RECENT ABUNDANCE OF CALIFORNIA SEA LIONS IN WESTERN BAJA CALIFORNIA, MEXICO AND THE UNITED STATES

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Abstract—Counts of California sea lions (*Zalophus californianus*) were obtained during the end of the breeding season in western Baja California, Mexico and in the U.S. Eight surveys were conducted at islands in western Baja California during 1989–2000; nine surveys were conducted at four of the Channel Islands in the Southern California Bight (SCB) during 1992–2000; and three surveys were conducted along the coastline and islands in central and northern California during 1998–2000. Sea lions were counted by biologists on the ground or in small vessels and from 126-mm-format aerial color photographs. During the 2000 census, 32,279 sea lions (13,611 pups) were counted at ten rookeries in western Baja California, 120,757 (49,335 pups) were counted at four rookeries in the SCB, and 17,546 (10 pups) were counted in central and northern California. Counts of pups since 1975 and of all age/sex classes since 1927 (obtained from the literature and from these surveys) were used to estimate average annual growth rates and population abundance. Declines in pup production occurred during 1992 in western Baja California (not all years were surveyed) and during 1983, 1992–93, and 1998 in the U.S., all of which corresponded to El Niño periods. The average annual population growth rate derived from counts of sea lion pups in western Baja California using two methods was estimated to be 0.4% or 3.2% and in the U.S. it was estimated to be 5.8% or 6.1%. In 2000, the western Baja California population was estimated to be 75,000 to 87,000 individuals and the U.S. population was estimated to be 238,000 to 241,000 individuals.

Keywords: abundance, California sea lion, growth rate, Mexico, population estimate, United States, Zalophus californianus

INTRODUCTION

The California sea lion (*Zalophus californianus*) population in Mexico and the U.S. was severely reduced by harvests conducted in the 19th century (Cass 1985). California sea lion abundance estimates in the U.S. have been updated periodically in recent years (Boveng 1988, Barlow et al. 1995, Forney et al. 2000), but the population in Mexico has been less well documented (Le Boeuf et al. 1983, Aurioles-Gamboa and Zavala-Gonzalez 1994). In 2000, California sea lions were counted during the end of the pupping season at major rookeries in western Baja California, Mexico and at all rookeries and at most haulout sites in California, U.S. to estimate abundance of this species in each region for that year. Data collected in 2000 were augmented with census data obtained from the literature, from other researchers, and from previous surveys we conducted to estimate the average annual growth rate in each region. In this report, we estimate average annual growth rate for the population in western Baja California and the U.S. and provide an estimate of total abundance of California sea lions in each of those regions for the 2000 breeding season.

MATERIALS AND METHODS

Counts

California sea lions were counted at, or near, the end of the breeding season in July or early August. In western Baja California, Mexico, sea lions were counted at Islas los Coronados, Isla San

Jeronimo, Isla Cedros, Piedra Colorada (off the southwestern corner of Isla Cedros), Isla Benito del Este, Isla Benito del Centro, Isla Benito del Oeste, Isla Natividad, Isla Asuncion, and Isla Santa Margarita (Fig. 1). In the U.S., sea lions were counted at Santa Barbara, San Clemente, San Miguel, and San Nicolas islands, located in the Southern California Bight (SCB; Fig. 1), and at sites located between Point Conception and the California-Oregon border. Henceforth, we will use the term rookery-island to denote islands having pups. The SCB includes the body of water between Point Conception to south of the U.S./Mexico border, but for this report we used the U.S./Mexico border as the southern limit (which excludes Islas los Coronados). Sea lion counts were obtained for five age/sex class categories: (1) pups, (2) juveniles, (3) adult females or young males of similar size, (4) subadult males, and (5) adult males. Age/sex class distinctions were subjectively determined based on size and other external characteristics (e.g., hair color on head, presence of sagittal crest, chest size, fore flipper width, snout shape, overall size, and body coloration). For some years only pups, adult males, and non-pups were counted. Replicate counts were made for some years by the same person or by different persons. For this report we only give counts of pups and the total count of all age/sex classes.

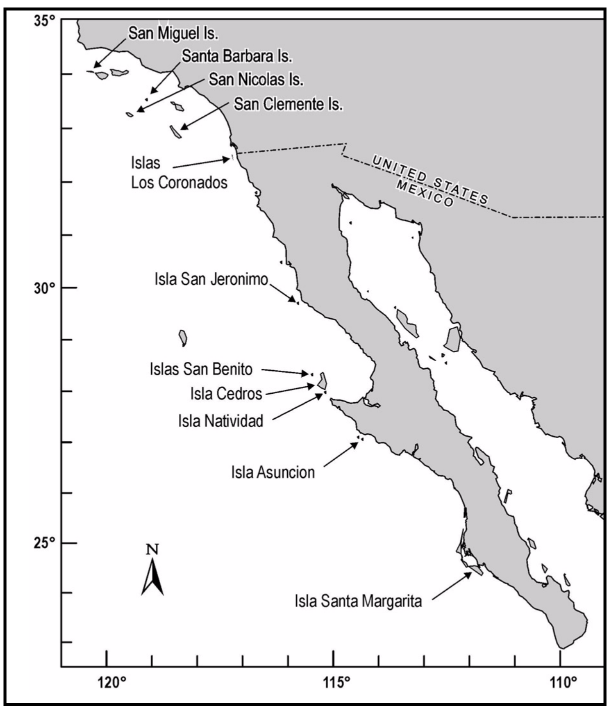

Figure 1. Names and locations of California sea lion rookery-islands in the U.S. and along the western side of the Baja California Peninsula, Mexico used in this study. Isla Benito del Este, Isla Benito del Centro and Isla Benito del Oeste make up Islas San Benito; Piedra Colorada at Isla Cedros is located on the southwestern point of the island; the rookery at Isla Cedros is located on the northern end of the island (sea lions are found in portions of the eastern, northern, and western sides of that region).

Ground And Small Boat Surveys

Biologists conducting ground and small boat surveys in Baja California, Mexico were transported by a Mexican naval vessel to islands inhabited by sea lions during 1992, 1993, 1995, and 1997. A small boat was then used as a platform to count sea lions from approximately 10 to 30 m from shore or, when possible, biologists disembarked from the small boat to count sea lions from the ground. In the U.S., biologists conducted ground surveys at Santa Barbara Island during 1983–1998, San Clemente Island during 1981–2000, and San Nicolas Island during 1991–1994 after being transported there by either chartered aircraft or by chartered vessel. Sea lions were tallied with mechanical hand-counters while being observed unaided, or through hand-held binoculars or a tripod-mounted spotting scope.

Aerial Photographic Surveys

Aerial photographic surveys in western Baja California, Mexico were conducted with a Hughes 500D helicopter, carried aboard the NOAA Ship *David Starr Jordan*, during 1989–90, 1992–93, 1999–2000. Photographic surveys in the U.S. were conducted with a twin-engine, Partenavia PN68C or PN68-observer model aircraft at Santa Barbara Island during 1998–2000, San Clemente Island during 1998–2000, San Miguel Island during 1987–1990 and 1992–2000, and San Nicolas Island during 1990 and 1992–2000 (Lowry 1999). The Hughes 500D helicopter was flown at an airspeed of 111 km/h, and the Partenavia fixed-wing aircraft was flown at an airspeed of 185 km/h. Surveys were made without regard to tidal conditions at any time of day between approximately two hours after sunrise and two hours before sunset.

Sea lions were photographed with a 126-mm-format Chicago Aerial Industries, Inc. KA-45A or KA-76 camera equipped with image motion compensation and operated at a cycle rate that achieved 67% overlap between adjacent frames. The camera was carried externally under the belly of the helicopter, or internally in the belly of the fixed-wing aircraft. The aircraft was flown at an altitude of 213 m for low-altitude photography and 396 m for higher level photography to prevent disturbance to nesting seabirds. A 152-mm focal-length lens was used for low-altitude (213 m) photography and a 305-mm focal–length lens was used for higher-altitude (396 m) photography. At these altitudes, California sea lions could be detected on rocky substrates, and different age/sex classes could be distinguished and accurately counted from aerial photographs (Lowry 1999). Multiple photographic passes were made over large rocks or islands to ensure that the entire rock or island was photographed. The geographical position of each photograph was recorded by linking the camera to a computer and Global Positioning System (GPS). We used Kodak Aerochrome MS Film 2448, a very fine-grained, medium-speed, color transparency film, or Aerochrome HS Film SO-359, a very fine-grained, high-speed, color transparency film. The camera was set at an aperture of f/5.6 with a shutter speed between 1/400 and 1/3,000 second.

Sea lions in photographs were counted using a 7-30X binocular microscope as the color transparency photograph was illuminated on a light table. Animals of each age/sex class were marked on a clear acetate plastic overlay with different colored pens as each was counted. Marks on the acetate were compared and verified with overlapping photographs, allowing the counter to view each animal from two additional angles for verification purposes. Counts from the photographs were made by one of the authors (M. Lowry).

Estimates for Missing Count Data

Counts of sea lions at some rookery-islands were not always obtained during surveys due to unfavorable weather and sea state conditions or due to camera malfunctions. In addition, in some years no count data were available in the literature. Counts of pups from rookery-islands not counted were estimated from multiple linear regressions derived from counts of pups obtained at neighboring rookery-islands using Systat 6.0 for Windows (SPSS Inc., Chicago, IL). Estimates were made for uncounted rookery-islands only for years that counts at other rookery-islands were available. For western Baja California, missing survey data were estimated from counts obtained at Isla Benito del Centro and Isla Benito del Este (Table 1). For the U.S., missing survey data were estimated from a combination of two of the four rookery-islands located in the SCB (Table 1). We estimated pup counts for those not counted by the multiple linear regression equation

$$\hat{Y}_j = a + b_{Y1}(X_1) + b_{Y2}(X_2) \qquad (1)$$

where Y_j is the estimated number of sea lion pups at rookery-island *j*, *a* is the constant, b_{Y1} is the partial regression coefficient (i.e., slope) of independent variable X_1, X_1 is the count of pups for neighboring rookery-island #1, b_{Y2} is the partial regression coefficient (i.e., slope) of independent variable X_2, and X_2 is the count of pups for neighboring rookery-island #2 (see Table 1).

Population Growth Rates And Trends

Counts of California sea lion pups made during late June through August 1975–2000 were compiled from the literature (Bonnell et al. 1980, DeMaster et al. 1982, Heath and Francis 1983, Huber et al. 1983, 1985, 1986, Le Boeuf et al. 1983, Stewart and Yochem 1984, Stewart and Yochem 1986, Lowry et al. 1987, Oliver and Lowry 1987, Oliver et al. 1988, Wexler and Oliver 1988, Francis and Heath 1991, Oliver and Wexler 1991, Oliver 1991a, 1991b, Stewart et al. 1993, Maravilla-Chavez et al. 1997, DeLong and Melin 2000, Lowry 1999, Carretta et al. 2000, Melin 2002), from unpublished sources (B. Stewart pers. comm. 12 June 2003), and from data collected during our July–August surveys. As mentioned previously, the number of pups at each rookery-island was estimated, when counts were unavailable, and the mean was used when two or more counts were available within the same year at the same rookery-island. For each region, the sum of yearly pup counts and estimates was used to examine trends and calculate average annual growth rates from the natural logarithm of the sums of pup counts for each region. Each growth rate excludes El Niño years (1992 and 1993 for western Baja California and 1983, 1984, 1992, 1993, and

Table 1. Values used in multiple regression equations for estimating number of California sea lion pups at rookery-islands that were not censused in western Baja California, Mexico and the U.S. from counts of pups at rookery-islands that were censused that year. R^2 and number of samples (n) used to derive the equation are provided for each equation.

Dependent variable (Y)	Constant (a)	Neighboring rookery-island[a] #1 (X_1)	Partial regression coefficient for variable X_1 (b_{Y1})	Neighboring rookery-island[a] #2 (X_2)	Partial regression coefficient for variable X_2 (b_{Y2})	R^2	Number of samples (n)
Islas los Coronados	6.922	IBE	0.036	IBC	0.008	0.841	7
Isla San Jeronimo	25.636	IBE	0.014	IBC	-0.018	0.429	7
Isla Cedros	413.670	IBE	1.084	IBC	0.301	0.865	6
Piedra Colorada, Isla Cedros	-6.368	IBE	0.236	IBC	-0.021	0.963	5
Isla Benito del Oeste	-12.309	IBE	0.044	IBC	0.097	0.807	6
Isla Natividad	450.433	IBE	0.940	IBC	0.010	0.841	6
Isla Asuncion	706.957	IBE	0.059	IBC	0.369	0.824	7
Isla Santa Margarita	1296.096	IBE	0.965	IBC	-0.387	0.538	5
Santa Barbara Island	-80.709	SMI	0.032	SNI	0.090	0.933	21
San Clemente Island	131.851	SMI	0.029	SBI	0.274	0.891	23
San Clemente Island	114.935	SMI	0.037	SNI	0.026	0.873	21
San Nicolas Island	-2905.816	SBI	6.394	SMI	0.447	0.940	21

[a] IBE = Isla Benito del Este; IBC = Isla Benito del Centro; SMI = San Miguel Island; SBI = Santa Barbara Island; SNI = San Nicolas Island.

1998 for U.S.) because they do not reflect optimum pup production. Counts of all age/sex classes of sea lions at rookeries in the SCB from our surveys and from Bonnot and Ripley (1948), Bartholomew and Boolootian (1960), Ripley et al. (1962), Carlisle and Aplin (1966, 1971), Frey and Aplin (1970), Odell (1971), and Bonnell et al. (1980) were used also to estimate the average annual growth rate of the U.S. California sea lion population since 1927.

Abundance Estimates

Pup mortality studies conducted prior to the late breeding-season pup count (which occurs during mid-to-late July) showed that 10 to 18% of pups died before the count was taken at San Nicolas Island and that 15 to 33% of pups born died before the count was taken at San Miguel Island (Stewart and Yochem 1986, Francis and Heath 1991, Melin 2002), indicating that mortality varies among years and sites. We have assumed that the sex ratio at birth is 1:1 and that 15% pre-census mortality rate represents a typical year and site.

Population size was then estimated using methodology developed by Boveng (1988) which predicts the proportion of newborn pups represented in a population with stable age distribution using a hypothetical survivorship schedule and an estimated annual factor of increase. Because survivorship schedules for California sea lions were unknown, Boveng (1988) developed a life table for sea lions by scaling the survivorship schedule (Smith and Polacheck 1981) of female northern fur seal (*Callorhinus ursinus*) by estimates of longevity for California sea lions using the method of Barlow and Boveng (1991). The stable age distribution (C_x) for a population of California sea lions with assumed survivorship schedules (l_x; Boveng 1988) was then computed for each estimated annual factor of increase (i.e., average annual growth rate from counts of pups in each region) using the equation in Boveng (1988)

$$C_x = \frac{l_x \lambda^{-x}}{\sum_{y=1}^{\omega} l_y \lambda^{-y}} \qquad (2)$$

where C_x is the stable age distribution (fraction of a population in age class x), l_x is the assumed survivorship schedule (see Appendix 1), x is the age class (years), λ is the annual factor of increase, and y represents all age/sex classes.

RESULTS

Baja California, Mexico

A total count of pups for ten western Baja California rookery-islands was obtained for two of nine years since 1979 (Table 2). Multiple linear regressions used for estimating number of pups at rookeries not counted had low R^2 values for Isla San Jeronimo and Isla Santa Margarita (0.429 and 0.538, respectively), and high R^2 values (0.807 to 0.963) for all other rookeries (Table 1). Average annual growth rates were calculated from the total of pup counts and estimates for all island-rookeries in western Baja California, excluding those from Isla San Jeronimo and Isla Santa Margarita because of low R^2 values in their multiple regression equation used to estimate number of pups. By regressing year with the natural logarithm of the total number of pups for rookery-islands having high R^2 values in their multiple regression equation, two average annual population growth rates were calculated for western Baja California sea lions: (1) 0.4% during 1979–2000 (slope = 0.004, SE = 0.012, df = 5, R^2 = 0.020), and (2) 3.2% during 1989–2000 (slope = 0.031, SE = 0.019, df = 4, R^2 = 0.389). The 1979–2000 rate includes all data available and is heavily influenced by the 1979 count, as it was ten years before the next count. The 1989–2000 rate includes only data collected by the authors and may reflect current conditions because it is not influenced by the 1979 data point.

In 2000, 32,279 sea lions of all age/sex classes were counted at rookery-islands surveyed in western Baja California, Mexico. The largest number of sea lion pups counted at a rookery-island were at Isla Cedros (excluding Piedra Colorada) and Isla Benito del Centro with 2,963 and 2,956 pups counted at each island, respectively (Table 2). In 2000, 13,611 pups were counted at all rookery-islands surveyed in western Baja California, Mexico. Assuming 15% pre-census mortality, approximately 15,653 pups were born in western Baja California in 2000. With an average annual population growth rate of 3.2%, newborn pups were estimated to be 19.2% of the female population and 23.1% of the male population in 2000 (Appendix 1). Overall, pups composed 20.9% of the entire population. The inverse of the proportion of female and male pups yielded a population estimate of 75,000 individuals during peak-breeding season in 2000 for western Baja California. If the average annual growth rate is 0.4%, newborn pups were estimated to be 16.2% of the female population and 20.3% of the male population (overall, pups composed 18.0% of the entire population), and the population estimate is 87,000 individuals in 2000 for western Baja California.

U.S.A.

A total count of pups for U.S. rookeries was obtained for 23 of 26 years during 1975–2000 (Table 3). Multiple linear regressions used for estimating number of pups at rookery-islands not counted had high R^2 values (0.873 to 0.940) for all rookery-islands (Table 1). Pup numbers were estimated in 1978–1980 (Table 3). Since 1975 the number of pups in the U.S. increased to a high of 49,335 in 2000, but declines occurred in 1983, 1992–93, and 1998 during El Niño conditions. After the 1983–84 El Niño, pup counts did not return to the pre-El Niño level until four years later, whereas after the 1992–93 and 1997–98 El Niño events, pup counts returned to the pre-El Niño level the following year. Average annual growth rates were calculated from the total of pup counts and estimates of pups since 1975 by regressing year with the natural logarithm total of pups in the U.S. The average annual population growth rate from pup counts was calculated to be 6.1% (slope = 0.059, SE. = 0.003, d.f. = 19, R^2 = 0.95). A second average annual growth rate (5.8% [slope = 0.056, SE = 0.003, d.f. = 25, R^2 = 0.95]) was calculated from counts of all age/sex classes at the four rookeries in the SCB since 1927 (Fig. 2).

In 2000, 120,757 sea lions of all age/sex classes were counted at four rookery-islands in the SCB, and 17,546 were counted in central and northern California. The largest rookery-island in the U.S. was at San Nicolas Island with 24,167 pups counted, followed by San Miguel Island (20,609 pups), Santa Barbara Island (2,851 pups) and San Clemente Island (1,698 pups; Table 3). Pups were counted in central and northern California in 2000, but their numbers were insignificant (10 pups) compared to those found in the SCB (Table 3). In 2000 there were 49,335 pups counted at rookeries in the U.S. Assuming 15% pre-census mortality, there were 56,735 newborn

Table 2. California sea lion (*Zalophus californianus*) pups counted during peak-breeding season or late-breeding season at rookery-islands located in western Baja California, Mexico. Numbers enclosed in brackets are estimates derived from multiple linear regressions with ± 1 SE. Totals are the sum of counts and estimates of all rookery-islands with the sum of ± 1 SE's.

	Year								
Rookery-Island	1979[a] (*n*)	1989[b] (*n*)	1990[b] (*n*)	1992[c] (*n*)	1993[c] (*n*)	1995[c] (*n*)	1997[d] (*n*)	1999[b] (*n*)	2000[b] (*n*)
Islas Los Coronados	[60 ± 10]	[40 ± 5]	52	12	42	34	52	64	82
Isla San Jeronimo	[0 ± 10]	[9 ± 5]	0	33	3	1	0	1	0
Isla Cedros	[2,160 ± 320]	[1,499 ± 161]	2,016	741	1,276	1,835	1,456	[1,982 ± 168]	2,963
Piedra Colorada, Isla Cedros	[152 ± 30]	[108 ± 13]	[158 ±14]	74	69	[75 ± 25]	117	137	309
Isla Benito del Este	900	609	849	347	416	495	695	914	1,547
Isla Benito del Centro	2,560	1,414	1,725	801	946	1,701	2,118	1,920	2,956
Isla Benito del Oeste	283	111	274	[81 ± 44]	83	[174± 50]	[224 ± 50]	205	320
Isla Natividad	[1,322 ± 314]	[1,037 ± 105]	1,627	715	786	951	[1,125 ± 268]	1,152	1,870
Isla Asuncion	1,582	1,334	[1,394 ± 82]	[1,023 ± 126]	913	1,550	1,472	1,558	1,891
Isla Santa Margarita	1,202	[1,337 ± 135]	1,638	[1,321 ± 204]	1,341	[1,115 ± 191]	[1,147 ± 210]	1,181	1,673
Sub-total[e]	9,019 ± 674	6,152 ± 284	8,095 ± 96	3,794 ± 170	4,531	6,815 ± 75	7,259 ± 318	7,932 ± 168	11,938
Percent of subtotal estimated (%)	41.0	43.0	19.2	29.1	0	3.7	18.6	25.0	0
Total (all rookery-islands)	[10,221 ± 684]	[7,498 ± 424]	[9,733 ± 96]	[5,148 ± 374]	5,875	[7,931 ± 266]	[8,406 ± 528]	[9,114 ± 168]	13,611
Percent of total estimated (%)	36.1	53.7	15.9	47.1	0	17.2	29.7	21.8	0

[a] LeBoeuf, et al. 1983
[b] Lowry (this study)
[c] Maravilla-Chavez and Lowry (this study)
[d] Maravilla-Chavez et al. 1997
[e] all rookery-islands except Isla San Jeronimo and Isla Santa Margarita

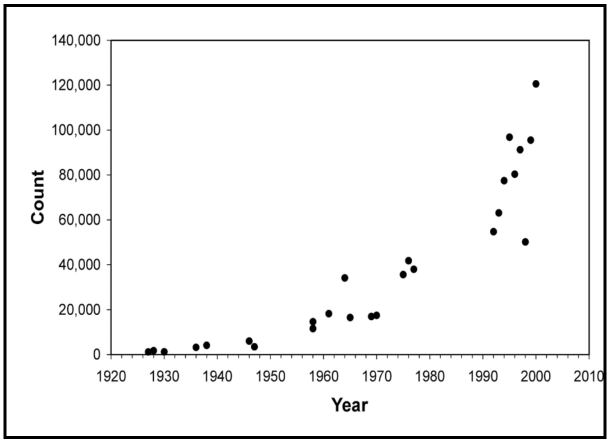

Figure 2. Counts of all age/sex classes of California sea lion made during the breeding season at Santa Barbara, San Clemente, San Miguel, and San Nicolas Islands (four rookery islands in the Southern California Bight [SCB]), U.S. Counts obtained from Bonnot and Ripley 1948, Bartholomew and Boolootian 1960, Ripley et al. 1962, Carlisle and Aplin 1966, 1971, Frey and Aplin 1970, Odell 1971, Bonnell et al. 1978, and this study.

pups in the U.S. in 2000. With an average annual growth rate of 6.1%, newborn pups were estimated to be 22.1% of the female population and 25.8% of the male population in 2000 (Appendix 1); overall, pups composed 23.8% of the entire population. The inverse of the proportion of female and male pups yielded a population estimate of 238,000 individuals during peak-breeding season in 2000 for the U.S. If the average annual growth rate is 5.8%, newborn pups were estimated to be 21.8% of the female population and 25.6% of the male population (overall, pups composed 23.5% of the entire population), and the population estimate is 241,000 individuals in 2000.

DISCUSSION

While it is obvious the population of California sea lions in the U.S. is growing, it is difficult to determine the growth rate for the population in western Baja California. The population in western Baja California appears to be recovering from the 1992–93 El Niño and did not surpass the 1979 and 1990 estimates of pups until 2000. The scarcity of data from western Baja California rookeries, as compared to data collected for rookeries in the U.S., make interpretation of growth rates difficult. Continued surveys of rookeries in western Baja California would likely result in an improved estimate of average annual growth rate for the population of California sea lions in that region.

Declines in the number of pups counted during El Niño episodes are the result of diminished food supply which compromises the ability of adult females to carry the fetus to full term, as well as to declines in their copulation rate, and increased pre-census pup mortality (Arntz et al. 1991, DeLong et al. 1991, Francis and Heath 1991, Melin 2002). Recovery in the number of pups produced after an El Niño episode is dependent on the extent that adult females experience above normal mortality (DeLong et al. 1991). In the U.S., sea lion pup production returned to the pre-El Niño level when adult females did not experience above normal mortality following the 1992–93 and 1997–98 El Niños (e.g., 1994 and 1999), but took several years (1985–1987) to recover when adult females experienced an increased mortality rate during the 1983–84 El Niño. The recovery since 1992 for western Baja California sea lions is comparable to the recovery of U.S. sea lions after the 1983–84 El Niño. Unfortunately, annual surveys were not conducted every year in western Baja California after 1993, and it is possible that adult female sea lions migrated to the U.S. or to areas in western Baja California we did not survey.

Thorough surveys of the coastline and offshore islands in Baja California are needed to verify the existence of other rookeries and to document population dispersal during El Niño periods when prey is not as abundant. The increase in pups at Isla San Jeronimo that occurred in 1992, as well as in central California during 1997–98, suggests that adult female sea lions disperse to other areas during severe El Niño periods.

Unfortunately, it is not always possible to obtain count data for all the rookery-islands in one year. Missing data was more of a problem for western Baja California rookery-islands than for U.S. rookery-islands. Although it would be possible to estimate average annual growth rates from data obtained at a few rookery-islands (e.g., Isla Benito del Este and Isla Benito del Medio in western Baja California, and San Miguel Island in the SCB), a better rate would be estimated by using combined count data from all rookery-islands in the region. High correlation values between rookery-islands in close proximity to each other (R^2 values $\geq$ 0.807 at

Table 3. California sea lion pups counted during peak-breeding season or late-breeding season at rookery-islands located at the California Channel Islands, and at various haulout sites in central and northern California, U.S. Numbers enclosed in brackets are estimates derived from multiple linear regressions with ± 1 SE. For northern and central California, data was available only for Farallon Islands in 1981–1985, Año Nuevo Island in 1992–1994 and 1996, and Año Nuevo Island and Farallon Islands in 1995 and 1997; and counts were not available (NA) for other years. Multiple counts are averaged for each island when computing the total count.

Year	Santa Barbara Island (*n*)	San Clemente Island (*n*)	San Miguel Island (*n*)	San Nicolas Island (*n*)	Northern and central California (*n*)	Total (*n*)	Percent of total estimated (%)
1975	684[a]	608[a]	7,323[b], 6,702[b], 6,236[a,b]	3,800[a]	NA	11,846	0
1976	582[a]	413[a]	7,130[b], 8,359[b], 7,808[b]	2,887[a]	NA	11,288	0
1977	493[a]	351[a]	5,304[a,b], 7,664[b], 7,162[b]	3,773[a]	NA	11,327	0
1978	465[c]	[465 ± 38]	7,268[b], 6,932[b]	[3,241 ± 592]	NA	[11,497 ± 630]	34.2
1979	625[c]	[549 ± 31]	8,710[b], 8,245[b]	[4,880 ± 499]	NA	[14,629 ± 530]	37.8
1980	[773 ± 54]	[619 ± 34]	9,275[b]	6,096[k], 6,288[b]	NA	[16,655 ± 88]	7.1
1981	730[c]	666[e]	8,937[b], 7,573[b]	6,704[c,k], 6,824[b], 5,693[l]	2[u]	16,060	0
1982	818[c]	941[e]	10,143[o]	7,738[k], 6,952[c]	NA	19,247	0
1983	237[d]	353[f]	7,393[o]	4,405[c]	2[v]	12,390	0
1984	280[d]	411[g]	9,143[o]	3,631[m], 4,360[c]	1[w]	13,830	0
1985	543[d]	609[h]	9,393[o]	4,556[n]	0[w]	15,101	0
1986	814[d]	718[i]	11,571[o]	4,317[n]	NA	17,420	0
1987	917[s]	782[i]	12,152[r], 12,807[r]	5,537[n]	NA	19,715	0
1988	1,089[s]	803[j]	11,133[r]	6,483[t]	NA	19,430	0
1989	1,307[s]	795[j]	12,704[r]	8,951[t]	NA	23,753	0
1990	1,286[s]	629[s]	11,741[r], 11,066[r]	10,683[p], 11,766[p]	NA	24,775	0
1991	1,504[s]	913[s]	15,357[o]	11,827[p]	NA	29,601	0
1992	1,470[s]	789[s]	10,753[s], 9,116[s]	8,869[p], 6,468[p], 9,348[p]	4[r]	20,426	0
1993	949[s]	745[s]	10,704[s], 11,985[s]	10,595[p], 9,262[p], 10,538[p], 9,748[p], 9,702[p], 8,382[p], 10,409[p], 8,723[p], 9,698[p], 10,345[p]	0[r]	22,779	0
1994	1,688[s]	1,067[s]	16,539[s], 17,076[y]	15,766[p], 16,889[p], 16,503[p]	1[r]	35,950	0
1995	1,647[s]	1,189[s], 1,028[s], 970[s]	15,624[s], 15,711[s], 16,751[x]	17,512[p], 16,926[p]	14[r]	35,971	0
1996	2,326[s]	1,047[s], 1,207[s], 1,040[s], 1,208[s], 1,243[s], 1,468[s]	16,962[s], 18,265[x]	19,308[p], 20,285[p]	3[r]	40,942	0
1997	2,467[s], 2,351[s], 2,095[s]	1,326[s], 1,203[s], 1,248[s]	14,941[s], 18,909[x]	20,488[p]	23[r]	40,999	0
1998	707[s], 539[s]	587[q], 600[q], 537[s], 682[s]	8,111[s], 9,277[x]	4,885[s]	121[s]	14,925	
1999	2,410[s]	1,004[q], 1,326[q]	18,074[s], 19,286[x]	19,878[s]	7[s]	42,140	0
2000	2,851[s]	1,660[s], 1,735[s]	20,609[s]	24,167[s]	10[s]	49,335	0

[a] Bonnell et al. 1980, [b] DeMaster et al.1982, [c] Francis and Heath 1991a, [d] Lowry et al. 1987, [e] Oliver and Lowry 1987, [f] Oliver et al. 1988, [g] Wexler and Oliver 1988, [h] Oliver and Wexler 1991, [i] Oliver 1991a, [j] Oliver 1991b, [k] Stewart and Yochem 1984, [l] Heath and Francis 1983, [m] Stewart and Yochem 1986, [n] Stewart et al. 1993, [o] DeLong and Melin 2000, [p] Lowry 1999, [q] Carretta et al. 2000, [r] Lowry unpubl. data, [s] Lowry (this study), [t] B. Stewart pers. comm. 11 June 2003, [u] Huber et al. 1983, [v] Huber et al. 1985, [w] Huber et al. 1986, [x] Melin 2002.

all but two rookeries) made it possible to utilize multiple linear regression analysis to estimate missing count data from counts obtained at other rookery-islands.

Counts of sea lions at rookery-islands in the SCB in 1927 indicate that only 1,229 non-pups were found at Santa Barbara, San Clemente, and San Miguel Islands (Bonnot and Ripley 1948). Since that time, censuses at the four sea lion rookery-islands in the SCB (Bonnot and Ripley 1948, Bartholomew and Boolootian, 1960, Ripley et al. 1962, Carlisle and Aplin 1966, 1971, Frey and Aplin 1970, Odell 1971, Bonnell et al. 1980, and our data) show exponential growth of the population with an average annual growth rate of 5.8% since 1927. This growth rate is quite close to the 6.1% we calculated from pup counts when El Niño years were removed from the 1975–2000 data set.

A total count of all sea lions is not possible for estimating total abundance because not all sea lions are ashore at the same time. Therefore, various correction methods have been used to extrapolate total abundance from counts of sea lions ashore. Le Boeuf et al. (1983) and Aurioles-Gamboa and Zavala-Gonzalez (1994) used correction factors on census data collected at various rookeries and haulouts. We used the method employed by Boveng (1988) that uses a life history model to estimate population size from pup counts made at the end of the breeding season. The advantage of using the life history method is that only pups at rookeries need to be counted, whereas the method used by Le Boeuf et al. (1983) and Aurioles-Gamboa and Zavala-Gonzalez (1994) requires that all rookeries and haulouts in the region be counted. The disadvantage of the life history model is that it is only applicable for estimating abundance from pup counts that are made after all pups are born (i.e., near the end of the pupping season) and it assumes a constant production rate.

Several factors could affect our population abundance estimates for 2000. First, pre-census mortality was not measured at each rookery-island or in each year, adding uncertainty to the estimate of the number of pups born. Second, the life history model, developed from female northern fur seals, may not represent the life history of California sea lions. Preliminary results of a branding study of California sea lions at San Miguel Island indicate higher survivorship for California sea lions than was reported for northern fur seals (Jeff Laake pers. comm.). If this is so, then we have underestimated abundance of sea lions in the U.S. and in western Baja California, Mexico.

Abundance estimates derived from Boveng's (1988) method (equation 2) are influenced by λ, the annual factor of increase (i.e., average annual growth rate). Population estimates increase as the growth rate decreases, making growth rate estimates a critical component of the equation. When two growth estimates are in close agreement, as for those derived for the U.S. population, abundance estimates are nearly equivalent. When two growth estimates are not in close agreement, as for those derived for the Baja California population, abundance estimates are dissimilar. The estimates for the U.S. population results in estimates (238,000 and 241,000 sea lions) being within 1% of each other, whereas those for Baja California (75,000 and 87,000) differ by 13.8%.

Le Boeuf et al. (1983) estimated that there were 145,000 sea lions in 1979–81, of which 23,200 (16%) were in the Gulf of California, 66,700 (46%) in western Baja California, 50,750 (35%) in the Southern California Bight (SCB), and 4,350 (3%) between central California and British Columbia, Canada. Although no current estimate exists for the population of sea lions in the Gulf of California, by adding the 1980's estimate of 31,000 made by Aurioles-Gamboa and Zavala-Gonzalez (1994) to our estimates, a total population estimate for sea lions in Mexico and the U.S. would be approximately 344,000 to 359,000 individuals. Of these, 9% are in the Gulf of California, 22–24% are in western Baja California, and 67–69% are in the U.S. It thus appears that the majority of the population in 2000 resides in the U.S., and that a major shift in abundance has occurred since Le Boeuf et al. (1983) made their estimates.

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Appendix 1. The estimated stable age distribution (C_x) for a population of California sea lions (*Zalophus californianus*) with assumed survivorship schedules (l_x; from Boveng [1988]) and an average annual growth rate of 0.4% and 3.2% for the western Baja California, Mexico population, and 5.8% and 6.1% for the U.S. population. Age class 1 is newborn pups.

		Females (C_x)						Males (C_x)			
		Baja California, Mexico		U.S.				Baja California, Mexico		U.S.	
Age class	l_x of ♀	0.4%	3.2%	5.8%	6.1%	Age class	l_x of ♂	0.4%	3.2%	5.8%	6.1%
1	1.000	0.162	0.192	0.218	0.221	1	1.000	0.203	0.231	0.256	0.258
2	0.702	0.113	0.130	0.145	0.146	2	0.643	0.130	0.144	0.155	0.157
3	0.534	0.086	0.096	0.104	0.105	3	0.468	0.094	0.101	0.107	0.107
4	0.431	0.069	0.075	0.079	0.080	4	0.371	0.074	0.078	0.080	0.080
5	0.365	0.058	0.062	0.064	0.064	5	0.314	0.063	0.064	0.064	0.064
6	0.320	0.051	0.052	0.053	0.053	6	0.277	0.055	0.055	0.053	0.053
7	0.289	0.046	0.046	0.045	0.045	7	0.252	0.050	0.048	0.046	0.046
8	0.266	0.042	0.041	0.039	0.039	8	0.234	0.046	0.043	0.040	0.040
9	0.248	0.039	0.037	0.035	0.034	9	0.220	0.043	0.039	0.036	0.035
10	0.235	0.037	0.034	0.031	0.030	10	0.207	0.041	0.036	0.032	0.031
11	0.223	0.035	0.031	0.028	0.027	11	0.195	0.038	0.033	0.028	0.028
12	0.213	0.033	0.029	0.025	0.025	12	0.183	0.036	0.030	0.025	0.025
13	0.204	0.032	0.027	0.023	0.022	13	0.167	0.032	0.026	0.022	0.021
14	0.195	0.030	0.025	0.021	0.020	14	0.148	0.029	0.023	0.018	0.018
15	0.185	0.028	0.023	0.018	0.018	15	0.125	0.024	0.019	0.015	0.014
16	0.174	0.027	0.021	0.016	0.016	16	0.097	0.019	0.014	0.011	0.010
17	0.161	0.025	0.019	0.014	0.014	17	0.067	0.013	0.009	0.007	0.007
18	0.145	0.022	0.016	0.012	0.012	18	0.038	0.007	0.005	0.004	0.004
19	0.127	0.019	0.014	0.010	0.010	19	0.017	0.003	0.002	0.002	0.002
20	0.107	0.016	0.011	0.008	0.008						
21	0.084	0.013	0.009	0.006	0.006						
22	0.060	0.009	0.006	0.004	0.004						
23	0.038	0.006	0.004	0.002	0.002						
24	0.021	0.003	0.002	0.001	0.001						

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