

Population Fluctuations of Guadalupe Fur Seals (*Arctocephalus philippii townsendi*) Between the San Benito Islands and Guadalupe Island, Mexico, During 2009 and 2010

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Abstract

The Guadalupe fur seal (*Arctocephalus philippii townsendi*, Merriam 1897) can now be found on Guadalupe Island and the San Benito Archipelago, off the west coast of the Baja California peninsula. Its population is rising after surviving two periods of intense exploitation during the 19th and 20th centuries. This study estimated the abundance of the Guadalupe fur seal at its main colonies on Guadalupe Island and investigated as to whether there were new colonies on other islands off Baja California. Visual surveys to count Guadalupe fur seals were conducted in 2009 and 2010 around ten islands and archipelagos in the Mexican Pacific. Two sightings were recorded outside the usual distribution range: (1) one juvenile on Todos Santos Island on 11 November 2009 and (2) one subadult male on Asunción Island on 3 June 2010. Differences were found between the fur seal populations counted on Guadalupe Island and the San Benito Islands. From 2009 to 2010, the total minimum counts on Guadalupe Island increased by 30%; while on San Benito, these counts were 50% lower. These fluctuations are presumed to have been caused by animal movements between the two islands, probably due to a northbound migration of this fur seal's prey caused by an El Niño event in 2009 and 2010. The abundance was estimated at 17,581 fur seals on Guadalupe Island in the summer of 2010, and this estimate was obtained by using a correction factor based on the substrate type on the coast and the number of animals not observed during boat-based counts. An abundance of 2,503 animals was recorded on the San Benito Islands.

Key Words: Guadalupe fur seal, *Arctocephalus philippii townsendi*, abundance, distribution, Mexico

Introduction

The Guadalupe fur seal (*Arctocephalus philippii townsendi*, Merriam 1897) (Committee on Taxonomy, 2016) is one of the four pinniped species found on the islands and coasts of the Mexican Pacific. As with other marine mammals, this subspecies was subject to intense hunting for its fur during the 19th and 20th centuries (Hamilton, 1951; Berdegué, 1957).

Before its exploitation, the Guadalupe fur seal could be found from the Gulf of the Farallones, California, to the Revillagigedo Islands, Mexico (Starks, 1922; Hamilton, 1951). After this period of exploitation, the only remaining colony was on Guadalupe Island. In 2005, an abundance estimation of 12,176 individuals was reported (Gallo-Reynoso et al., 2005). Since 1954, intermittent sightings outside the breeding colonies have been recorded on the Channel Islands in California (Peterson et al., 1968; Peterson & LeBoeuf, 1969; Stewart, 1981; Seagars, 1984; Stewart et al., 1987; Melin & DeLong, 1999), the Farallon Islands (Hanni et al., 1997), the California coast (Webber & Roletto, 1987; Hanni et al., 1997), some islands in the Gulf of California, and on the coast of Sonora, Mexico (Auriolos-Gamboa & Hernández-Camacho, 1999; Gallo-Reynoso et al., 2010). In 1997, 256 fur seals were reported on the San Benito Archipelago (Maravilla-Chávez & Lowry, 1999), a population which, by 2008, had increased to 2,113 individuals (Auriolos-Gamboa et al., 2010). During recent years, Guadalupe fur seals have been found in places other than the

three San Benito Islands, mainly due to the arrival of animals from Guadalupe Island (Aurioles-Gamboa et al., 2010). In addition, new sightings have been recorded in the Gulf of California (Aurioles-Gamboa & Hernández-Camacho, 1999; Gallo-Reynoso et al., 2010). However, 59 y after its rediscovery in Mexico, the Guadalupe fur seal only reproduces on Guadalupe Island and the San Benito Islands.

Due to the recent growth of the Guadalupe fur seal population, this study presents information on the abundance of this animal's two main colonies—Guadalupe Island and the San Benito Islands—between 2009 and 2010, as well as the results of monitoring conducted on the islands off the west coast of the Baja California peninsula in search of new colonies.

Methods

Counts were carried out during the summers of 2009 and 2010 on the main islands in the Guadalupe fur seal's distribution range: Guadalupe Island (18 to 21 July 2009 and 17 to 22 July 2010) and the San Benito Archipelago (8 to 10 August 2009 and 6 to 8 August 2010; Figure 1), which comprises the San Benito Este, San Benito Centro, and San Benito Oeste Islands. Furthermore, all islands close to its main range in the Mexican Pacific (Coronados, Todos Santos, San Martín, San Jerónimo, Cedros, Natividad, San Roque, and Asunción; Figure 1) were monitored over the four seasons of 2009 (spring, summer, fall, and winter) and two seasons in 2010 (spring and summer) in search for new colonies.

Boat surveys around the islands were conducted in small local fishing boats with outboard engines using 7 × 50 binoculars and maintaining a distance of 5 to 20 m from the coast. All animals observed on the shore were recorded. Two experienced observers dictated the numbers into two recorders, separating the animals by age and sex categories.

Based on previous descriptions (Peterson et al., 1968; Fleischer, 1978; Gallo-Reynoso, 1994), the categories were males (both subadults and adults), females, juveniles, pups, and miscellaneous (undetermined). The male category did not distinguish between subadults and adults because the counts were performed on dates when the territories were still being defined (Gallo-Reynoso, 1994), with all males thus considered to be reproducing. The geographical positions of each individual or group of individuals were also obtained during counts using a GPS, and the groups were then photographed.

On both Guadalupe Island and the San Benito Archipelago, it was necessary to conduct surveys

on foot. On Guadalupe Island, the southern extreme (Punta Sur) has a high, broad platform, and counts made from boats tend to underestimate colony sizes (Figure 1). Consequently, Punta Sur was divided along its long axis, and each section was counted by three people on foot. Both counts were combined to obtain the total number of individuals by category. As geographical features on San Benito Centro in the San Benito Archipelago allow the animals to walk inland, the counts here were always performed on foot.

On Guadalupe Island, two pairs of counters worked simultaneously. On San Benito Centro and Este, two people counted; and on San Benito Oeste, only one person did this. Given that two people participated in most of the counts, it was necessary to apply a repeatability test to average the results. This test is based on the correlation coefficient that shows the similarity between variables according to the equation (Lessels & Boag, 1987)

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

where

r = correlation coefficient

S^2 = variance within groups as computed by the equation

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

variance between groups as computed by the equation

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

where n_0 is a coefficient related to the sample size of each group in the analysis of variance, estimated as follows:

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

where a is the number of groups (individuals) and n_i is the sample size of the group.

The values (counts) with a confidence interval equal to or higher than 0.95 were considered to have a high repeatability and were averaged.

Moreover, the totals of the minimum counts obtained in the summer of 2009 and 2010 on both Guadalupe Island and the San Benito Archipelago were used to infer either the growth or decrease of the population in these two seasons, without applying correction factors. In addition, the literature

was reviewed for historical counts comparable to the counts obtained in this study to explain the movements of fur seals between the main colonies, with counts considered comparable when

studies reported boat surveys of the islands' entire coasts.

To estimate abundance on Guadalupe Island, data from summer 2010 were used because observers

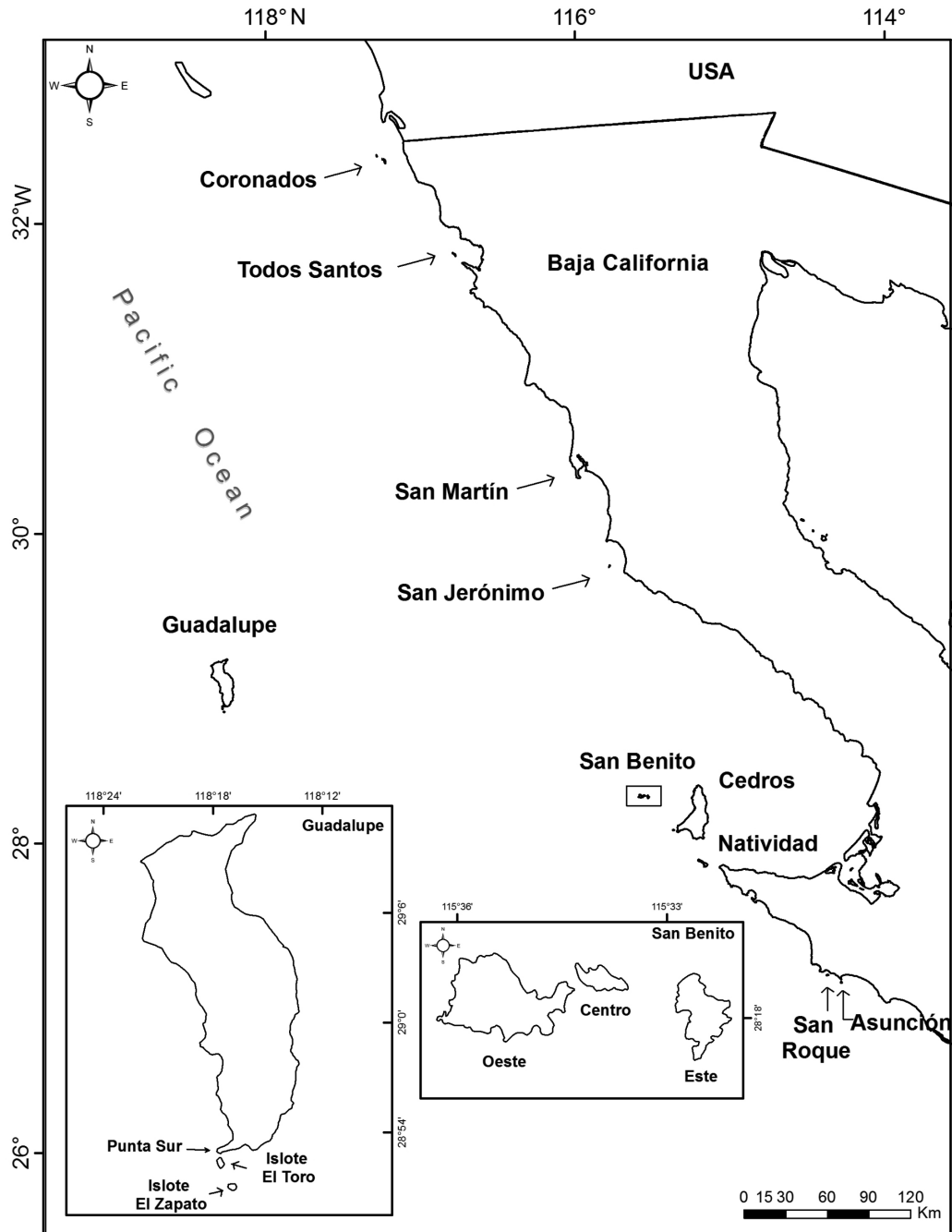


Figure 1. Islands monitored for Guadalupe fur seals (*Arctocephalus philippii townsendi*) in the Mexican Pacific in 2009 and 2010

were more experienced in categorizing individuals than in 2009. For the San Benito Archipelago, only raw counts (i.e., the population's minimum abundance) are shown.

For the abundance estimation on Guadalupe Island, correction factors were applied for animals that were only partially visible or not visible at all from a boat due to the substrate. Therefore, the eastern coast of the island (where fur seals are most abundant) was classified into sections according to the dominant substrate. To obtain correction factors, areas with dominant substrates and natural boundaries were located at which two people conducted surveys on foot while, at the same time, two people counted from a boat. This ensured that counts were carried out in the same area at the same time of day and, therefore, at the same sea level. The differences between onshore and offshore counts were used as a correction factor and were classified according to substrate and age and sex categories. Finally, the total number of animals counted from a boat for each category on each substrate was corrected to estimate total abundance.

Seven substrate types were identified based on the following grain size classification (Wentworth, 1922): large boulder cliff (LBC), medium-sized boulder cliff (MBC), cobble beach (CB), high platform (HP), low platform (LP), wall (W), pebble beach (PB), and sandy beach (SB). Correction factors were obtained for the first five substrate types because they can totally or partially hide the animals due to their grain size. LBCs have rocks larger than 1 m in diameter, while MBCs have rocks less than 1 m but larger than 0.25 m. Cobble is larger than 0.06 m but less than 0.25 m, with pups easily overlooked on this substrate because they may be resting behind rocks. HPs are very high rocky outcrops with rugged terrain and tide pools where only animals on the periphery can be counted. As LPs are lower than HPs, visibility is better, although some animals are still overlooked. As the grain size on PBs and SBs range from 0.06 to 60 mm, the animals are completely visible. However, no fur seals were found on sandy substrates. Some coastal sections of Guadalupe Island

have cliffs without platforms and are referred to here as *walls* because they are almost vertical.

Results

Over the summers of 2009 and 2010, we visited nine islands and archipelagos west of the Baja California Peninsula. Guadalupe fur seal colonies were found on Guadalupe Island and the San Benito Islands only. The counts carried out on the islands during 2009 and 2010 showed an increase on Guadalupe Island and a decrease on the San Benito Islands during the same period (Table 1).

In 2010, fieldwork on Guadalupe Island was carried out in 32.5 h; while on the San Benito Islands, the counts were accomplished in 15.5 h. Two sightings of this species were recorded during the counts for the rest of the surveyed islands: (1) on 11 November 2009 (fall), a juvenile was observed on Todos Santos Island; and (2) on 3 June 2010 (spring), a subadult male was observed on Asunción Island.

Repeatability tests were applied for the counts conducted on Guadalupe Island during the summer of 2010, with the paired counts averaged and given the following estimated figures: males (0.98), females (0.98), pups (0.99), and miscellaneous (0.96). The correction factor was applied to the abundance estimation for Guadalupe Island.

Table 2 shows the correction factors for each age category and substrate considered during the counts on Guadalupe Island. Females and pups had the highest correction percentages, while no correction was necessary for juveniles.

For some substrates, such as CBs and Ws, it was not necessary to apply correction factors. Other areas for which a correction factor was not necessary included the western coast of Guadalupe Island and El Zapato Islet. As the counts were always conducted on foot at Punta Sur on Guadalupe Island, no correction factors were applied. The counts conducted on substrates or in areas where no correction factors were applied were added to the estimates as the minimum population size because some unknown portion of the population is found at sea (Table 3). The substrates with fewer fur seals

Table 1. Minimum total counts on Guadalupe Island and the San Benito Islands in the summer of 2009 and 2010 with no correction factors applied. The San Benito data correspond to the three islands of the archipelago.

Islands	Year	Males	Females	Juveniles	Pups	Miscellaneous	Total
Guadalupe	2009	2,763	1,567	300	2,298	3,104	10,032
	2010	3,980	3,855	26	3,183	2,283	13,327
San Benito	2009	438	63	633	7	4,130	5,271
	2010	683	538	296	8	978	2,503

Table 2. Correction factors for each substrate on the eastern coast of Guadalupe Island based on age and sex categories

Substrate	Males	Females	Juveniles	Pups
LBC	22.40%	56.25%	--	92%
MBC	--	42.50%	--	79%
CB	--	--	--	50%
HP	47%	75%	--	90%
LP	23.50%	50%	--	93%

LBC = large boulder cliff, MBC = medium-sized boulder cliff, CB = cobble beach, HP = high platform, and LP = low platform

Table 3. Total number of Guadalupe fur seals (*Arctocephalus philippii townsendi*) classified according to age and sex categories on each substrate on Guadalupe Island in the summer of 2010. Cells with gray background indicate numbers estimated with correction factors.

Substrate/area	Males	Females	Juveniles	Pups	Miscellaneous	Total
LBC	1,379	1,625	5	1,530	671	5,210
MBC	716	1,221	1	1,061	469	3,468
CB	342	324	3	503	192	1,364
HP	563	522	3	401	248	1,737
LP	1,022	1,206	2	1,012	518	3,760
PB	229	54	6	39	99	427
W	28	8	0	1	8	45
West coast	47	35	1	16	29	128
El Zapato Islet	27	8	0	1	4	40
Punta Sur	255	428	6	667	46	1,402
Total	4,608	5,431	27	5,231	2,284	17,581

LBC = large boulder cliff, MBC = medium-sized boulder cliff, CB = cobble beach, HP = high platform, LP = low platform, PB = pebble beach, and W = wall

Table 4. Guadalupe fur seals counted on the San Benito Archipelago in the summer of 2010

	Males	Females	Juveniles	Pups	Miscellaneous	Total
SBE	188	82	--	3	94	367
SBO	495	454	296	5	884	2,134
SBC	--	2	--	--	--	2
Total	683	538	296	8	978	2,503

SBE = San Benito Este, SBO = San Benito Oeste, and SBC = San Benito Centro

were the LBCs and LPs (Table 3). The estimated abundance for the Guadalupe fur seal on Guadalupe Island in summer 2010 was 17,581 individuals.

For the San Benito Archipelago, only the repeatability for counts on San Benito Este Island was tested because on San Benito Centro Island, where paired counts were carried out, fur seals

were almost absent. On San Benito Este Island, only the male category showed a high level of repeatability (0.98); thus, the paired values for this category were averaged, while, for the rest of the age and sex categories, the values obtained by a single counter were used.

The counts on the San Benito Islands (Table 4) represent the population minimum since no correction factor was applied. The total number recorded in summer 2010 was 2,503 individuals (Table 4).

Discussion

The two sightings in this study of individuals out of the reproductive season comprise the most recent record of Guadalupe fur seals at sites other than the breeding colonies. The juvenile on Todos Santos Island was wounded at the base of its pectoral fins and may have been resting. The presence of juvenile fur seals outside their distribution range and the reproductive season has been recorded for other fur seals (Torres & Aguayo, 1984; Wilson et al., 2006; Bester & Reisinger, 2009; Velozo et al., 2009). The subadult male on Asunción Island may have been on a foraging trip since it was observed at the beginning of the breeding season when adult males arrive at the rookeries while subadult males leave (Gallo-Reynoso, 1994).

The counts on both Guadalupe Island and the San Benito Islands showed fluctuations from one year to another. A 30% population increase was recorded on Guadalupe Island from 2009 to 2010; while, in contrast, a 50% increase was recorded on the San Benito Islands in 2009 compared to the 2008 data compiled by Aurióles-Gamboa et al. (2010), who reported 2,113 individuals. In 2010, however, the population decreased by the same percentage. The population changes at both sites may be interpreted as having been caused by the birth and/or death of a great number of individuals, animal movements, or sampling errors (Bowen et al., 2009). This study worked on the assumption that the fur seals moved from Guadalupe Island to the San Benito Islands and vice versa.

Such a significant increase in the Guadalupe fur seal birth rate from one year to another on the San Benito Islands is unlikely to have occurred. As mentioned previously, the population growth on these islands has been assumed to be due to the arrival of animals from Guadalupe Island (Aurióles-Gamboa et al., 2010). In addition, only a small number of pups (≤ 10) has been reported in the years since the rediscovery of the species in 1997 (Maravilla-Chávez & Lowry, 1999; Aurióles-Gamboa et al., 2010). A mass death event would involve several hundreds of individuals in a short time period (Hall & Harwood, 2009). However, there are no records of a mass death event involving Guadalupe fur seals or any of the other pinniped species found on the San Benito Islands (Lubinsky, 2010; Franco-Ortiz, 2012; Milanés-Salinas, 2012). In addition, the difference between the years sampled in terms of the number of individuals on both Guadalupe Island and the San Benito Islands was

confirmed by counts based on the photographic records of fur seals on both islands compiled in this study in 2009 and 2010. These counts were compared to the direct counts, with a proportional difference found between the 2 y on both islands (data not shown). Therefore, sampling errors do not seem to be the main reason for the differences from one year to another.

The mass migration of fur seals from Guadalupe Island to the San Benito Islands could explain the higher number of individuals recorded in this 2009 study compared to the 2008 counts conducted by Aurióles-Gamboa et al. (2010). The decrease recorded on the San Benito Islands in 2010 may indicate a further mass movement to Guadalupe Island and explain the population increase on Guadalupe Island from 2009 to 2010.

A possible cause for fur seal movements between islands may be the movement of its prey. Prey availability is considered to be the main factor influencing the distribution and abundance of pinnipeds during local or large-scale oceanographic changes in both the short and long term (Trillmich & Ono, 1991). Events like El Niño may change the distribution of pinnipeds through their impact on the trophic chain. The diet of the Guadalupe fur seals on Guadalupe Island and the San Benito Islands is mainly composed of cephalopods, with the market squid its main prey (*Loligo opalescens*) (Aurióles-Gamboa & Camacho-Ríos, 2007; Hernández-Montoya, 2009).

Sea surface temperature increases, such as those that occur during El Niño, may cause a significant decrease in the availability of the market squid as prey (Brady, 2008). In 2009, a moderate El Niño event developed from spring onwards and lasted until the beginning of 2010 (National Oceanic and Atmospheric Administration [NOAA], 2010). Even though it was a moderate event, it may have influenced the northbound movement of squid in 2009 (Melin et al., 2010). These same authors reported an increase in the frequency of squid (30.8%) in the diet of the California sea lion (*Zalophus californianus*) in central California compared to what had been reported at the beginning of this century (8.6%), meaning that squid were more available than usual in summer 2009 in central California (Melin et al., 2010). Therefore, this event may have caused the fur seals from the San Benito Islands that were foraging in summer to follow the northbound movement of their prey. These animals may have been recorded on Guadalupe Island during the summer of 2010, which would explain the significant increase in the 2010 counts on this island compared to those conducted in 2009.

Although there are several reports of pinnipeds moving due to El Niño events in the eastern

Pacific Ocean (Huber, 1991; Hanni et al., 1997; Zeidberg et al., 2006), it is also possible that our results represent a continuous exchange of animals between the two breeding colonies and may show an adjustment period that occurs during the expansion of the distribution range of the Guadalupe fur seal.

The counts for Guadalupe Island in this study are the highest reported since 1993 (Gallo-Reynoso, 1994). However, to have a more efficient abundance estimation, we applied the correction factor based on substrate features, which have to be considered when counts from boats are carried out. While there is no correction factor for pinniped counts comparable to those conducted in this study, it seems that substrate features represent a discrete factor that corrects pup counts, a category that can easily be overlooked during boat surveys (Auriolles-Gamboa et al., 2010).

Choosing different substrate types to classify the coast of Guadalupe Island was important for proposing different correction factors. As the Guadalupe fur seal, like other fur seal species, hides from the sun when hauled out (Peterson et al., 1968), it was considered necessary to determine the percentage of animals overlooked during boat counts. This is especially evident for pups, which recorded the highest percentage on all substrates, and females on some substrates. When hauled out, females spend time nursing their pups or resting (Figueroa-Carranza, 1994), activities which require sites with shade and access to water when the air temperature is high (Pierson, 1987), meaning that sites with these features may have led to females being overlooked during counts.

The substrate with the highest number of individuals, also for the age and sex categories, was the LBC. Other studies have reported the fur seals' preference for areas with large lava blocks and large rocks (Peterson et al., 1968; Fleischer, 1987; Gallo-Reynoso, 1994; Belcher & Lee, 2002) that offer refuge during the hottest hours.

At Punta Sur on Guadalupe Island, pups were the most abundant category, followed by females and males. It is possible that at the time of counting, a proportion of females were on foraging trips, which may explain the higher count for pups than females. The number of juveniles was very low on this part of the island, which confirms that, during the reproductive season, this category is less abundant at breeding sites (Gallo-Reynoso, 1994).

In contrast to the work conducted on Guadalupe Island, it was decided not to estimate a correction factor for the San Benito Islands, mainly due to the physical features of these islands which make it easy to detect most of the animals during boat counts. Furthermore, at sites where not all animals could be seen, surveys were conducted on foot. The number

of pups could be overestimated because there are still very few on the San Benito Archipelago (less than ten on the three islands), which coincides with other reports (Maravilla-Chávez & Lowry, 1999; Auriolles-Gamboa et al., 2010).

Even though it was possible to count in detail the different age and sex categories on both sites and carry out corrections by substrate type on Guadalupe Island, the estimation made in this study did not consider individuals on foraging trips (adult females) or immature individuals that do not stay on the island during the breeding season. This means that the absolute abundance of this species will not be completely estimated until a correction factor is applied for animals that are in the water at the time the surveys are carried out.

The arrival of fur seals at San Benito Islands from Guadalupe Island is the result of the population increase during the last 20 y, and this might lead to assume a reduction in the species' vulnerability. However, abundance variations between these two locations and the fact that at the San Benito Archipelago, less than ten pups are counted every year prevents us from considering this a stable rookery.

Recolonization mechanisms of natural populations are poorly understood and are difficult to document. The Guadalupe fur seal's present population dynamics offers an opportunity to understand the recolonization process and, therefore, it is important to continue monitoring the colonies.

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