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The Pacific Harbor Seal's (*Phoca vitulina richardii*) Breeding Colonies in Mexico: Abundance and Distribution

Denise Lubinsky-Jinich,[1] Yolanda Schramm,[1] and Gisela Heckel[2]

[1]*Universidad Autónoma de Baja California, Carretera Transpeninsular Ensenada-Tijuana No. 3917, Fraccionamiento Playitas, 22860 Ensenada, Baja California, México*
E-mail: yschramm@uabc.edu.mx
[2]*Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Carretera Ensenada-Tijuana No. 3918, Zona Playitas, 22860 Ensenada, Baja California, México*
Current address for Denise Lubinsky-Jinich: CICESE, Carretera Ensenada-Tijuana No. 3918, Zona Playitas, 22860 Ensenada, Baja California, México

Abstract

The Pacific harbor seal (*Phoca vitulina richardii*) can be found from Japan to Baja California Sur, Mexico. In Mexico, harbor seals are found on nine islands and along part of the Baja California Peninsula coast. Information on their abundance in Mexico is scarce, although it is recognized to be low in contrast to their northern distribution. This study's objectives were to determine the distribution of harbor seals in Mexico and to estimate their minimum abundance during the pupping (winter) and molting (spring) seasons. During winter and spring 2009, we visited the islands west of the Baja California peninsula (from Asunción to Coronado, including Guadalupe Island) to photograph the harbor seal's haul-out sites from a boat. In addition, during the pupping season, we carried out one aerial survey along the coast from Ensenada, Baja California, to Asunción Bay, Baja California Sur, with the same purpose. Harbor seals in the photographs taken at the haul-out sites were counted by three independent counters; results were compared, and repeatability values > 0.95 were obtained, which represent the proportion of similarity between counters. There were harbor seal colonies from Asunción to Coronado Islands, and they were found along the coast almost continuously from Ensenada southward to 29° 32' N. Pups were found on all these islands, and we report for the first time that San Roque Island is a breeding colony. The colonies with the highest counts were San Roque, Natividad, San Jerónimo, and Cedros. During the molting season, we counted more individuals on the islands (3,785) than during the pupping season (3,138). However, the highest abundance of harbor seals was during the pupping season (4,862) when we included all the colonies on nine islands and along the coast of the Baja California Peninsula—the complete distribution in Mexico. The only previous extensive survey in Mexico was carried out from winter to spring between 1982 and 1986 on seven islands, with a total of 1,715 harbor seals reported. On the same islands, we counted 2,326 individuals in 2009, so we suggest there has been an increase in the abundance since then.

Key Words: Pacific harbor seal, *Phoca vitulina richardii*, Baja California, Mexico, abundance, distribution

Introduction

The Pacific harbor seal (*Phoca vitulina richardii*) is found from Japan to near the west-central coast of Baja California, Mexico (Committee on Taxonomy, 2014). In Mexico, the harbor seal inhabits nine islands (from north to south): Coronado, Todos Santos, San Martín, San Jerónimo, Cedros, San Benito, Natividad, San Roque, and Asunción—and can be found along part of the Baja California Peninsula coast (Gallo-Reynoso & Aurioles-Gamboa, 1984; Padilla-Villavicencio, 1990; Lubinsky-Jinich, 2010). However, there is no complete record of its distribution.

Information on the abundance of the harbor seal in Mexico is scarce (Anthony, 1925; Bartholomew & Hubbs, 1952; Kenyon & Scheffer, 1953; King, 1964; Brownell et al., 1974; Mate, 1977; Gisiner et al., 1980; LeBoeuf & Bonnell, 1980; Padilla-Villavicencio, 1990; Loya-Salinas et al., 1992; Maravilla-Chávez & Lowry, 1996; Lubinsky-Jinich, 2010). However, researchers concur that its abundance is low in Mexico in contrast to the United States and Canada (325,000 individuals) (Allen & Angliss, 2015): 47% of the population is in Alaska, 32% is in Canada (Department of Fisheries and Oceans [DFO], 2010), 12% are between Washington and Oregon, and the

remaining 9% are in California (Carretta et al., 2015). In Mexico, the most complete abundance estimation was carried out between 1982 and 1986, from the Coronado Islands to Natividad Island, with a total of 1,715 individuals reported (Padilla-Villavicencio, 1990).

The harbor seal is listed under the category "Least Concern" on the International Union for Conservation of Nature's (IUCN) *Red List of Threatened Species* (Thompson et al., 2008) because it is considered an abundant and widely distributed species. In Mexico, it is also listed in the lowest category ("Under Special Protection") on the Mexican "List of Endangered Species" (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT], 2010). In this case, their placement in the lowest category may be due to a lack of information. Therefore, in this study, our aim was to update the information on the harbor seal's distribution and abundance in Mexico with the goal of starting a long-term monitoring program.

To obtain an accurate abundance estimation, it is helpful to carry out counts during the season when the highest number of individuals are hauled out. Depending on the study area, this may occur during the pupping (Jeffries, 1985; Miller, 1988; Huber et al., 2001) or molting seasons (Brown & Mate, 1983; Thompson & Harwood, 1990; Codde et al., 2012). Haul-out sites are more often used by harbor seals during the pupping season because these are places where females give birth and care for their young, while males spend more time on land to mate (Boness et al., 2006). Harbor seals also spend a greater than average amount of time ashore during the molting season (Daniel et al., 2003).

When this study was carried out, we only knew that pupping occurred in Mexico in February (Scheffer, 1974; Padilla-Villavicencio, 1990; Reeves et al., 1992; Burns, 2009) or March (Gallo-Reynoso & Aurioles-Gamboa, 1984; Padilla-Villavicencio, 1990; Reeves et al., 1992). This information was only based on the presence of pups on one or more of the Mexican islands, but the date of peak pup counts for the different sites was not known.

Recently, the pupping and molting phenology for a harbor seal colony was studied at the Punta Banda Estuary near Ensenada, Baja California (Fernández-Martín et al., 2016). Fernández-Martín et al. estimated the highest abundance of adult and immature individuals on land occurred during the molting season. Furthermore, she suggested that the best dates to count and estimate the abundance at that site was between 5 May and 10 June, and this period corresponded to the molting season.

Besides the date, several factors, such as sea level, rain, wind, cloud cover, time of day, or human disturbance, may influence the number of individuals that haul out (Allen et al., 1984; Watts, 1996; Frost et al., 1999; Boveng et al., 2003; Jemison et al., 2006). This varies among sites; however, tide height has been the most frequently reported (Allen et al., 1984; Pauli & Terhune, 1985; Olesiuk et al., 1990; Watts, 1996; Boveng et al., 2003; Small et al., 2003; Cunningham et al., 2010; Cowles et al., 2013). Thus, the highest number of individuals hauling out occurs during low tide at most sites.

Pinniped counts represent only the minimum population size; therefore, we have to consider the number of individuals in the water during surveys by estimating a correction factor (CF) to estimate abundance. There are some studies of time ashore for radio-tagged harbor seals to estimate this CF (Huber et al., 2001). Huber et al., as well as Harvey & Goley (2011), were the first ones to use a sufficient number of radio tags on a representative sample (i.e., a proportional number of males and females from various age classes) from the population, and this yielded a more accurate CF (not underestimated) (Harvey & Goley, 2011).

Using similar methods, Huber et al. (2001) carried out surveys in Oregon and Washington during the pupping season, while Harvey & Goley (2011) did so in California during the molting season. Huber et al. (2001) proposed a 1.53 CF, and Harvey & Goley (2011) proposed a CF of 1.54. Both figures are almost equal, and Huber et al. (2001) did not find significant differences between six sites with different environments nor between sex and age categories, nor inter-annual variations; and the authors mention that the method to obtain the CF is repeatable. Despite this, the authors recommended that their CF should not be applied to other localities. Up to now, no CFs have been estimated for harbor seal colonies in Mexico. Therefore, in this paper, we report the raw counts of *P. v. richardii* in all the haul-out sites in Mexico during the seasons with the highest abundance of harbor seals ashore (the pupping and molting seasons) as a first approximation for a long-term study.

Methods

We completed harbor seal counts in photographs taken during aerial and boat-based surveys. The photographs were taken during the pupping (surveys in February and March) and molting (surveys in May and June) seasons in 2009. We used Canon EOS 10D and 20D digital cameras with a Canon lens 100 to 400 mm, f/4.5. Boat-based surveys were performed around all of the islands in Mexico where harbor seals haul out: Coronados, Todos Santos, San Jerónimo, San Martín, San Benito, Cedros, Natividad, San Roque, and Asunción (Figure 1).

The aerial photographs were taken along the coast of the Baja California Peninsula from Todos Santos Bay to Asunción Bay (Figure 1). Two aerial surveys were achieved: one from Asunción Bay to El Rosario Bay on 4 March 2009, and the other from El Rosario Bay to Ensenada on 20 March 2009. We also recorded the geographic location of the colonies by means of a Garmin 76CSX GPS (approximate precision 5 m).

We navigated around the islands on outboard motor boats at a distance of between 5 and 20 m from shore. Two observers counted *in situ*, using 7 × 50 binoculars, dictating the numbers into two recorders. The total harbor seals counted *in situ* (data not shown here) were compared to the totals counted in photographs. The latter were always higher, so in this study, we only report the data from photographs. We also carried out counts on foot on several islands, but due to their physiography, during most of these counts the seals flushed. However, at some sites on some islands we photographed them while we were onshore, when the colony was not visible from the boat. Unfortunately, we did not carry out aerial counts of the islands due to logistical restraints. Most of the counts in this study were done during low

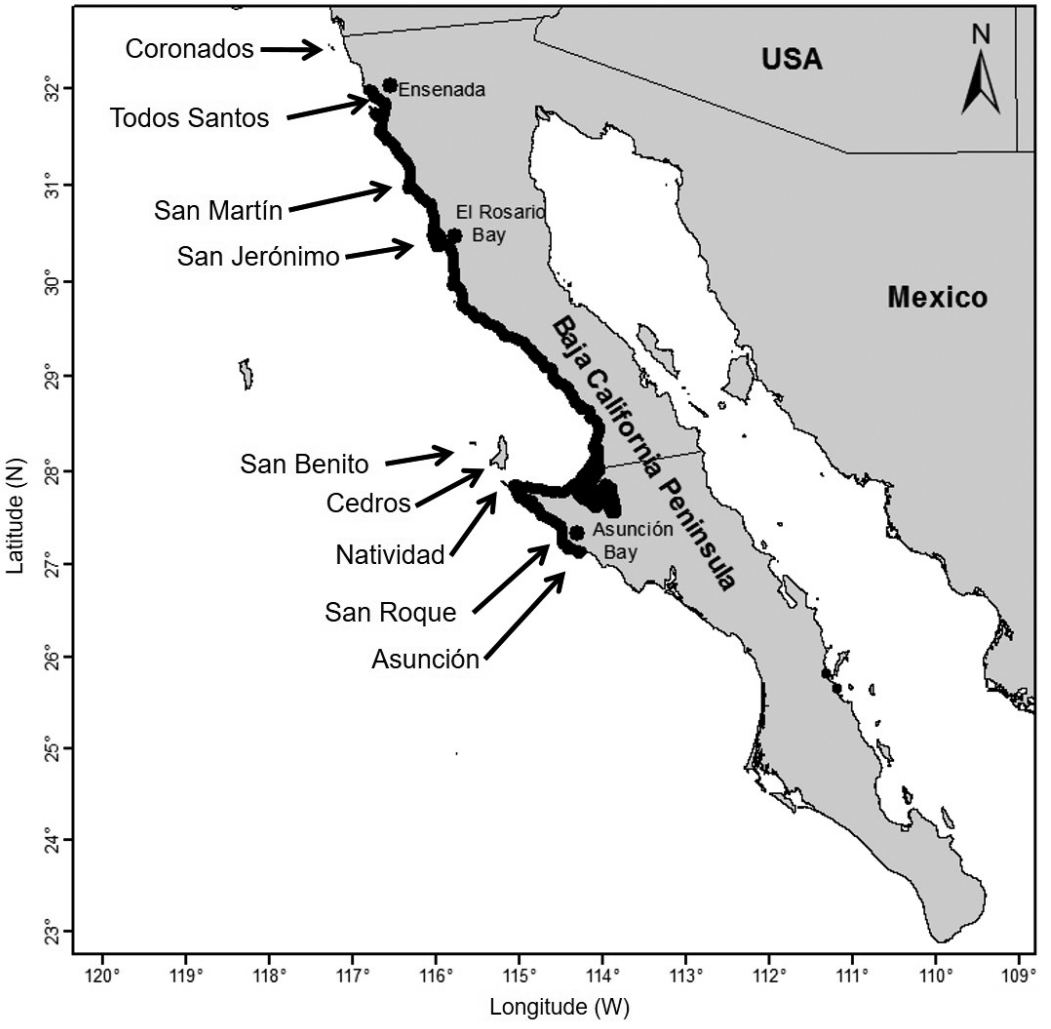

Figure 1. Location of study area and distribution of *Phoca vitulina richardii* in Mexico, including nine islands and the aerial survey along the coast from Asunción Bay to Ensenada (marked in bold); harbor seals were observed and studied on each of the islands and along the coast.

tide and with good environmental conditions (i.e., Beaufort sea state < 2 and no precipitation).

Photographs were assembled into sequences with a ~10% overlap with the program *PTAssembler*, Version 5.0 (TawbaWare, 2009). Harbor seals were counted with *Image-Pro Plus*, Version 6.0.0.260 (Media Cybernetics Inc., 2006), by three independent counters; results were compared, and repeatability values were obtained based on Equation 1 (Lessels & Boag, 1987). This test is based on the correlation coefficient that shows the similarity between variables, according to the equation

$$r = \frac{S_A^2}{(S^2 + S_A^2)} \quad (1)$$

Where

r = correlation coefficient

S^2 = variance within counters, computed by the equation

$$S^2 = MS_W \quad (2)$$

MSw = Mean square variance within counters

S_A^2 = Variance among counters, computed by the equation

$$S_{A=}^2 \frac{MS_{A-} MS_W}{n_0} \quad (3)$$

Where MS_A is the mean square variance among counters and n_0 is a coefficient related to the number of haul-out sites counted by each counter in the analysis of variance, estimated as follows:

$$n_0 = \left[\frac{1}{(a-1)}\right] \bullet \left[\sum_{i=1}^{a} n_i - \left(\frac{\sum_{i=1}^{a} n_i^2}{\sum_{i=1}^{a} n_i}\right)\right] \quad (4)$$

Where a is the number of counters and n_i is the number of haul-out sites counted by the ith counter.

The values with a correlation coefficient equal to or higher than 0.95 were considered to have high repeatability and were averaged. This analysis was performed with the program *SPSS*, Version 17.0 (SPSS Inc., 2008).

Results

We applied repeatability tests to the counts of three independent counters. On all islands and along the peninsula's coast, the repeatability values were equal to or higher than 0.95.

The total number of harbor seals on the islands was higher during the molting than during the pupping season ($\chi^2 = 43.4$, $p < 0.001$), although the highest count per island did not always correspond to that season (Table 1). The islands with the highest abundances were San Jerónimo, Cedros, Natividad, and San Roque. We discarded

Table 1. Harbor seal (*Phoca vitulina richardii*) counts from photographs on islands (boat surveys) and the coast of the Baja California Peninsula (aerial surveys) during the pupping and molting seasons in 2009. Counts on Cedros Island during the pupping season were discarded due to methodological problems; no aerial surveys were carried out along the coast during the molting season due to logistical constraints.

	Pupping season		Molting season	
Site	Date	Count	Date	Count
Coronado Islands	4 February	321	3 June	312
Todos Santos Island	18 March	473	8 June	341
San Martín Island	19 February	148	19 June	136
San Jerónimo Island	20 February	523	18 June	642
Cedros Island	--	--	25 & 26 May	732
San Benito Islands	21-23 January	42	21 & 22 May	21
Natividad Island	29 January	724	24 May	551
San Roque Island	10 February	633	17 May	779
Asunción Island	10 February	274	17 May	271
Total islands		3,138		3,785
Coast	4 & 20 March	1,724	--	--
Total islands + coast		4,862		

the counts during the pupping season at Cedros because the survey here was not carried out during low tide. The count was done in a single day on this very large island (130,970 m perimeter) (Samaniego et al., 2007), so many hours were required to accomplish this, and the counts at sites with the highest harbor seal concentration did not coincide with the low tide. When we compared the counts between islands, we found significant differences during both the pupping ($\chi^2 = 1{,}313$, $p < 0.001$) and the molting ($\chi^2 = 1{,}362$, $p < 0.001$) seasons (Table 1). In addition, we counted 1,724 individuals along the coast of the Baja California Peninsula during the pupping season; and when added to the counts on the islands (3,138), we obtained a total of 4,862 harbor seals during the same season. Figure 2 shows that the harbor seal colonies along the west coast of the Baja California Peninsula are more abundant in the north than in the south.

Pups were sighted on all islands and along the Baja California Peninsula coast. Thus, we report for the first time that San Roque is a breeding colony as are the colonies along the coast.

Discussion

This paper presents information on the distribution and minimum population size of the harbor seal in Mexico. To achieve an accurate abundance estimate, it is helpful to know the dates with the highest abundance of individuals ashore. These dates may vary depending on the latitude where the colony is located (Huber et al., 2001; Jemison et al., 2006) because the harbor seal's pupping season is mainly controlled by the photoperiod (Temte, 1994). The same occurs in the molting season because it comes immediately after the breeding season (Burns, 2009). In other words, there is a latitudinal cline in the pupping season (Temte et al., 1991), which can be seen in the number of harbor seals ashore. Even though the date of peak abundance for each colony in Mexico is not known, the survey dates in this study coincide with the pupping and molting seasons at Punta

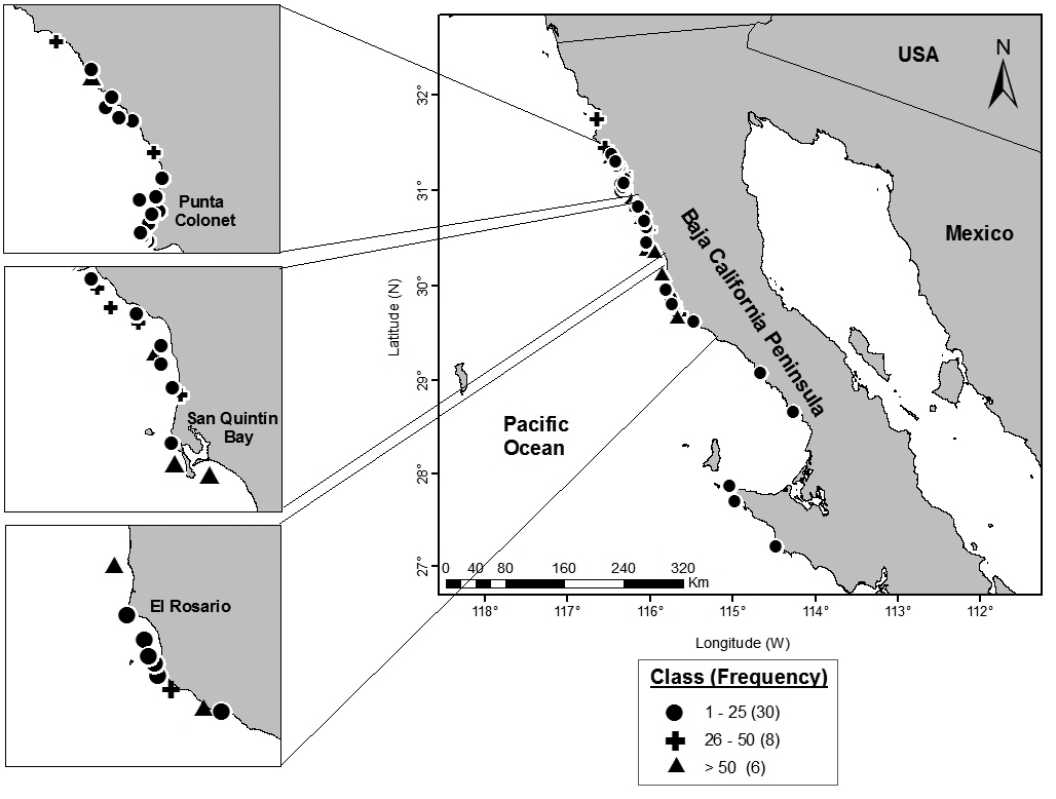

Figure 2. Harbor seal distribution along the Baja California coast from Todos Santos Island (north) to Asunción Bay (south) during the pupping season; the size of the colonies (frequency) is shown according to the symbols.

Banda Estuary, the only colony in Mexico where the peak abundance during pupping and molting seasons has been reported (Fernández-Martín et al., 2016). Fernández-Martín et al. mentioned that the pupping season started in mid-February and ended in mid-April, and that the highest number of pups was found in mid-March. Molting occurs from the end of March to the beginning of July, with the highest proportion of individuals ashore at the beginning of June. Therefore, the counts in this study were done around the dates when we expected to find the highest number of individuals ashore during both seasons (pupping: 21 January to 20 March; molting: 17 May to 19 June; Table 1).

Most harbor seal monitoring is carried out by using aerial photographs (Huber et al., 2001; Gilbert et al., 2005; Harvey & Goley, 2011; Lonergan et al., 2013; Jansen et al., 2015) because the detection is better than onshore or from boats (Thompson & Harwood, 1990; Cronin et al., 2007). However, depending on the topography of the sampling site, counting on foot or from a boat may be more accurate (Thompson & Harwood, 1990; Mathews & Pendleton, 2006; Cronin et al., 2007). In most of the haul-out sites in Mexico, it is very difficult to count on foot without seals flushing because of the beaches' morphology or because the seals are too close to cliffs to be observed from above. Therefore, in this particular study area, the best option was to count from boats.

At other sites, it has been reported that boat surveys represent an underestimation when compared to aerial surveys (Thompson & Harwood, 1990), and this may be the case for Mexico. Therefore, we assume that our counts represent the minimum harbor seal population in Mexico.

To date (2015), our counts represent the highest number when compared to the only other previous extensive counts (1,715 individuals) by Padilla-Villavicencio (1990). The total number of individuals counted on the same islands (from Coronado to Natividad) in our study was 2,326. The same is true when we compare our counts with those reported for different islands by other authors (Brownell et al., 1974; Mate, 1977; LeBoeuf & Bonnell, 1980; Maravilla-Chávez & Lowry, 1996). We do not think the increase in the number of animals is due to methodological factors since we applied the same methods as the cited articles (counts from photographs taken during boat surveys from all animals on the islands). Therefore, we may conclude that the population has increased, although it is small relative to the size of most other harbor seal populations that have been documented throughout the species' range since it is found in the southernmost part of its distribution, and habitat conditions may be suboptimal.

During the molting season, we counted more seals on the islands (3,785) than during the pupping season (3,233). This concurs with Fernández-Martín et al. (2016), the only study of a colony in Mexico where the abundance between the two seasons is compared. They reported that the abundance is higher during the molting season than the pupping season.

However, in this study, we report higher counts during the pupping season (4,957) than the molting season (3,233) because it was during the pupping season that we also counted harbor seals along the coast of the Baja California Peninsula—that is, their complete distribution in Mexico. Unfortunately, logistical restraints prevented us from carrying out aerial surveys along the coast during the molting season.

The islands with the highest abundances were San Roque, Natividad, San Jerónimo, and Cedros during both seasons. Islands with a higher abundance may be explained by several factors such as highly productive waters, larger distance from human disturbance, and the absence of predators (Simpkins et al., 2003), and may also be because harbor seals do not have to compete for space with other pinnipeds as they do on San Roque Island. Other studies have stated that harbor seals choose sites with low levels of disturbance (Suryan & Harvey, 1999; Montgomery et al., 2007) near productive areas (Pitcher & McAllister, 1981; Suryan & Harvey, 1998), protected from wind exposure (Bjorge et al., 2002) and with access to deep waters (Montgomery et al., 2007).

Most of the colonies located along the Baja California Peninsula coast are concentrated in the northern half of the study area. They are found on small cobblestone beaches that are well protected from the wind and waves. The difference between the north and south distribution may be a higher presence of cliffs along the northern coast, making it difficult for predators to access the harbor seal colonies. Along the southern coast, there are more open, sandy beaches, probably giving predators easier access to prey.

To achieve an accurate abundance estimation of harbor seals in Mexico, it is still necessary to gather data on the dates of the highest counts at the different haul-out sites, as well as estimating a CF regarding the harbor seals that are not ashore when a survey is carried out. The 2009 count data we present in this study could then be used again to estimate abundance. We believe that our data represent the most recent and complete information on the distribution and the minimum abundance of the Pacific harbor seal in Mexico.

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