1971-2014. Counts were made by biologists on the ground or small boat (Gr), estimated from ground count (Est), and from vertical 126-mm format aerial color photographs (Ph) or vertical aerial digital photographs (DPh). Counts were repeated on some dates by the same counter or counted by different people. AO denotes aerial observation when no animals were observed during the survey. No data obtained for blank cells.

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
Anacapa Island											
2003 Jul 11	Ph	5	0	351	341	0	341	11	10	713	718
2004 Jul 17	Ph	1	0	203	138	2	140	8	4	355	356
2005 Jul 8	Ph	4	0	257	182	1	183	6	11	457	461
2007 Jul 10	Ph	6	0	388	339	60	399	11	28	826	832
2008 Jul 12	Ph	6	0	840	400	2	402	7	14	1,263	1,269
2011 Jul 11	Dph	32	1	323	579	127	706	12	24	1,065	1,097
2012 Jul 13	Dph	50	0	458	418	113	531	15	14	1,018	1,068
2013 Jul 8	Dph	48	0	261	642	179	821	38	26	1,146	1,194
2014 Jul 8	Dph	52	0	189	400	230	630	49	20	888	940
Richardson Rock											
1992 Jul 18	Ph	0	0	17			86	8	5	116	116
1994 Jul 17	Ph	0	0	7			125	42	10	184	184
1999 Jul 12	Ph	0	0	25			97	50	18	190	190
2000 Jul 7	Ph	2	0	35			86	52	24	197	199
2001 Jul 16	Ph	0	0	215			154	33	6	408	408
2003 Jul 8	Ph	0	0	70	77	7	84	78	8	240	240
2004 Jul 11	Ph	0	0	31	145	0	145	30	6	212	212
2005 Jul 21	Ph	0	0	85	46	47	93	33	9	220	220
2007 Jul 10	Ph	0	0	55	197	85	282	36	14	387	387
2008 Jul 12	Ph	0	0	32	171	76	247	36	12	327	327
2011 Jul 13	Dph	0	0	53	186	4	190	23	16	282	282
2012 Jul 14	Dph	1	0	51	135	2	137	20	7	215	216
2014 Jul 10	Dph	0	0	78	387	17	404	19	12	513	513
San Clemente Island											
1981 Aug 18-19[a]	Gr	666								1,052	1,718
1981 Aug 18-19	Gr	605								1,119	1,724
1981 Aug 18-19	Gr	590								1,031	1,621
1982 Jul 27-29[a]	Gr	941								1,280	2,221
1983 Jul 21-25[b]	Gr	353								1,274	1,627
1984 Jul 26-27[c]	Gr	411								841	1,252
1985 Aug 25[d]	Gr	609								739	1,348
1986 Jul 25-28[e]	Gr	718								1,106	1,824
1987 Jul 31-Aug 3[e]	Gr	782								1,034	1,816
1988 Jul 29-Aug 1[f]	Gr	803							65	960	1,763
1988 Jul 29-Aug 1	Gr	790							57	999	1,789

Table 2. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
San Clemente Island (Continued)											
1989 Jul 21-23[f]	Gr	795							65	1,460	2,255
1990 Jul 20-21[f]	Gr	629							88	960	1,589
1991 Jul 12-14[f]	Gr	913							77	1,560	2,473
1992 Jul 24-25[g]	Gr	789							54	737	1,526
1993 Jul 23-24[g]	Gr	745							52	637	1,382
1994 Jul 23[g]	Gr	1,067							64	1,205	2,272
1995 Aug 15[g]	Gr	1,189								1,656	2,845
1995 Jul 21[g]	Ph	1,028	0	395			1,650	50	90	2,185	3,213
1995 Jul 22[g]	Ph	970	2	362			1,481	39	79	1,961	2,931
1996 Jul 12-14[g]	Gr	1,207		227			1,076	49	111	1,463	2,670
1996 Jul 12-14[g]	Gr	1,047		211			1,081	42	84	1,418	2,465
1996 Jul 12-14[g]	Gr	1,040		225			1,085	45	93	1,448	2,488
1996 Jul 12-14[g]	Gr	1,208		220			1,132	55	112	1,519	2,727
1996 Jul 21[g]	Ph	1,243	3	120			1,192	57	87	1,456	2,699
1996 Jul 23[g]	Ph	1,468	1	138			1,198	29	79	1,444	2,912
1997 Jul 14[g]	Ph	1,326	4	89			953	56	140	1,238	2,564
1997 Jul 15-16[g]	Gr	1,248		147			857	26	89	1,119	2,367
1997 Jul 15-16[g]	Gr	1,203		122			866	26	99	1,113	2,316
1998 Jul 18-20[g]	Gr	537		35			787	7	87	916	1,453
1998 Jul 18-20[g]	Gr	587		44			830	17	84	975	1,562
1998 Jul 20[g]	Ph	682	4	97			1,291	43	123	1,554	2,236
1998 Jul 26[h]	Ph	600	0	80			1,142	41	96	1,359	1,959
1999 Jul 10[g]	Ph	1,004	3	339			1,837	55	161	2,392	3,396
1999 Jul 14[g]	Gr	1,326		220			1,170	8	93	1,491	2,817
2000 Jul 25-26[g]	Gr	1,660		338			1,305	14	87	1,744	3,404
2000 Jul 7[g]	Ph	1,735	1	422			2,454	127	174	3,177	4,912
2001 Jul 12	Ph	1,722	0	330			2,179	102	182	2,793	4,515
2001 Jul 17	Gr	1,629		328			1,576	97	79	2,080	3,709
2002 Jul 13	Ph	2,081	4	438	2,799	38	2,837	100	188	3,563	5,644
2002 Jul 30-31	Gr	1,631		315			2,150	35	51	2,551	4,182
2003 Jul 16-18	Gr	1,128		214			1,232	110	88	1,644	2,772
2003 Jul 7	Ph	1,549	3	311	2,337	5	2,342	148	160	2,961	4,510
2004 Jul 10	Ph	1,839	0	454	2,547	95	2,642	197	180	3,473	5,312
2004 Jul 29	Gr	1,630		96			1,686	33	68	1,883	3,513
2005 Jul 20	Ph	1,587	3	231	2,229	99	2,328	93	199	2,851	4,438
2005 Jul 56	Gr	1,479		129			1,685	91	201	2,106	3,585
2006 Jul 17	Ph	2,130	3	363	2,141	131	2,272	98	202	2,935	5,065
2006 Jul 18-19	Gr	1,859		178			1,581	54	181	1,994	3,853
2007 Jul 24-25	Gr	2,146		143			1,898	47	162	2,250	4,396
2008 Jul 10	Ph	2,144	3	496	2,292	149	2,441	203	267	3,407	5,551
2008 Jul 22-23	Gr	2,086		397			1,348	98	158	2,001	4,087
2009 Jul 21-22	Gr	1,813		566			1,377	62	123	2,128	3,941

Table 2. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
San Clemente Island (Continued)											
2010 Jul 13-14	Gr	1,680		390			1,812	116	181	2,562	4,242
2011 Jul 11	Dph	2,883	12	344	3,243	104	3,347	57	225	3,973	6,856
2011 Jul 67	Gr	2,460		268			2,327	307	213	3,115	5,575
2012 Jul 13	Dph	3,220	2	689	2,634	60	2,694	176	269	3,828	7,048
2012 Jul 27-28	Gr	2,616		291			2,165	63	118	2,637	5,253
2013 Jul 13	Dph	2,458	11	777	3,703	83	3,786	184	223	4,970	7,428
2013 Jul 26-27	Gr	2,182		389			2,410	54	87	2,940	5,122
2014 Jul 18-21	Gr	1,679		134			2,388	46	151	2,719	4,398
2014 Jul 7	Dph	1,927	12	696	4,064	83	4,147	121	265	5,229	7,156
San Miguel Island											
1971 Jul 25	Gr	5,285[i]									
1971 Jul 25	Est	5,496[j]									
1972 Aug 21	Gr	3,501[i]									
1972 Aug 21	Est	3,641[j]									
1975 Aug 19-20	Gr	7,166									
1976 Jul 28-29	Gr	8,008									
1977 Jul 29-30	Gr	7,095									
1978 Aug 4	Gr	6,854[i]									
1978 Aug 4	Est	7,128[j]									
1979 Jul 31-Aug 2	Gr	8,359									
1980 Aug 2-5	Gr	6,950									
1981 Aug 13	Gr	8,270[i]									
1981 Aug 13	Est	8,601[j]									
1982 Aug 5-7	Gr	10,132[i]									
1982 Aug 5-7	Est	10,537[j]									
1983 Jul 30	Gr	7,326[i]									
1983 Jul 30	Est	7,619[j]									
1984 Aug 2	Gr	8,873[i]									
1984 Aug 2	Est	9,228[j]									
1985 Jul 24 & Aug 4	Gr	9,516									
1986 Jul 26	Gr	12,065									
1987 Jun 28	Ph	12,152[k]									
1987 Jun 28	Est	12,760[k]									
1987 Jul 26	Ph	11,807[l]									
1988 Jul 24	Ph	11,077[l]									
1989 Jul 21	Ph	12,704[g]									
1990 Jul 18	Ph	11,741[g]									
1990 Jul 25	Ph	11,066[g]									

Table 2. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
San Miguel Island (Continued)											
1991 Aug 4	Gr	16,503									
1992 Jul 18	Ph	9,116[g]	77	4,629			13,413	561	1,367	19,970	29,086
1992 Jul 20	Ph	10,753[g]	23	3,278			14,323	297	1,276	19,174	29,927
1993 Jul 15	Ph	11,985[g]	66	2,390			17,223	1,566	1,760	22,939	34,923
1993 Jul 17	Ph	10,704[g]	20	2,338			15,138	791	1,536	19,803	30,507
1994 Jul 16	Ph	16,539[g]	408	2,190			16,328	1,151	1,249	20,918	37,457
1994 Jul 17	Ph	14,704[g]	446	2,053			19,214	1,436	1,338	24,041	38,745
1995 Jul 23	Ph	15,624[g]	173	8,815			18,873	1,492	1,311	30,491	46,115
1995 Jul 25	Ph	15,711[g]	121	6,782			19,880	1,015	1,044	28,721	44,432
1996 Jul 22	Ph	16,962[g]	166	3,324			13,737	1,157	1,157	19,375	36,337
1997 Jul 14	Ph	14,941[g]	74	3,696			22,350	2,012	2,180	30,238	45,179
1998 Jul 20	Ph	8,111[g]	208	2,275			12,174	1,328	1,509	17,286	25,397
1999 Jul 12	Ph	18,074[g]	110	1,948			19,183	2,501	2,673	26,305	44,379
2000 Jul 7	Ph	20,609[g]	169	4,460			22,020	2,787	3,718	32,985	53,594
2001 Jul 16	Ph	19,552	24	4,803			17,096	1,656	3,405	26,960	46,512
2002 Jul 16	Ph	21,126	50	9,980	19,477	2,071	21,548	2,594	3,295	37,417	58,543
2003 Jul 8	Ph	17,765	104	6,111	14,631	2,024	16,655	3,311	3,641	29,718	47,483
2004 Jul 11	Ph	18,278	56	10,821	25,745	1,764	27,509	2,740	3,145	44,215	62,493
2005 Jul 21	Ph	22,088	62	9,616	25,711	1,981	27,692	1,699	2,889	41,896	63,984
2006 Jul 17	Ph	24,583	47	4,905	25,140	3,129	28,269	1,513	2,092	36,779	61,362
2007 Jul 10	Ph	23,234	15	5,781	26,835	3,351	30,186	1,821	2,841	40,629	63,863
2008 Jul 12	Ph	25,148	21	4,966	26,004	2,829	28,833	2,549	2,688	39,036	64,184
2009 Jul 22-29 & Aug 19	Gr	12,806									
2010 Jul 22-26 & Aug 1	Gr	15,131									
2011 Jul 13	Dph	26,953	260	10,094	26,109	2,003	28,112	2,853	3,401	44,460	71,413
2012 Jul 14	Dph	28,289	708	7,972	21,664	1,508	23,172	3,064	3,163	37,371	65,660
2013 Jul 11	Dph	21,014	167	8,563	26,826	1,708	28,534	3,402	2,878	43,377	64,391
2014 Jul 10	Dph	23,607	393	4,075	23,410	1,223	24,633	2,700	3,490	34,898	58,505
San Nicolas Island											
1990 Jul 18	Ph	10,683[g]									
1990 Jul 25	Ph	11,766[g]									
1991 Jul 19-21	Gr	11,827[m]							1,025	15,929	27,756
1992 Jul 17-18	Gr	6,468[m]							642	9,947	16,415
1992 Jul 18	Ph	8,869[m]	22	554			9,705	438	983	11,680	20,549
1992 Jul 23	Ph	9,348[m]	50	1,397			7,691	187	775	10,050	19,398
1993 Jul 11	Ph	10,595[m]	78	1,556			10,649	747	1,031	13,983	24,578
1993 Jul 11	Ph	10,538[m]	173	1,354			10,878	872	1,078	14,182	24,720
1993 Jul 15	Ph	9,702[m]	53	2,185			10,305	652	1,007	14,149	23,851
1993 Jul 15	Ph	10,409[m]	112	1,876			10,662	1,078	1,082	14,698	25,107
1993 Jul 16-18	Gr	9,262[m]							998	11,696	20,958
1993 Jul 16-18	Gr	9,748[m]							941	12,135	21,883

Table 2. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
San Nicolas Island (Continued)											
1993 Jul 17	Ph	9,698[m]	84	2,066			9,373	620	1,067	13,126	22,824
1993 Jul 17	Ph	10,345[m]	104	1,706			9,668	907	1,132	13,413	23,758
1993 Jul 23-26	Gr	8,723[m]							400	8,113	16,836
1993 Jul 23-26	Gr	8,382[m]							683	7,782	16,164
1994 Jul 12-13	Gr	16,503[m]							803	15,777	32,290
1994 Jul 14	Ph	15,766[m]	180	1,020			12,534	1,181	1,144	15,879	31,645
1994 Jul 16	Ph	16,889[m]	247	966			12,782	1,101	1,171	16,020	32,909
1995 Jul 21	Ph	17,512[g]	97	4,831			16,591	1,323	1,222	23,967	41,479
1995 Jul 22	Ph	16,926[g]	117	5,363			14,205	1,285	1,055	21,908	38,834
1996 Jul 21	Ph	19,308[g]	112	1,659			12,199	853	1,206	15,917	35,225
1996 Jul 22	Ph	20,285[g]	85	1,776			12,178	603	1,082	15,639	35,924
1997 Jul 14	Ph	20,488[g]	120	1,167			13,531	1,511	1,986	18,195	38,683
1998 Jul 20	Ph	4,885[g]	61	1,679			10,445	900	1,567	14,591	19,476
1999 Jul 10	Ph	19,878[g]	87	2,010			16,531	1,517	2,614	22,672	42,550
2000 Jul 7	Ph	24,167[g]	59	3,951			17,554	2,504	2,908	26,917	51,084
2001 Jul 12	Ph	24,741	56	5,248			17,140	2,037	2,797	27,222	51,963
2002 Jul 22	Ph	19,719	86	2,591	10,806	518	11,324	1,742	1,943	17,600	37,319
2003 Jul 7	Ph	15,702	50	4,496	15,384	1,652	17,036	3,112	2,824	27,468	43,170
2004 Jul 10	Ph	20,866	30	2,722	17,792	2,496	20,288	2,874	2,773	28,657	49,523
2005 Jul 21	Ph	21,799	85	2,459	17,015	1,807	18,822	1,311	2,109	24,701	46,500
2006 Jul 14	Ph	26,154	121	2,228	18,208	2,145	20,353	1,865	3,355	27,801	53,955
2007 Jul 11	Ph	25,198	5	2,053	16,811	2,119	18,930	1,970	3,246	26,199	51,397
2008 Jul 11	Ph	29,052	102	2,307	18,173	2,261	20,434	2,510	3,309	28,560	57,612
2009 Jul 3-4[n]	Est	19,697									
2010 Jul 16[n]	Est	15,131									
2011 Jul 18	Dph	28,087	411	3,629	15,191	924	16,115	1,755	2,316	23,815	51,902
2012 Jul 13	Dph	31,972	276	5,317	20,171	1,527	21,698	2,612	3,251	32,878	64,850
2013 Jul 17	Dph	16,225	78	8,037	24,277	956	25,233	2,688	2,881	38,839	55,063
2014 Jul 9	Dph	19,587	81	4,205	23,363	1,082	24,445	2,446	3,350	34,446	54,033
Santa Barbara Island											
1983 Jun 30[p]	Gr	237									
1984 Jul 11-12[p]	Gr	280									
1985 Jul 5-6[p]	Gr	543									
1986 Jul 9-10[l, p]	Gr	796							110	1,166	1,962
1986 Jul 9-10[l, p]	Gr	792							92	1,241	2,033
1987 Jul 9-10	Gr	917[g]							95	1,349	2,266
1988 Jul 8-9	Gr	1,089[g]									
1989 Jul 14	Gr	1,307[g]							104	2,240	3,547
1990 Jul 8-9	Gr	1,286[g]							155	2,549	3,838
1991 Jul 8-9	Gr	1,504[g]							151	2,974	4,478
1992 Jul 6-7	Gr	1,470[g]							125	1,956	3,427

Table 2. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
Santa Barbara Island (Continued)											
1993 Jul 6-7	Gr	949[g]		230			1,725	40	106	2,101	3,050
1994 Jul 6-7	Gr	1,688[g]		540			2,637	109	143	3,429	5,117
1995 Jul 17-18	Gr	1,647[g]							164	4,592	6,239
1996 Jul 7	Gr	2,326[g]		549			2,466	175	170	3,360	5,686
1997 Jul 18	Ph	2,095[g]	0	211			2,185	61	146	2,603	4,698
1997 Jul 8	Gr	2,467[g]		146			2,047	83	160	2,436	4,903
1997 Jul 8	Gr	2,351[g]		162			1,898	93	204	2,357	4,709
1998 Jul 13	Gr	564[l]							195	2,616	3,180
1998 Jul 20	Ph	707[g]	1	186			2,191	30	129	2,536	3,243
1999 Jul 31	Ph	2,410[g]	9	266			2,439	14	87	2,806	5,216
2000 Jul 7	Ph	2,851[g]	5	1,009			3,932	166	305	5,412	8,263
2001 Jul 12	Ph	3,061	18	1,328			3,399	167	274	5,168	8,229
2002 Jul 15	Ph	2,697	9	458	3,177	102	3,279	245	242	4,224	6,921
2003 Jul 10	Ph	1,528	6	554	2,613	51	2,664	208	206	3,632	5,160
2004 Jul 10	Ph	2,484	3	545	4,191	112	4,303	196	267	5,311	7,795
2005 Jul 20	Ph	2,827	4	375	2,992	142	3,134	179	257	3,945	6,772
2006 Jul 11	Ph	3,277	11	374	3,294	190	3,484	141	325	4,324	7,601
2007 Jul 12	Ph	3,473	14	435	3,056	181	3,237	204	384	4,260	7,733
2008 Jul 11	Ph	3,424	16	516	2,697	249	2,946	217	342	4,021	7,445
2009[o]	Est	1,597									
2010[o]	Est	1,508									
2011 Jul 18	Dph	3,941	31	359	2,414	165	2,579	134	244	3,316	7,257
2012 Jul 13	Dph	3,558	26	452	2,862	221	3,083	208	271	4,014	7,572
2013 Jul 11	Dph	2,918	24	615	3,495	100	3,595	258	351	4,819	7,737
2014 Jul 8	Dph	2,498	17	296	3,785	111	3,896	153	284	4,629	7,127
Santa Catalina Island											
2002 Jul 13	Ph	0	0	79	0	12	12	1	3	95	95
2003 Jul 10	Ph	0	0	19	16	0	9	2	2	32	32
2005 Jul 20	Ph	0	0	50	0	76	76	6	0	132	132
2007 Jul 11	Ph	0	0	218	135	0	132	0	4	357	357
2008 Jul 10	Ph	0	0	118	89	0	89	3	1	211	211
2011 Jul 11	Dph	17	0	118	251	22	273	2	6	399	416
2012 Jul 13	Dph	31	0	74	147	6	153	4	7	238	269
2013 Jul 12	Dph	20	0	109	294	5	299	10	8	426	446
2014 Jul 7	Dph	19	0	36	247	24	271	3	12	322	341
Santa Cruz Island											
1992 Jul 18	Ph	0	0	31			105	3	6	145	145
2002 Jul 16	Ph	0	0	29	0	98	98	12	6	145	145
2003 Jul 11	Ph	2	0	311	398	122	260	27	4	602	604
2004 Jul 17	Ph	0	0	117	0	256	128	11	2	258	258
2005 Jul 8	Ph	0	0	56	155	17	172	7	6	241	241

Table 2. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
Santa Cruz Island (Continued)											
2007 Jul 10	Ph	0	0	309	740	25	382	13	4	708	708
2008 Jul 12	Ph	0	0	40	305	11	316	18	1	375	375
2011 Jul 11	Dph	1	0	285	683	16	699	38	3	1,025	1,026
2012 Jul 13	Dph	0	0	402	1,078	56	1,134	20	15	1,571	1,571
2013 Jul 8	Dph	0	0	450	935	31	966	34	19	1,469	1,469
2014 Jul 8	Dph	0	0	119	650	56	706	32	13	870	870
Santa Rosa Island											
2002 Jul 16	AO	0	0	0	0	0	0	0	0	0	0
2003 Jul 11	Ph	0	0	33	53	0	53	2	1	89	89
2004 Jul 17	Ph	0	0	8	0	52	26	3	3	40	40
2005 Jul 8	Ph	0	0	4	11	1	12	0	3	19	19
2007 Jul 10	Ph	0	0	6	17	2	19	2	1	28	28
2008 Jul 12	Ph	0	0	234	296	0	296	4	2	536	536
2011 Jul 11	Dph	0	0	365	515	6	521	9	5	900	900
2012 Jul 13-14	Dph	3	0	609	835	87	922	38	12	1,581	1,584
2013 Jul 11	Dph	3	0	155	561	5	566	32	15	768	771
2014 Jul 10	Dph	1	0	109	651	118	769	12	7	897	898

[a]Oliver and Lowry (1987)
[b]Oliver et al. (1988)
[c]Wexler and Oliver (1988)
[d]Oliver and Wexler (1991)
[e]Oliver (1991a)
[f]Oliver (1991)
[g]Lowry and Maravilla-Chavez (2005)
[h]Carretta, et al. (2000)
[i]Castle Rock (the sub-island at San Miguel Island) was not censused
[j]Estimate for Castle Rock added to ground count (ground count multiplied by 1.04)
[k]Revised count for Lowry and Maravilla-Chavez (2005); multiplying 12,152 pups counted by 1.05 yields 12,760 pups.
[l]Revised count for Lowry et al. (1987) and Lowry and Maravilla-Chavez (2005)
[m]Lowry (1999)
[n]Appendix 1
[o]Estimated from data in Appendix 1 (subtracted SMI+SNI+SCI from total estimate)
[p]Lowry, et al. (1987)

Table 3. Number of California sea lions counted within seven zones in central and northern California for surveys conducted in July or August (refer to map in Figure 1A for location of zones). Some zones required more than one day to survey due to weather conditions. Counts were made by biologists on the ground (Gr), from vertical 126-mm format aerial color photographs (Ph), vertical aerial digital photographs (DPh), or hand-held digital photographs (HDPh). AO denotes aerial observation when no animals were observed during the survey.

Census date(s)	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total Live
Northern California: Zone A											
1998 Jul 15-16	Gr/Ph	0	0	358			206	148	22	734	734
1999 Jul 7	Ph	0	0	111			167	5	4	287	287
2000 Jul 8	Ph	0	0	49	0	52	52	3	6	110	110
2001 Jul 17	Ph	0	0	361	0	49	49	37	14	461	461
2002 Jul 9	Ph	0	0	204	0	426	426	1	0	631	631
2003 Jul 12	Ph	0	0	1,521	0	333	333	20	2	1,876	1,876
2004 Jul 5	Ph	0	0	702	0	303	303	4	0	1,009	1,009
2005 Jul 12	Ph	0	0	254	0	267	267	15	1	537	537
2009 Jul 8	Ph	0	0	1,416	19	1,241	1,260	104	68	2,848	2,848
2011 Jul 15	DPh	0	0	34	0	233	233	6	2	275	275
2012 Jul 5-6	DPh	0	0	43	0	228	228	12	20	303	303
2013 Jul 6	DPh	0	0	0	0	5	5	4	4	13	13
Northern California: Zone B											
1998 Jul 7, 13, 15	Ph	0	0	2,382			116	162	62	2,722	2,722
1999 Jul 7	Ph	0	0	6			6	1	1	14	14
2000 Jul 8	Ph	0	0	1	0	1	1	2	0	4	4
2001 Jul 17	Ph	0	0	17	0	31	31	24	7	79	79
2002 Jul 9	Ph	0	0	13	0	6	6	2	0	21	21
2003 Jul 12	Ph	0	0	360	0	51	51	1	1	413	413
2004 Jul 5	Ph	0	0	0	0	9	9	2	1	12	12
2005 Jul 12	Ph	0	0	2	0	3	3	0	0	5	5
2009 Jul 8	Ph	0	0	446	0	161	161	58	31	696	696
2011 Jul 15	DPh	0	0	0	0	1	1	5	3	9	9
2012 Jul 5	DPh	0	0	60	0	88	88	20	23	191	191
2013 Jul 6	AO	0	0	0	0	0	0	0	0	0	0
Northern California: Zone C											
1998 Jul 13, 18	Ph	0	0	320			287	190	101	898	898
1999 Jul 7	Ph	0	0	0			0	1	0	1	1
2000 Jul 12	Ph	0	0	72	0	5	5	28	11	116	116
2001 Jul 17	Ph	0	0	422	0	181	181	132	146	881	881
2002 Jul 12	Ph	0	0	638	0	83	83	2	2	725	725
2003 Jul 8, 11, 12	Ph	1	0	1,644	1	450	451	40	14	2,149	2,150
2004 Jul 9	Ph	0	0	5	0	0	0	0	0	5	5
2005 Jul 12	Ph	0	0	137	0	33	33	10	18	198	198
2009 Jul 8, 10, 12, 13	Ph	0	0	965	62	876	938	94	28	2,025	2,025
2011 Jul 14-15	DPh	1	0	10	19	11	30	2	7	49	50

Table 3. (Continued)

Census date(s)	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total Live
Northern California: Zone C (Continued)											
2012 Jul 4	DPh	0	0	58	0	116	116	16	29	219	219
2013 Jul 5	DPh	0	0	20	10	9	19	6	12	57	57
Central California: Zone D											
1998 Jul 18	Ph	55	0	1,918			7,318	1,283	290	10,809	10,864
1999 Jul 6, 8	Ph	3	0	193			970	109	91	1,363	1,366
2000 Jul 8, 12	Ph	4	0	789	6	441	447	252	90	1,578	1,582
2001 Jul 17	Ph	0	0	1,658	58	856	914	441	190	3,203	3,203
2002 Jul 9, 23	Ph	29	0	2,863	49	2,110	2,159	91	122	5,235	5,264
2003 Jul 8, 9, 14	Ph	48	0	4,117	437	3,043	3,480	241	98	7,936	7,984
2004 Jul 19	Ph	10	0	2,055	47	568	615	451	224	3,345	3,355
2005 Jul 23, 24	Ph	11	0	859	446	1,133	1,579	592	430	3,460	3,471
2007 Jul 18	Ph	12	0	3,893	505	656	1,161	732	262	6,048	6,060
2009 Jul 7, 11, 13	Ph	71	0	1,841	4,988	1,059	6,047	585	170	8,643	8,714
2011 Jul 14	DPh	136	3	399	1,367	727	2,094	184	183	2,860	2,996
2012 Jul 4	DPh	174	2	1,068	963	2,639	3,602	254	257	5,181	5,355
2013 Aug 6	HDPh	141	0	617	2,885	860	3,745	986	346	5,694	5,835
Central California: Zone E											
1998 Jul 10	Ph	54	0	2,920			3,226	564	178	6,888	6,942
1999 Jul 9, 11	Ph	4	0	1,226			5,652	398	65	7,341	7,345
2000 Jul 6, 8	Ph	6	0	6,690	481	759	1,240	224	121	8,275	8,281
2001 Jul 14	Ph	2	0	7,219	306	2,179	2,485	612	283	10,599	10,601
2002 Jul 23	Ph	5	0	7,808	172	2,450	2,622	1,314	480	12,224	12,229
2003 Jul 8	Ph	48	0	1,536	5,451	981	6,432	242	92	8,302	8,350
2004 Jul 9	Ph	11	0	1,764	88	402	490	86	64	2,404	2,415
2005 Jul 10	Ph	11	0	3,408	1,009	23	1,032	124	67	4,631	4,642
2007 Jul 1	Ph	13	0	3,926	228	28	256	85	50	4,317	4,330
2009 Jul 7	Ph	75	1	1,724	8,280	639	8,919	407	125	11,175	11,250
2011 Jul 14, 15, 16	DPh	52	0	3,320	5,567	990	6,557	850	296	11,023	11,075
2012 Jul 3	DPh	94	0	2,046	1,592	2,788	4,380	307	168	6,901	6,995
2013 Jul 7	DPh	92	0	2,061	1,266	224	1,490	152	228	3,931	4,023
Central California: Zone F											
1998 Jul 10	Ph	12	0	63			510	125	50	748	760
1999 Jul 9, 11	Ph	0	0	270			578	90	14	952	952
2000 Jul 6	Ph	0	0	1,569	222	443	665	80	41	2,355	2,355
2001 Jul 14	Ph	0	0	574	248	319	567	124	81	1,346	1,346
2002 Jul 8	Ph	1	0	3,140	24	686	710	61	44	3,955	3,956
2003 Jul 8	Ph	10	0	632	647	387	1,034	52	29	1,747	1,757
2004 Jul 9	Ph	1	0	2,264	0	756	756	31	6	3,057	3,058
2005 Jul 10	Ph	4	0	2,168	694	7	701	57	28	2,954	2,958
2007 Jul 1	Ph	5	0	2,850	525	10	535	24	11	3,420	3,425
2009 Jul 6-7	Ph	0	0	476	985	63	1,048	79	27	1,630	1,630

Table 3. (Continued)

Census date(s)	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total Live
Central California: Zone F (Continued)											
2011 Jul 16	DPh	6	0	1,327	1,195	231	1,426	228	72	3,053	3,059
2012 Jul 3	DPh	6	0	1,712	609	196	805	47	18	2,582	2,588
2013 Jul 7	DPh	0	0	1,619	897	190	1,087	35	21	2,762	2,762
Central California: Zone G											
1998 Jul 10	Ph	0	0	779			1,362	92	30	2,263	2,263
1999 Jul 9	Ph	0	0	919			2,426	186	63	3,594	3,594
2000 Jul 6	Ph	0	0	2,637	1,632	620	2,252	148	61	5,098	5,098
2001 Jul 14, 16	Ph	0	0	3,810	2,271	489	2,760	191	50	6,811	6,811
2002 Jul 8, 23	Ph	0	0	4,825	0	1,496	1,496	214	49	6,584	6,584
2003 Jul 8	Ph	3	0	1,569	754	1,339	2,093	182	50	3,894	3,897
2004 Jul 9, 17	Ph	0	0	2,959	117	2,058	2,175	156	29	5,319	5,319
2005 Jul 10	Ph	0	0	4,757	2,505	7	2,512	195	57	7,521	7,521
2007 Jul 1,10	Ph	1	0	7,949	1,775	587	2,362	146	74	10,531	10,532
2009 Jul 6	Ph	2	0	2,096	7,229	2,973	10,202	288	106	12,692	12,694
2011 Jul 15, 16, 18	DPh	1	0	1,344	2,981	748	3,729	212	72	5,357	5,358
2012 Jul 3	DPh	2	0	2,475	931	673	1,604	166	77	4,322	4,324
2013 Jul 7	DPh	0	0	2,701	1,663	337	2,000	107	62	4,870	4,870

Table 4. Counts of California sea lions at Año Nuevo Island, South Farallon Islands, and North Farallon Islands from aerial photographic surveys conducted during 1992-2013.

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
Año Nuevo Island											
1992 Jul 08	Ph	4	0	554			1,505	179	71	2,309	2,313
1993 Jul 08	Ph	0	0	263			2,975	113	61	3,412	3,412
1994 Jul 06	Ph	1	0	82			2,696	58	59	2,895	2,896
1995 Jul 11	Ph	3	0	1761			3,490	358	96	5,705	5,708
1996 Jul 10	Ph	3	0	383			2,938	417	224	3,962	3,965
1997 Jul 10	Ph	1	0	454			7,404	277	223	8,358	8,359
1998 Jul 10	Ph	51	0	2,692			2,687	451	126	5,956	6,007
1999 Jul 09	Ph	4	0	1,010			4,925	205	61	6,201	6,205
2000 Jul 08	Ph	6	0	4,893	456	353	809	154	93	5,949	5,955
2001 Jul 14	Ph	2	0	5,704	202	1,965	2,167	517	267	8,655	8,657
2002 Jul 23	Ph	5	0	5,525	172	2,147	2,319	1,149	441	9,434	9,439
2003 Jul 08	Ph	48	0	1,077	5,451	69	5,520	196	81	6,874	6,922
2004 Jul 09	Ph	11	0	1,688	88	384	472	74	56	2,290	2,301
2005 Jul 10	Ph	11	0	2,877	927	18	945	109	60	3,991	4,002
2007 Jul 01	Ph	13	0	3,652	225	28	253	85	48	4,038	4,051
2009 Jul 07	Ph	75	1	934	7,157	564	7,721	356	102	9,113	9,188
2011 Jul 14	DPh	52	0	1,418	4,381	320	4,701	624	253	6,996	7,048
2012 Jul 03	DPh	94	0	1,162	1,301	2,226	3,527	275	151	5,115	5,209
2013 Jul 05	DPh	92	0	1,785	1,165	142	1,307	136	209	3,437	3,529
South Farallon Islands											
1995 Jul 11	Ph	11	0	1,432			2,254	211	69	3,966	3,977
1997 Jul 10	Ph	22	0	61			7,226	313	188	7,788	7,810
1998 Jul 18	Ph	55	0	1,380			7,102	1,231	281	9,994	10,049
1999 Jul 06	Ph	3	0	186			939	108	91	1,324	1,327
2000 Jul 12	Ph	4	0	761	6	427	433	250	90	1,534	1,538
2001 Jul 17	Ph	0	0	1,613	58	850	908	427	186	3,134	3,134
2002 Jul 09	Ph	29	0	2,726	49	2094	2,143	78	91	5,038	5,067
2003 Jul 14	Ph	48	0	2,186	437	2855	3,292	233	92	5,803	5,851
2004 Jul 19	Ph	10	0	2,004	47	547	594	434	218	3,250	3,260
2005 Jul 24	Ph	11	0	858	446	1129	1,575	582	414	3,429	3,440
2007 Jul 18	Ph	12	0	3,860	505	632	1,137	659	175	5,831	5,843
2009 Jul 11	Ph	71	0	1,144	4,815	830	5,645	511	145	7,445	7,516
2011 Jul 14	DPh	136	3	398	1,367	727	2,094	184	182	2,858	2,994
2012 Jul 04	DPh	174	2	1,066	963	2599	3,562	254	254	5,136	5,310
2013 Aug 06	DPh	141	0	616	2,876	844	3,720	979	343	5,658	5,799

Table 4. (Continued)

Census date	Method	Live pups	Dead pups	Juveniles	Adult females	Young males	Adult females or young males	Sub-adult males	Adult males	Non-pup total	Total live
North Farallon Islands											
1995 Jul 11	Ph	0	0	48			44	1	1	94	94
1998 Jul 18	Ph	0	0	47			53	14	0	114	114
1999 Jul 06	Ph	0	0	2			1	0	0	3	3
2000 Jul 12	Ph	0	0	27	0	13	13	2	0	42	42
2001 Jul 17	Ph	0	0	1	0	1	1	0	0	2	2
2002 Jul 09	Ph	0	0	136	0	16	16	2	0	154	154
2003 Jul 14	Ph	0	0	171	0	117	117	3	1	292	292
2004 Jul 19	Ph	0	0	51	0	21	21	17	6	95	95
2007 Jul 18	Ph	0	0	20	0	18	18	23	2	63	63
2009 Jul 11	Ph	0	0	100	93	36	129	14	5	248	248
2012 Jul 04	DPh	0	0	2	0	40	40	0	3	45	45
2013 Aug 06	DPh	0	0	1	9	16	25	7	3	36	36

Table 5. Published counts or estimates of CSL live-pups and non-pups used to estimate population trends. Date or count of live-pups enclosed within parenthesis is an estimate.

Census date	Live-pups counted (estimated maximum)	Non-pups counted	Citation
		San Miguel Island	
1964 Jun 20	1,895 (2,350)	12,456	Odell (1971)
1965 Jun 1-3		11,641	Carlisle & Aplin (1966)[a, b]
1975 Jun 27	6,236 (6,610)	12,192[c]	Bonnell et al. (1980)
1976 Jun 19	7,130 (9,269)	16,965[c]	Bonnell et al. (1980)
1976 Jun 30	6,323 (6,513)	16,474[c]	Bonnell et al. (1980)
1977 Jul 2	5,304	14,122[c]	Bonnell et al. (1980)
		San Nicolas Island	
1964 Jun 20	2,300 (2,852)	10,539[d]	Odell (1971)
1965 Jul 4-6	3,604	5,771	Peterson & Bartholomew (1967)
1968 Aug 3-4	875		Odell (1972)
1969 Jun 14-15	2,679 (4,501)	9,056	Odell (1972)
1969 Jul18-20	2,957		Odell (1972)
1970 Jul 3-4	2,271	7,522	Odell (1972)
1971 Jul 3-5	3,500	8,806[e]	Odell (1972)
1975 Jun28	3,800 (3,990)	9,649	Bonnell et al. (1980)
1976 Jun19-20	3,533 (4,381)	10,159	Bonnell et al. (1980)
1976 Jul1	2,887 (2,945)	9,430	Bonnell et al. (1980)
1977 Jul 3	3,773	11,534	Bonnell et al. (1980)
1977 Jul 26-30	3,155		Bonnell et al. (1980)
1978	(3,241 ± 592)		Lowry & Maravilla-Chavez (2005)
1979	(4,880 ±499)		Lowry & Maravilla-Chavez (2005)
1980 Jul 6	6,096	8,211	Stewart & Yochem (1984)
1981 Jul 5	6,704	9,305	Stewart & Yochem (1984)
1981 Jun 24	5,693	11,645	Heath & Francis (1983)
1982 Jun 20	6,648 (8,244)	13,680	Heath & Francis (1983)
1982 Jul 4	7,738	12,554	Stewart & Yochem (1984)
1982 Jul 12	6,805	11,035	Heath & Francis (1983)
1982 Jul 26	6,952	8,547	Heath & Francis (1983)
1983 Jun 19	3,281 (4,265)	9,535	Heath & Francis (1984)
1983 Jul 5	4,405	7,760	Heath & Francis (1984)
1983 Jul 17	4,005	5,645	Heath & Francis (1984)
1984 Jul 2	3,631	6,966	Stewart & Yochem 1986
1985 (Jul 2)	(4,524[f])		Stewart et al. (1993)
1986 (Jul 2)	(4,157[f])		Stewart et al. (1993)
1987 (Jul2)	(5,321[f])		Stewart et al. (1993)
		Santa Barbara Island	
1964 Jun 12	220 (497)	3,062	Odell (1971)
1965 Jun 1-3		1,100	Carlisle & Aplin (1966)[a, b]
1975 Jun 29	684 (711)	1,104	Bonnell et al. (1980)
1976 Jun 19-20	410 (533)	1,382	Bonnell et al. (1980)
1976 Jun 29-Jul 2	515 (530)	1,114	Bonnell et al. (1980)

Table 5. (Continued)

Census date	Live-pups counted (estimated maximum)	Non-pups counted	Citation
	Santa Barbara Island		
1976 Jul 29	582		Bonnell et al. (1980)
1976 Jul 31–Aug 3	403		Bonnell et al. (1980)
1977 Jun 30-Jul 3	349	1,200	Bonnell et al. (1980)
1977 Jul 29	492		Bonnell et al. (1980)
1978 (Jul 2)	465		Heath & Francis (1983)
1979 (Jul 2)	625		Heath & Francis (1983)
1980	(773 ± 54)		Lowry & Maravilla-Chavez (2005)
1981 (Jul 2)	730		Heath & Francis (1983)
1982 (Jul 2)	818		Heath & Francis (1983)
	San Clemente Island		
1964 Jun 12	183 (414)	3,637	Odell (1971)
1965 Jun 1-3		1,900	Carlisle & Aplin (1966)[a, b]
1975 Jun 29	608 (632)	1,239	Bonnell et al. (1980)
1976 Jun 19-20	413 (512)	1,463	Bonnell et al. (1980)
1976 Jul 31-Aug 3	438		Bonnell et al. (1980)
1977 Jul 3	351	1,067	Bonnell et al. (1980)
1978	(465 ± 38)		Lowry & Maravilla-Chavez (2005)
1979	(549 ± 31)		Lowry & Maravilla-Chavez (2005)
1980	(619 ± 34)		Lowry & Maravilla-Chavez (2005)
	Richardson Rock		
1975 Jun 27	0	131	Bonnell et al. (1980)
1976 Jun 19		368	Bonnell et al. (1980)
1976 Jun 30	3	274	Bonnell et al. (1980)
1977 Jul 2	0	305	Bonnell et al. (1980)
	Anacapa Island		
1965 Jun 1-3		0	Carlisle & Aplin (1966)
1975 Jun 27-30	0	0	Bonnell et al. (1980)
1977 Jun 30-Jul 3	0	0	Bonnell et al. (1980)
	Santa Cruz Island		
1964 Jun 20	0	89	Odell (1971)
1965 Jun 1-3		401	Carlisle & Aplin (1966) [a, b]
1975 Jun 27-30	0	25	Bonnell et al. (1980)
1976 Jun 19-20	0	212	Bonnell et al. (1980)
1976 Jun 29-Jul 2	0	239	Bonnell et al. (1980)
1977 Jun 30-Jul 3	0	185	Bonnell et al. (1980)
	Santa Rosa Island		
1964 Jun 20	0	0	Odell (1971)
1965 Jun 1-3		125	Carlisle & Aplin (1966) [a, b]
1975 Jun 27-30	0	0	Bonnell et al. (1980)
1976 Jun 29-Jul 2	0	111	Bonnell et al. (1980)
1977 Jun 30-Jul 3	0	0	Bonnell et al. (1980)

Table 5. (Continued)

Census date	Live-pups counted (estimated maximum)	Non-pups counted	Citation
	Santa Catalina Island		
1964 Jun 20	0	92	Odell (1971)
1965 Jun 1-3		35	Carlisle & Aplin (1966) [a, b]
1975 Jun 27-30	0	0	Bonnell et al. (1980)
1976 Jun 29-Jul 2	0	14	Bonnell et al. (1980)
1977 Jun 30-Jul 3	0	106	Bonnell et al. (1980)
	South Farallon Islands		
1982 July 15	2	1,836	Huber et al. (1983)
1983 July 7	2	3,494	Huber et al. (1985)
1984 July 6	1	2,297	Huber et al. (1986)
	Central California		
1980 July 1-3		4,272	Bonnell et al. (1983)
1981 June 30-July 2		7,935	Bonnell et al. (1983)
1982 June 28-30		11,208	Bonnell et al. (1983)
	Northern California		
1980 July 1-3		214	Bonnell et al. (1983)
1981 June 30-July 2		0	Bonnell et al. (1983)
1982 June 28-30		1	Bonnell et al. (1983)

[a]Counts of CSLs south of Point Conception may include Steller sea lions.

[b]Count of non-pups may contain pups.

[c]Count for Richardson Rock removed from San Miguel Island total.

[d]Non-pup total derived from sum of adult males and females/immature males.

[e]Non-pup total derived from sum of total males and females/immature males.

[f]Counts estimated by digitizing Figure 4 in Stewart et al. (1993).

Table 6. Previously published counts of live California sea lion pups at San Nicolas Island, California used to estimate corrections for survey date (see text) when live pup counts were made prior to the July 2 maximum.

Year	date	Julian day	Live-pup count	Proportion of maximum live-pup count	Source of pup count data
1982	16-May	136	6	0.001	Heath and Francis (1983)
1982	23-May	143	43	0.006	Heath and Francis (1983)
1982	6-Jun	157	1,853	0.267	Heath and Francis (1983)
1982	20-Jun	171	6,648	0.956	Heath and Francis (1983)
1982	12-Jul	193	6,805	0.979	Heath and Francis (1983)
1982	26-Jul	207	6,952	1	Heath and Francis (1983)
1983	15-May	135	2	0	Heath and Francis (1984)
1983	29-May	149	127	0.029	Heath and Francis (1984)
1983	5-Jun	156	728	0.165	Heath and Francis (1984)
1983	19-Jun	170	3,281	0.745	Heath and Francis (1984)
1983	5-Jul	186	4,405	1	Heath and Francis (1984)
1980	17-May	138	34	0.006	Stewart and Yochem (1984)
1980	8-Jun	160	1,276	0.209	Stewart and Yochem (1984)
1980	6-Jul	188	6,096	1	Stewart and Yochem (1984)
1981	16-May	136	0	0	Stewart and Yochem (1984)
1981	22-May	142	121	0.018	Stewart and Yochem (1984)
1981	12-Jun	163	3,336	0.498	Stewart and Yochem (1984)
1981	5-Jul	186	6,704	1	Stewart and Yochem (1984)
1981	11-Jul	192	6,626	0.988	Stewart and Yochem (1984)
1981	24-Jul	205	6,676	0.996	Stewart and Yochem (1984)
1982	29-May	149	274	0.035	Stewart and Yochem (1984)
1982	12-Jun	163	3,396	0.439	Stewart and Yochem (1984)
1982	4-Jul	185	7,738	1	Stewart and Yochem (1984)
1984	19-May	140	3	0.001	Stewart and Yochem (1986)
1984	10-Jun	162	631	0.174	Stewart and Yochem (1986)
1984	17-Jun	169	1,786	0.492	Stewart and Yochem (1986)
1984	2-Jul	184	3,631	1	Stewart and Yochem (1986)

Table 7. Mean percentage distribution (with standard deviation [SD]) of seven CSL age/sex class categories counted at the Main Channel Islands rookeries, Other Channel Islands, central California, and northern California from surveys conducted in 2003-2005, 2007 (pups only), and 2011-2013.

	Southern California							
	Main Channel Island Rookeries		Other Channel Islands		Central California		Northern California	
Age/sex class	Mean %	SD	Mean %	SD	Mean %	SD	Mean %	SD
Live pups	99.71	0.239	0.05	0.044	0.29	0.197	0.00	0.001
Juveniles	59.41	8.142	3.50	1.894	33.70	6.607	3.39	5.741
Adult females	87.22	7.297	2.42	1.590	10.35	6.565	0.01	0.013
Young males	50.40	15.126	2.68	1.525	42.72	14.470	4.21	2.510
Sub-adult males	82.85	6.027	1.29	0.352	15.44	6.108	0.41	0.310
Adult males	91.90	2.748	0.56	0.277	7.22	2.488	0.32	0.324
Non-pups	77.35	5.040	2.40	1.378	18.96	3.675	1.29	1.770

Table 8. Mean percentage distribution (with standard deviation [SD]) of seven CSL age/sex class categories counted at zones in central California, northern California, and at each of the Channel Islands in southern California from surveys conducted in 2003-2005, 2007 (pups only), and 2011-2013. Refer to Figure 1 for location of zones and islands (Richardson rock is 10 km northwest of Point Bennett, San Miguel Island).

Zone, Rock, or Island	Live pups		Juveniles		Adult females		Young males		Sub-adult males		Adult males		Non-pups	
	Mean %	SD	Mean %	SD	Mean %	SD	Mean %	SD	Mean %	SD	Mean %	SD	Mean %	SD
Northern CA, zone A	0.00	0.00	1.77	2.52	0.00	0.00	2.89	1.59	0.16	0.12	0.07	0.10	0.70	0.74
Northern CA, zone B	0.00	0.00	0.30	0.61	0.00	0.00	0.25	0.35	0.07	0.11	0.06	0.12	0.11	0.18
Northern CA, zone C	0.00	0.00	1.32	2.77	0.01	0.01	1.06	1.64	0.18	0.19	0.19	0.14	0.48	0.92
Central CA, zone D	0.14	0.13	6.33	5.91	1.71	1.46	18.49	8.50	7.06	4.83	3.78	1.97	4.77	2.10
Central CA, zone E	0.09	0.07	9.86	3.65	4.79	4.96	10.30	9.72	4.49	4.47	2.18	1.35	6.25	3.25
Central CA, zone F	0.01	0.01	6.69	2.35	1.21	0.66	3.66	2.81	1.19	1.21	0.42	0.33	2.69	0.49
Central CA, zone G	0.00	0.00	10.82	4.74	2.64	1.85	10.28	7.78	2.70	1.08	0.83	0.23	5.25	1.46
Richardson Rock	0.00	0.00	0.24	0.08	0.22	0.08	0.28	0.37	0.56	0.28	0.14	0.05	0.24	0.03
San Miguel Island	44.78	2.96	36.89	7.49	42.70	6.18	26.15	9.27	42.35	2.12	46.18	4.19	40.12	5.22
Santa Rosa Island	0.00	0.00	0.84	1.06	0.56	0.62	0.27	0.35	0.19	0.23	0.09	0.08	0.54	0.61
Santa Cruz Island	0.00	0.00	1.13	0.63	0.95	0.73	0.97	0.99	0.33	0.17	0.12	0.10	0.84	0.53
Anacapa Island	0.04	0.04	1.29	0.42	0.68	0.30	1.16	1.52	0.21	0.13	0.21	0.12	0.78	0.29
Santa Barbara Island	5.80	0.88	2.00	0.37	5.74	1.41	1.86	0.82	3.01	0.67	3.86	0.70	4.17	0.72
San Nicolas Island	44.71	3.49	18.34	7.78	33.54	4.44	20.94	7.46	35.31	5.82	38.78	3.73	29.22	3.91
Santa Catalina Island	0.02	0.02	0.31	0.18	0.23	0.20	0.37	0.56	0.08	0.05	0.06	0.05	0.24	0.15
San Clemente Island	4.41	0.76	1.93	0.85	5.06	0.48	1.14	0.71	2.12	0.67	3.03	0.48	3.64	0.48

Table 9. Average annual rates of increase (λ) during 1964 to 2014 predicted from (A) counts of live-pups and (B) counts of non-pups at rookeries or regions. Rates are estimated from the year coefficient of a backward-stepwise Generalized Linear Model (GLM) with Multivariate ENSO Index (MEI), Sea Level Height at Los Angeles, California harbor (SLH-LA), Pacific Decadal Oscillations (PDO), and North Pacific Gyre Oscillation (NPGO) as continuous covariates. Only significant ($p \leq 0.05$) covariates are included.

Rookery, group, or region (year data range)	N	Adjusted R^2	Effect	Coefficient	t	p-Value	95% CI for regression coefficients		Predicted λ	95% CI for λ	
							Lower	Upper		Lower	Upper
A. Live pup counts											
San Miguel Island (1964-2014)	41	0.878	Constant	-71.364	-14.935	<0.001	-81.037	-61.691			
			Year	0.041	16.909	<0.001	0.036	0.045	1.042	1.037	1.046
			SLH-LA	-2.279	-2.906	0.006	-3.866	-0.691			
San Nicolas Island (1964-2014)	39	0.841	Constant	-101.084	-12.844	<0.001	-114.523	-85.984			
			Year	0.054	13.758	<0.001	0.048	0.062	1.055	1.049	1.064
			SLH-LA	-7.830	-5.776	<0.001	-9.932	-4.090			
			NPGO	-0.115	-2.208	0.034	-0.262	-0.044			
Santa Barbara Island (1964-2014)	38	0.856	Constant	-101.084	-12.844	<0.001	-117.077	-85.09			
			Year	0.054	13.758	<0.001	0.046	0.062	1.055	1.047	1.064
			SLH-LA	-7.83	-5.776	<0.001	-10.585	-5.075			
			NPGO	-0.115	-2.208	0.034	-0.22	-0.009			
San Clemente Island (1964-2014)	38	0.905	Constant	-84.83	-16.817	<0.001	-95.070	-74.589			
			Year	0.046	18.202	<0.001	0.041	0.051	1.047	1.042	1.052
			SLH-LA	-4.633	-6.011	<0.001	-6.198	-3.068			
Año Nuevo Island (1992-2013)	19	0.739	Constant	-421.492	-7.222	<0.001	-545.219	-297.76			
			Year	0.212	7.262	<0.001	0.15	0.274	1.236	1.162	1.315
			SLH-LA	11.951	2.603	0.019	2.216	21.686			
S. Farallon Islands (1981-2013)	18	0.493	Constant	-237.021	-4.137	0.001	-358.472	-115.57			
			Year	0.120	4.185	0.001	0.059	0.181	1.127	1.061	1.198
Año Nuevo Is. + S. Farallon Islands (1995-2013)	15	0.557	Constant	-379.106	-4.118	0.001	-579.693	-178.52			
			Year	0.191	4.158	0.001	0.091	0.291	1.210	1.095	1.338
			SLH-LA	15.651	2.322	0.039	0.968	30.335			
Main Channel Islands rookeries (1964-2014)	34	0.923	Constant	-81.521	-16.992	<0.001	-91.319	-71.723			
			Year	0.046	19.13	<0.001	0.041	0.051	1.047	1.042	1.052
			SLH-LA	-5.369	-6.361	<0.001	-7.092	-3.645			
			NPGO	-0.100	-3.223	0.003	-0.164	-0.037			
U.S. population (1964-2014)	34	0.924	Constant	-81.669	-17.120	<0.001	-91.411	-71.927			
			Year	0.046	19.271	<0.001	0.041	0.051	1.047	1.042	1.052
			SLH-LA	-5.346	-6.370	<0.001	-7.059	-3.632			
			NPGO	-0.099	-3.215	0.003	-0.162	-0.036			
B. Non-pup counts											
San Miguel Island (1964-2014)	26	0.849	Constant	-46.827	-9.793	<0.001	-56.719	-36.935			
			Year	0.029	11.922	<0.001	0.024	0.034	1.029	1.024	1.035
			SLH-LA	-1.785	-2.102	0.047	-3.542	-0.028			
San Nicolas Island (1964-2014)	33	0.891	Constant	-54.591	-13.732	<0.001	-62.710	-46.472			
			Year	0.032	16.176	<0.001	0.028	0.036	1.033	1.028	1.037
			SLH-LA	-2.318	-3.079	0.004	-3.855	-0.780			

Table 9. (Cont.)

Rookery, group, or region (year data range)	N	Adjusted R^2	Effect	Coefficient	t	p-Value	95% CI for regression coefficients Lower	Upper	Predicted λ	95% CI for λ Lower	Upper
B. Non-pup counts (Cont.)											
Santa Barbara Is. (1964-2014)	31	0.575	Constant	-50.12	-5.565	<0.001	-68.539	-31.701			
			Year	0.029	6.449	<0.001	0.020	0.038	1.029	1.020	1.039
San Clemente Island (1964-2014)	39	0.498	Constant	-39.671	-3.879	<0.001	-60.412	-18.93			
			Year	0.024	4.617	<0.001	0.013	0.034	1.024	1.013	1.035
			PDO	-0.277	-3.71	0.001	-0.428	-0.126			
Main Channel Islands rookeries (1964-2014)	26	0.885	Constant	-46.782	-11.237	<0.001	-55.394	-38.17			
			Year	0.029	13.843	<0.001	0.025	0.033	1.029	1.025	1.034
			SLH-LA	-2.157	-2.916	0.008	-3.686	-0.627			
Southern California (1964-2014)	14	0.942	Constant	-45.599	-11.76	<0.001	-54.048	-37.15			
			Year	0.028	14.568	<0.001	0.024	0.033	1.028	1.024	1.034
Other Channel Is. (1964-2014)	14	0.647	Constant	-120.165	-4.71	0.001	-175.751	-64.579			
			Year	0.064	4.978	<0.001	0.036	0.092	1.066	1.037	1.096
Año Nuevo Island (1992-2013)	19	0.197	Constant	20.46	0.6	0.557	-51.884	92.803			
			Year	-0.006	-0.351	0.730	-0.042	0.030	0.994	0.959	1.030
			NPGO	0.204	2.312	0.034	0.017	0.392			
S. Farallon Islands (1982-2013)	18	0.459	Constant	-58.83	-2.641	0.019	-106.31	-11.35			
			Year	0.034	3.010	0.009	0.010	0.057	1.035	1.010	1.059
			MEI	0.403	3.459	0.004	0.155	0.652			
Año Nuevo Island + S. Farallon Is. (1995-2013)	15	0	Constant	23.312	0.729	0.479	-45.794	92.418			
			Year	-0.007	-0.440	0.667	-0.042	0.027	0.993	0.959	1.027
Central California (1980-2013)	16	0.603	Constant	-65.962	-4.251	0.001	-99.244	-32.681			
			Year	0.038	4.878	<0.001	0.021	0.054	1.039	1.021	1.055
N. California (1980-2013)	15	0.340	Constant	-284.712	-2.808	0.015	-503.748	-65.677			
			Year	0.145	2.866	0.013	0.036	0.255	1.156	1.037	1.290
Central + North. California (1980-2013)	15	0.556	Constant	-67.063	-3.754	0.002	-105.653	-28.474			
			Year	0.038	4.301	0.001	0.019	0.058	1.039	1.019	1.060

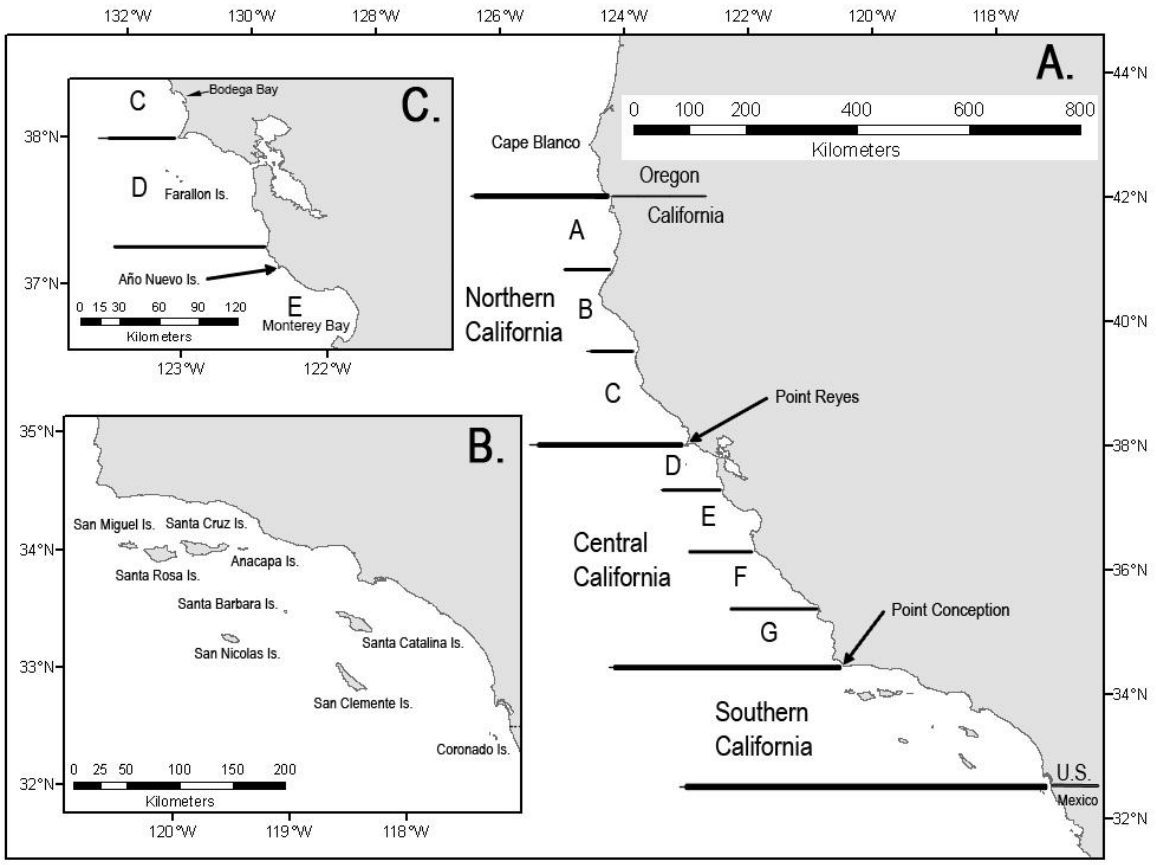

Figure 1. A. Map of California shoreline showing *a posteriori* strata of the coastline comprised of three sections (southern, central, and northern) and zones A through G within central and northern California. B. Map of Southern California strata showing names and location of California Channel Islands. Most of the U.S. population of CSL breeds at rookeries on San Clemente, San Nicolas, Santa Barbara and San Miguel Islands. C. Map of coastline from Monterey Bay to Bodega Bay showing location of northernmost CSL rookeries at Año Nuevo Island and the Farallon Islands.

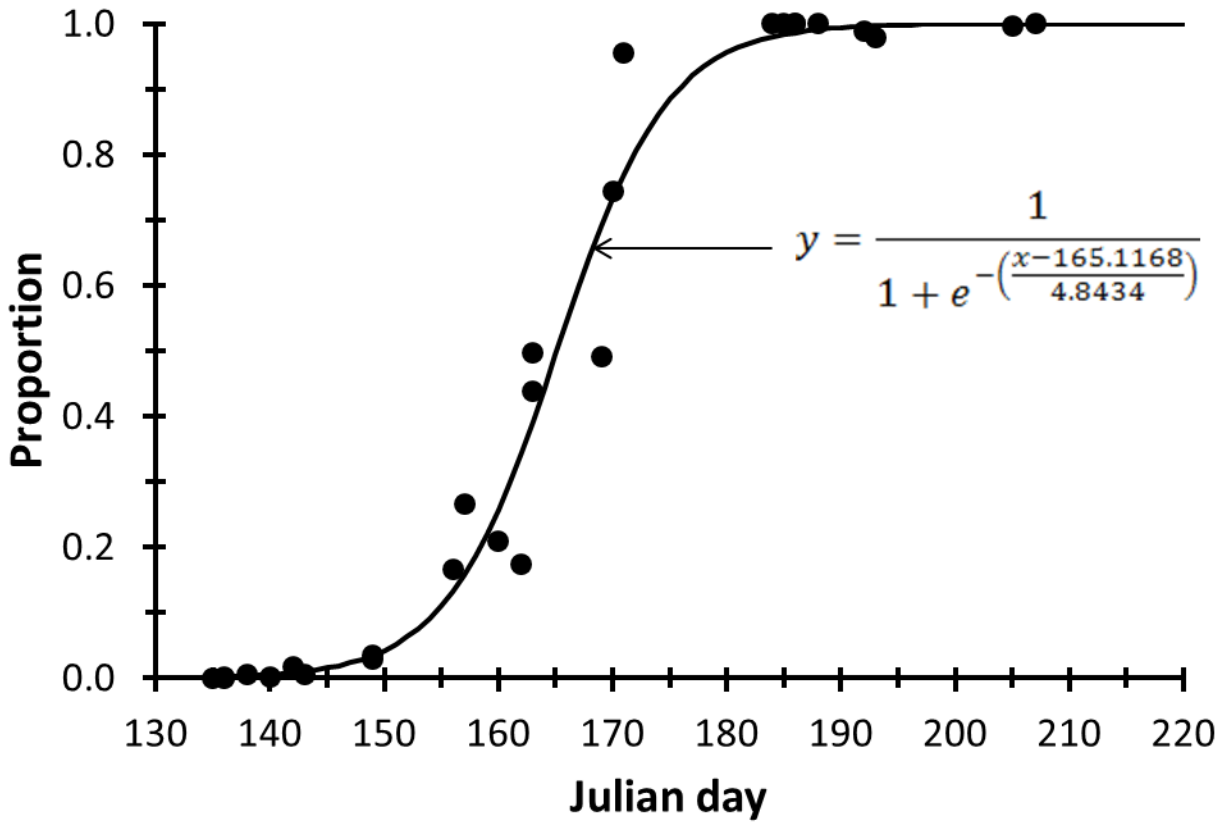

Figure 2. Cumulative proportion of live pups counted for each Julian day that a count was made. Logistic equation (black line) is fit to published data (black circles) of live-pup counts made at San Nicolas during the breeding season (data from Heath and Francis 1983, 1984, Stewart and Yochem 1984, 1986). The logistic curve is parameterized to estimate the expected proportion of pups that would be counted on July 2 (Julian day 183).

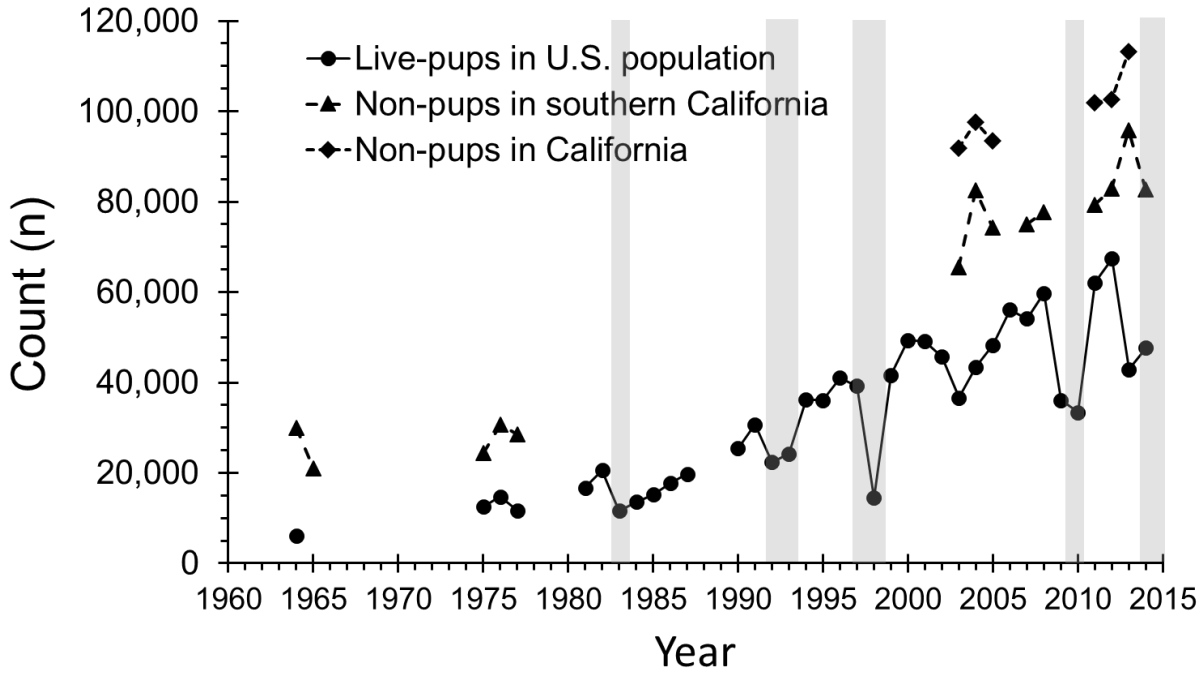

Figure 3. Counts of CSL live-pups in the U.S. population, and counts of non-pups in southern California and total for California (southern California mainland not surveyed) for surveys conducted during 1964-2014. Grey bars indicate moderate or strong El Niño conditions based on SLH-LA. Gaps represent years when no counts were available.

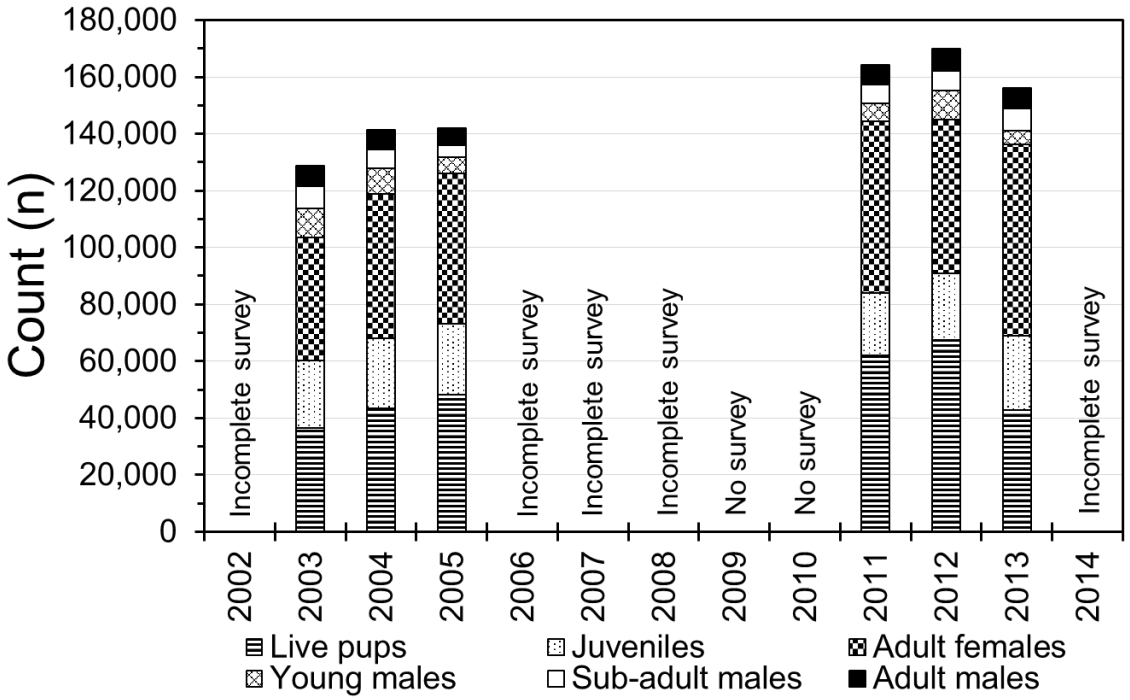

Figure 4. Total of CSL age/sex class counts from complete surveys conducted in southern California, central California, and northern California during non-consecutive years, July 2002-2014.

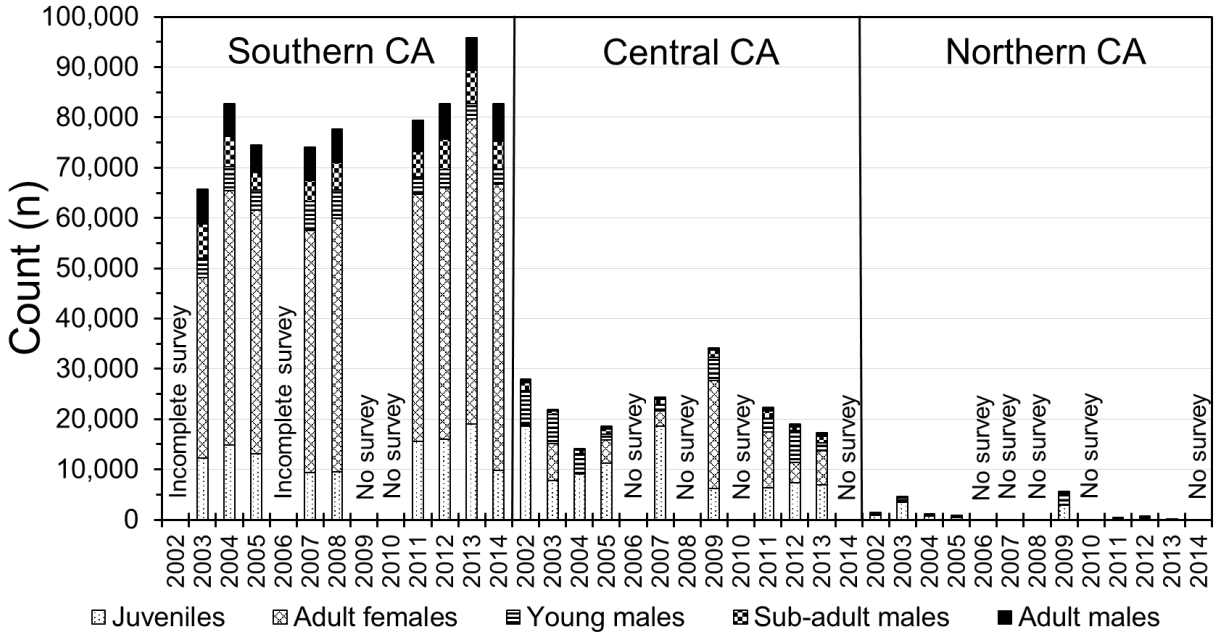

Figure 5. Total of CSL age/sex classes of non-pups counted in southern California (CA), central California, and northern California during surveys conducted in non-consecutive years, July 2002-2014.

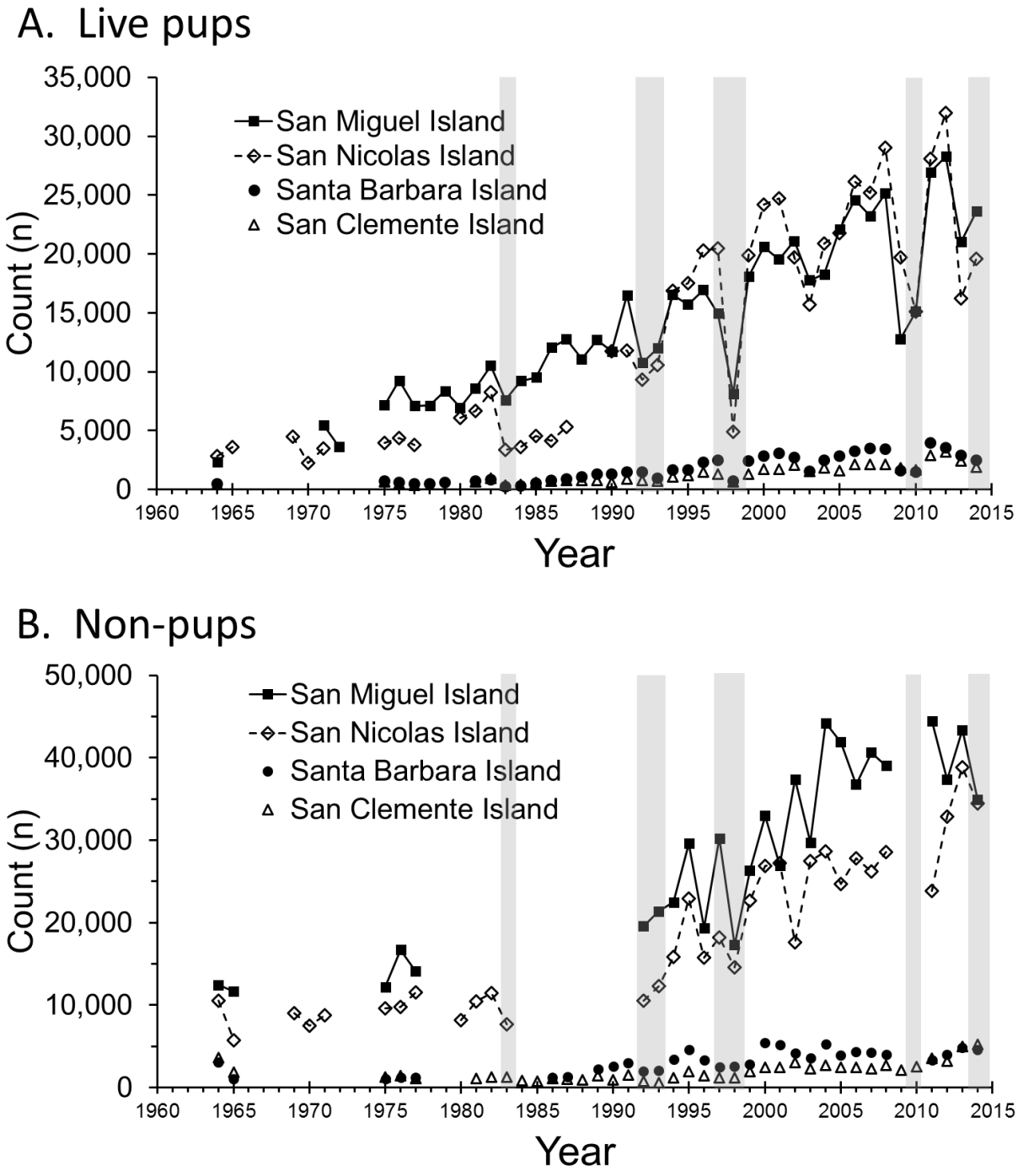

Figure 6. (A) CSL counts of live-pups and (B) counts of CSL non-pups at each of the four Main Channel Islands rookeries in southern California during 1964-2014. Grey bars indicate moderate or strong El Niño conditions based on SLH-LA. Gaps represent years when no counts were available.

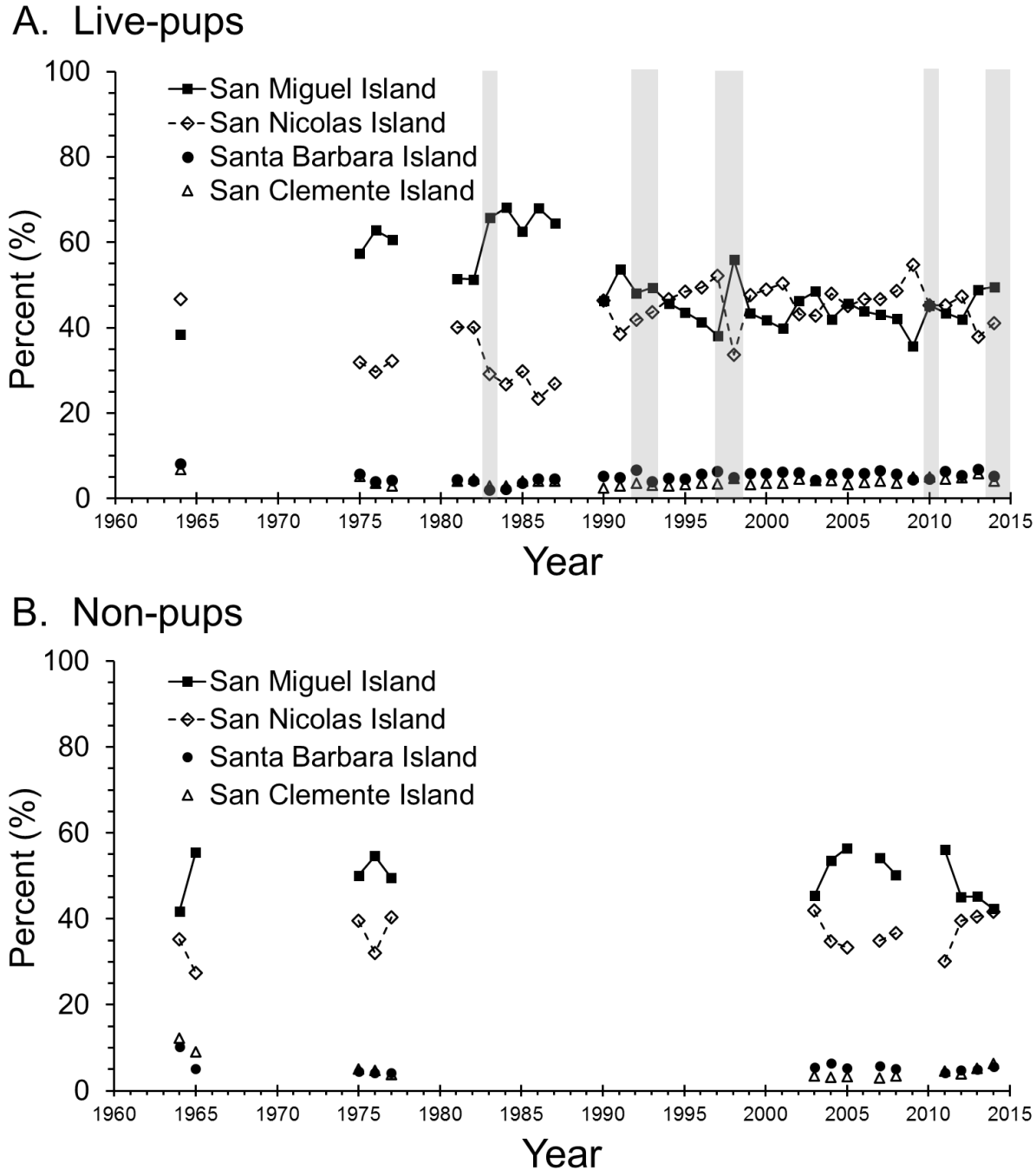

Figure 7. (A) Percentage distribution of CSL counts of live-pups and (B) counts of non-pups at each of the Main Channel Islands rookeries in southern California during 1964-2014. Grey bars in panel (A) indicate moderate or strong El Niño conditions based on SLH-LA. Gaps represent years when no counts were available.

Appendix 1. California sea lion pup calculation for the U. S. stock in 2009-2010

Total California sea lion (CSL) pup counts for the U.S. population were not available for 2009 and 2010, but a complete ground count was available for San Miguel Island (SMI) and a partial ground count was available for San Nicolas Island (SNI). The partial ground counts at SNI were obtained within the SNI trend study area (Figure A1). To expand the partial count from the SNI trend study area to a total island count, aerial photo count data at SNI for the years 1990, 1992-2008, and 2011-2013 was used (Table 3). For each year the proportion of pups in the trend study areas was computed from aerial photographic surveys (Table A1). A temporal trend with a cubic polynomial was fitted to the proportions with a log-link and a normal error distribution (Figure A2). With the predicted proportions from the regression for 2009 and 2010, the partial ground count was expanded to a total island count for SNI for those years. The SNI estimated total count was then added to the SMI ground count (Table A2). With the aerial survey data, the total U.S. count was regressed against the count at SMI and SNI to provide a correction factor to expand the total from SMI and SNI to the total U.S. pup count (Figure A3, Table A2).

Table A1. Aerial survey counts of California sea lion pups from 1990, 1992-2008, and 2011-2013 at San Nicolas Island. Counts are for the entire island and for the SNI trend study area. The proportion of the count in the SNI trend study area is also shown. Multiple counts were available for some years.

Year	SNI Trend study area	U.S. Total	Proportion
1990	9,765	10,683	0.914
1990	10,361	11,766	0.881
1992	7,268	8,869	0.819
1992	7,617	9,348	0.815
1993	8,463	10,595	0.799
1993	8,315	10,538	0.789
1993	7,920	9,702	0.816
1993	8,366	10,409	0.804
1993	7,831	9,698	0.807
1993	8,285	10,345	0.801
1994	11,079	15,766	0.703
1994	11,885	16,889	0.704
1995	11,395	17,512	0.651
1995	11,218	16,926	0.663
1996	11,264	19,308	0.583
1996	11,841	20,285	0.584
1997	11,951	20,488	0.583
1998	2,373	4,885	0.486
1999	9,882	19,878	0.497
2000	11,323	24,167	0.469
2001	11,023	24,741	0.446
2002	8,717	19,719	0.442
2003	6,568	15,702	0.418
2004	8,167	20,866	0.391
2005	8,072	21,799	0.370
2006	9,232	26,154	0.353
2007	8,962	25,198	0.356
2008	10,134	29,052	0.349
2011	9,075	28,087	0.323
2012	10,399	31,972	0.325
2013	4,569	16,225	0.282
2014	5,676	19,587	0.290

Table A2. Ground count of California sea lion pups at San Miguel Island, estimated number of pups at San Nicolas Island from partial ground count and estimate of total number of pups in U.S. waters for 2009-2010.

Year	SMI Ground Count	SNI Estimate	U.S. Total Estimate
2009	12,806	19,697	35,913
2010	15,131	15,554	33,873

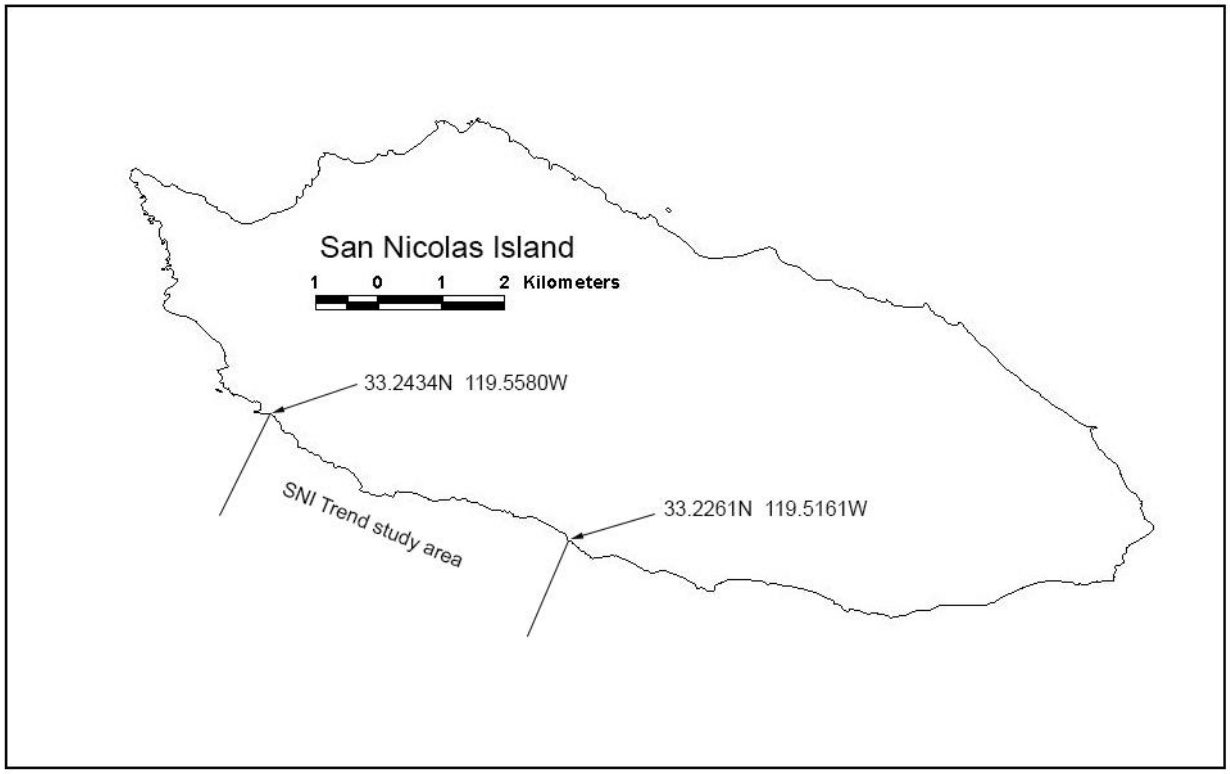

Figure A1. Location of SNI Trend study area for monitoring California sea lion pup production at San Nicolas Island, California.

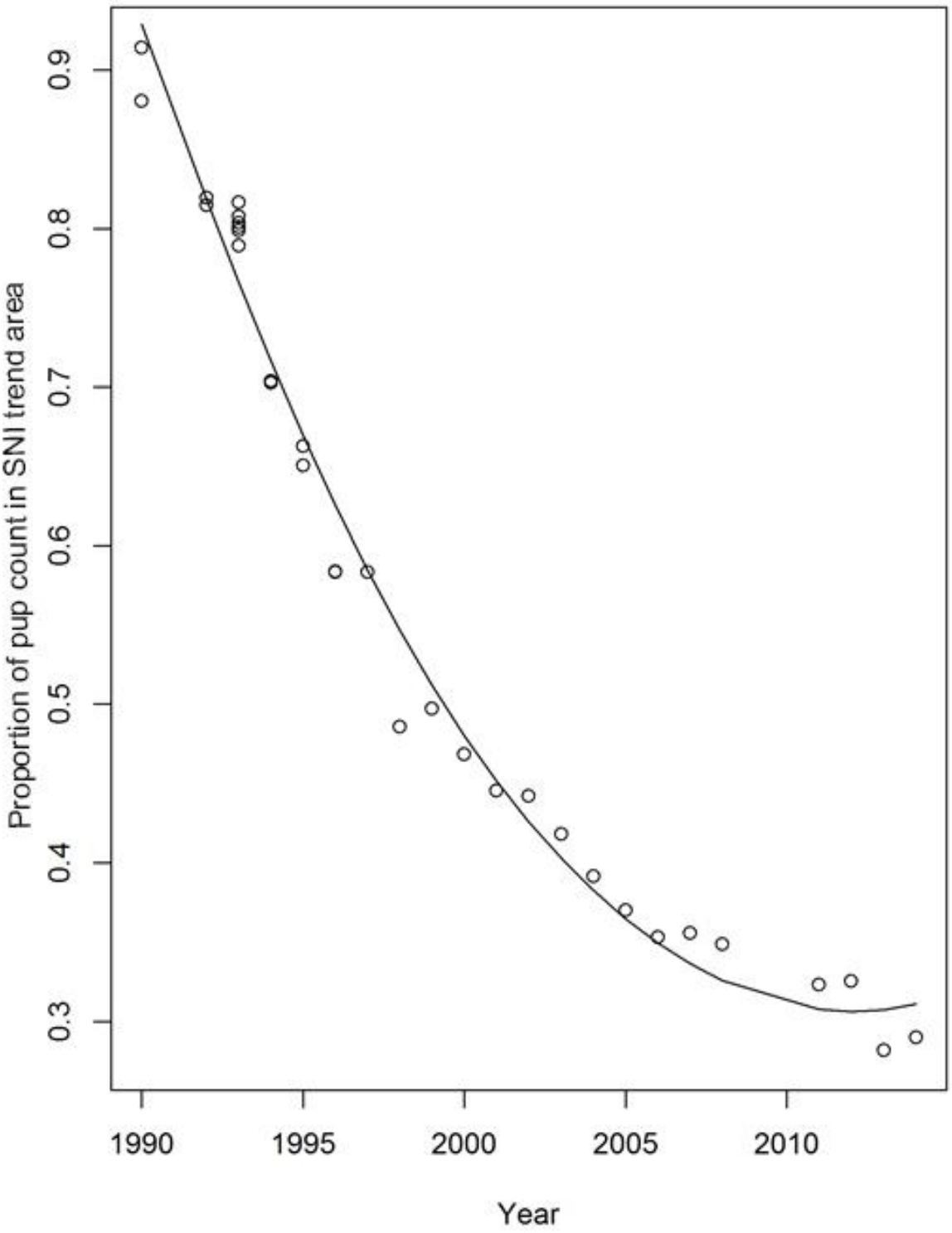

Figure A2. Proportion of California sea lion pup counts in SNI trend area and the fitted cubic polynomial.

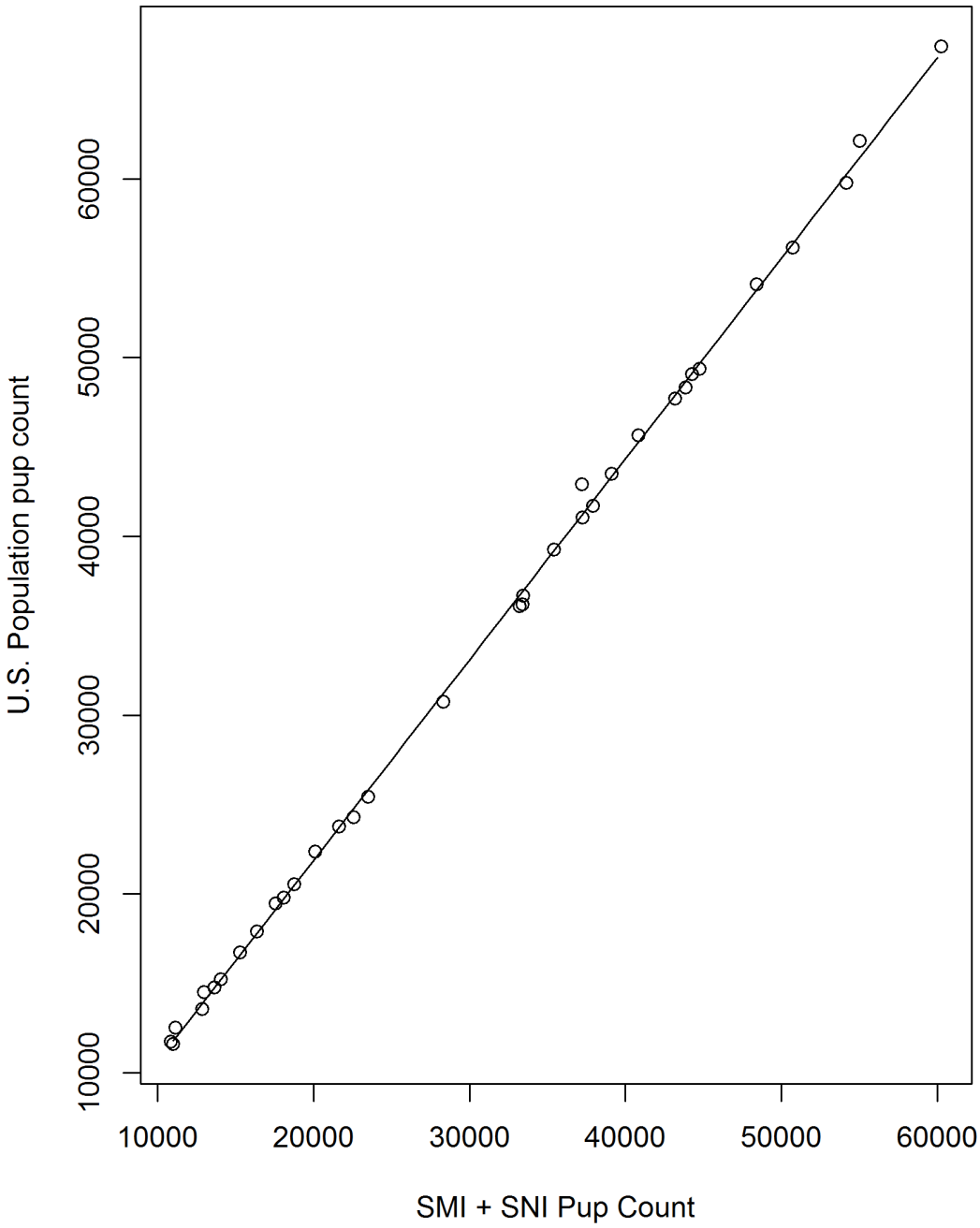

Figure A3. Linear regression of total U.S. pup count against total of San Miguel Island and San Nicolas Island pup counts.