Entanglement of California sea lions, *Zalophus californianus californianus*, in fishing gear in the central-northern part of the Gulf of California, Mexico

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The range of the California sea lion, *Zalophus californianus californianus*, extends from British Columbia south to Mazatlan, Mexico, and includes the Gulf of California. The population of sea lions in Mexico has been estimated at 74,467 individuals along the Pacific coast (Lowry et al.[1]), 28,220 in the Gulf of California (Zavala, 1990). Little is known about the Pacific coast population, but there are probably 8 breeding colonies (Lowry et al., 1992). In the Gulf there are 40 rookeries: 13 breeding colonies and 27 haulouts (Zavala et al., in press). Strong tidal forces cause a constant upwelling condition in the central-northern part of the Gulf of California that sustains high nutrient and phytoplankton concentrations, especially around the Midriff Islands in the central Gulf (Alvarez-Borrego, 1983; Alvarez-Borrego and Lara-Lara, 1991). This upwelling condition allows the existence of large populations of fish, marine mammals, and marine birds.

Between the 1960's and the 1980's, the population at some breeding colonies of California sea lions in the Gulf of California increased 30% (Le Boeuf et al., 1983). During the 1980's and early 1990's, the yearly increase in those populations was between 2% (Morales, 1990; Zavala et al., in press) and 4.7% (Aurioles and Arizpe[2]). After 1991 some populations experienced a slight reduction in size and later a partial recovery (Heath et al., 1994; Zavala et al.[3]).

Since 1985, we have censused annually 10 of the 11 reproductive sea lion colonies that account for 94.9% of all sea lions in the Gulf of California (Fig. 1 in Aurioles and Zavala, 1994). In 1991 we commenced seeing more sea lions with pieces of fishing gear entangled around their head and neck than we had remembered seeing during previous years (Zavala and García[4]) and began documenting the incidence of entanglement. We report the numbers of entangled sea lions observed between 1991 and 1995 in the central-northern part of the Gulf of California and comment on the effect this may have on the conservation of the species.

Methods

Ten of 11 breeding colonies in the central-northern Gulf of California were studied (Fig. 1). Only Roca Consag (31°12'N, 114°29'W) was excluded. Between 1991 and 1995, we made eight cruises to the 10 breeding colonies: 16 Jun–19 Jul 1991, 8 Jul–4 Aug 1992, 16–25 Jun 1993, 10–29 Jul 1993, 16–25 Jun 1994, 11–20 Jul 1994, 1–4 Aug 1994, and 15–28 Jun 1995. San Jorge and El Coloradito were visited only once each year whereas Los Cantiles and San Pedro Mártir were not surveyed in 1991 and 1992, respectively. All other islands were surveyed on every trip.

All cruises were made on patrol ships of the Mexican Navy, leaving from Guaymas, Sonora. Surveys around the islands were made aboard small (7 m in length) fiberglass boats with 35–55 hp outboard motors. We cruised at about 2 knots, 30–50 m from the coast, to census the animals. They were classified as adult males, subadult males, females, juveniles, or pups (sensu LeBoeuf et al., 1983; Aurioles and Zavala, 1994).

Entanglement frequencies were calculated by dividing the total number of entangled animals (those animals with pieces of fishing gear around head and neck) by the total number of adult, subadult, and

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[3] Zavala, A., H. de la Cueva, and E. Mellink. 1991. Unpubl. data. Departamento de Ecología, Centro de Investigación Científica y Educación Superior de Ensenada, Apdo. Postal 2732, Ensenada, B.C., México.

[4] Zavala, A., and M. C. Garcia. 1991. Departamento de Ecologia, Centro de Investigación Cientifica y Educación Superior de Ensenada, Apdo. Postal 2732, Ensenada, Baha California, México. Personal obs.

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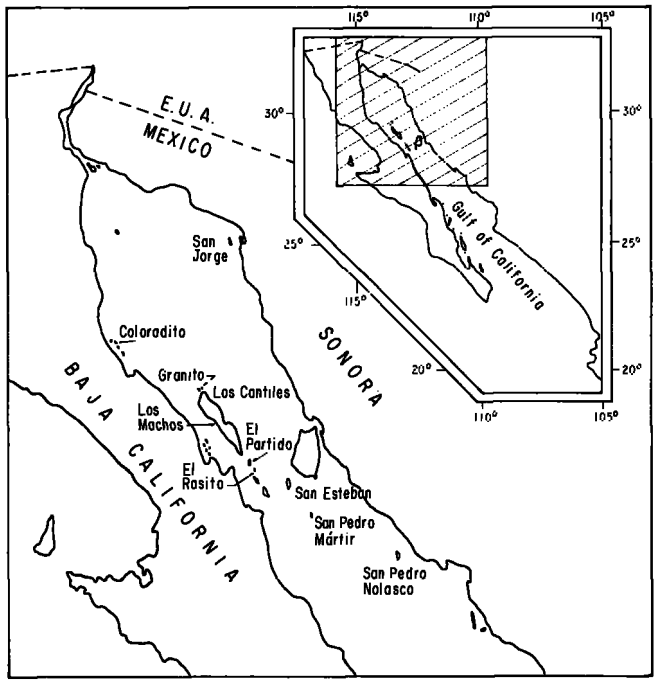

Figure 1
Central-northern Gulf of California, showing the study localities.

young animals. We excluded dead animals because time since death could not be assessed. Pups spend most of their time on land and have virtually no interaction with fishing gear during the survey periods. When we made more than one survey per year, we considered the highest rate of entanglement as the best estimator.

We used the "differences-between-proportions" test (Zar, 1974) to compare the proportions of age and sex classes between the entangled animals and the population. Differences between sea lion colonies and years were compared by using a two-factor Analysis of Variance (ANOVA) and Newman-Keuls (N-K) tests (Zar, 1974) on the basis of the number of entangled animals (adjusted by a square-root transformation) and entanglement rates (adjusted by an arcsine transformation). Variation in the number of entangled animals and in the average transformed entanglement rates over time, as well as the relationship between number of entangled animals and colony size, were analyzed with simple linear regressions (Zar, 1974).

In the two cases where we lacked data, we used the eight colonies, for which we had complete information, to calculate the relationship between the year with missing data (1991 or 1992) and the average of the remaining four years,and then used the average of the problem colony (Los Cantiles or San Pedro Mártir) to estimate the missing value. This was done in order to perform the statistical tests on a standard basis.

Types of fishing gear involved were recorded from dead entangled animals. This information was completed with records about the size and characteristics of the fishing gear used by fishermen working in the islands. Similarly, fishing gear debris found on sea lion rookeries and showing evident signs of having been associated with a sea lion (bites, sea lion fat,) was noted. We also interviewed local fishermen about their problems with sea lions.

Results and discussion

Sea lion entanglement

During the study, we counted 237 entangled animals (Table 1), 207 of which could be assigned to a particular sex and age class: 46.4% were young animals (1–3 yr), 41.5% females, 7.2% subadult males, and 4.8% adult males. The percentage of young animals among the entangled animals was statistically higher than their proportion in the censused population (25.8%, Z=6.70, P=7.13×10^{-11}), whereas that of females was lower (60.5%, Z=–5.53, P=0.913×10^{-8}). This is probably a result of young animals being more curious, less experienced, and weaker, in addition to foraging closer to the surface (senior author, personal observation [1994–95]). In other species (northern fur seals, *Callorhinus ursinus*) high rates of juvenile mortality might have caused a decrease in the population (Trites, 1992). Our data are not sufficient to establish or discard any such links. Percentages of entanglement of subadult and adult males were not different from percentages of proportion of subadult and adult males in the population (6.3%, Z=0.78, P=0.294 and 7.4%, Z=1.5, P=0.13, respectively).

Between 1991 and 1995, the number of recorded entangled sea lions for all 10 rookeries combined varied from 34 (±2.27, 95% CI) (adjusted to 36) to 72, with a low of 24 (±4.02, 95% CI) (adjusted to 27) in 1992 (Table 1). Regression analysis between number of entangled animals and year was significant (n=5, r^2=0.79, F=11.05, P=0.045). Significant differences were found only between 1992 and 1995: the other years were not different from one other (F=3.09, P=0.027).

In 1992, there were not only fewer entangled animals, but also there were fewer sites with entangled animals. This year saw the worst recent fishing season in the central Gulf according to information at the Bahía de Los Ángeles fishing office, and this finding is likely a reflection of the prevailing El Niño Southern Oscillation conditions, which had strong

Table 1

Number of entangled and total (in parentheses, including entangled) California sea lions, except pups, in 10 breeding colonies in the central-northern Gulf of California, 1991–95.

	Locations		Year				
Rookeries	Lat.	Long.	1991	1992	1993	1994	1995
San Jorge	31°01'N	113°15'W	8 (4,536)	14 (2,915)	10 (2,183)	4 (2,208)	24 (3,200)
Coloradito	30°03'N	114°29'W	4 (2,100)	2 (1,610)	7 (1,662)	3 (1,749)	13 (1,688)
Granito	29°34'N	113°33'W	2 (609)	1 (603)	6 (390)	2 (923)	4 (631)
Los Cantiles	29°32'N	113°29'W	—	1 (712)	3 (620)	1 (602)	6 (916)
Los Machos	29°18'N	113°31'W	0 (718)	0 (601)	1 (718)	4 (659)	1 (512)
El Partido	28°53'N	113°02'W	5 (463)	2 (524)	4 (798)	3 (311)	1 (402)
El Rasito	28°49'N	113°00'W	1 (353)	0 (326)	1 (101)	5 (223)	0 (198)
San Esteban	28°43'N	112°35'W	10 (4,758)	4 (3,135)	10 (2,610)	20 (3,859)	14 (3,396)
S.P. Mártir	28°23'N	112°20'W	1 (1,379)	—	11 (676)	8 (770)	7 (937)
S.P. Nolasco	27°58'N	111°23'W	3 (1,009)	0 (338)	1 (517)	3 (340)	2 (358)
Total			34 (15,925)	24 (10,764)	54 (10,275)	53 (11,644)	72 (12,238)

effects in the Gulf (Hamman et al., 1995). Entanglement rate did not exhibit any tendency through time (n=5, r^2=0.44, F=2.35, P=0.223), and the ANOVA detected only 1992 as statistically inferior to 1993 and 1994, whereas 1991 and 1995 were not different from any other year (F=4.20, P=0.007).

San Jorge and San Esteban exhibited the largest overall numbers of sea lions (>2,000 California sea lions) (Table 1); El Coloradito had intermediate values (>1500, <2200), and the other colonies ≤1400 sea lions.The ANOVA indicated that the first two sites had statistically more entangled sea lions than did El Partido, Granito, Cantiles, San Pedro Nolasco, El Rasito, and Los Machos, whereas San Pedro Mártir and El Coloradito were not different from any other site (F=7.67, P<0.001). This pattern corresponds to differences in the size of the colonies; a regression linking total number of entangled animals at each colony and size of the different colonies was highly significant (n=10, r^2=0.92, F=89.71, P<0.001).

We have no detailed records of differences in the fishing effort throughout the study area, although it seems to be larger in the Midriff region than in the northern Gulf (E. Mellink, personal obs. [1995]). The ANOVA did not show differences in the entanglement rates between colonies (F=0.64, P=0.76), and the number of incidents seemed to be more a function of the size of the colony than of local and yearly variations in fishing effort, although, as suggested by the 1992 data, these effects cannot be neglected.

Entanglement rates in our region varied between 0% and 2.24%. These values are substantially lower than the 3.9–7.9% detected in Los Islotes, Bahía de La Paz, in the southern Gulf of California (24°35'N, 110°23'W; Harcourt et al., 1994). In the latter locality, high values may have been due to the proximity of Los Islotes to a moderate-size city (La Paz, approx. 250,000 inhabitants) and to abundant sport and commercial fishing. However, our entanglement values are higher than those at California islands (0.08%, Stewart and Yochem, 1987) and, again, this could be due to differences in the intensity and type of fishing practiced.

The main fishing gear involved in sea lion entanglement in the study area were nets and, to a lesser degree, lines and ropes. The nets included monofilament, purse seine, and gill nets (with stretched mesh sizes 3", 3.2", 4,5", 5", and 8"), cotton gill nets (1.5" and 5.1" mesh size), and trammel nets (either cotton or nylon monofilament with 14" to 16" mesh size). These nets originally measure 120–180 fathoms long and 7 fathoms high. The lines involved were all nylon of different thickness and, in most cases, were found tied around the animal. In only one case did we see a hook in a sea lion's mouth, or a line coming out of it.

Most entanglement occurs during fishing, either when the net and the catch are hauled out or when a net is deployed during 24–48 hr periods. In other regions of the North Pacific, in addition to entanglement during events involving active fishing, entanglement occurs because marine mammals encounter drifting debris, especially when they are foraging or migrating (Fowler, 1987). In the central-northern Gulf of California it is rare to encounter fishing gear debris drifting in the water. Artesanal fishermen, who carry out most of the fishing in the area, cannot afford to lose nets; therefore nets are usually fixed, not drifted. When part of a net or a complete net is no longer usable, it is usually discarded in a local gar-

bage dump. When a fisherman finds a lost drifting net at sea, he takes it for his own use. Unlike other areas of the world (Croxall et al., 1990) and the southern Gulf of California (Harcourt et al., 1994), the central-northern portion of the Gulf of California did not provide evidence of sea lions entangled in nonfishing plastic debris.

Sea lion conservation

In addition to accidental entanglements reported here, there is a deliberate (although illegal) killing of sea lions in the region for baiting shark longlines. At Isla San Pedro Mártir, Thomson and Mesnick[5] found 14 sea lions entangled in a gill net in a cave about 15–20 m from a breeding site, in July 1993. They concluded that the net had been set to intentionally capture sea lions. In December 1993, about 20 sea lions were captured in a gill net in San Pedro Nolasco (El Imparcial, Hermosillo, Sonora, 25 December 1993). The fishermen involved argued that the capture had been accidental, resulting from their lack of expertise. In addition to their intentional capture, sea lions are sometimes shot with firearms because fishermen believe that they interfere with fishing gear (Delgado-Estrella et al., 1994).

Our data were limited to a single season in each year of a 5-yr span and did not include animals that died without us having seen them on the islands. However, according to our assessment, the current entanglements rate of 0.49% does not seem to pose a threat to the conservation of California sea lions in the central-northern Gulf of California. We believe, however, that entanglement should be routinely monitored and studied in further detail.

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