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# Short Note

## Guadalupe Fur Seal Encounters in the Mexican Central Pacific During 2010-2015: Dispersion Related to the Species Recovery?

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The intense commercial hunt of Guadalupe fur seals (GFSs) (*Arctocephalus philippii townsendi*) during the 18th and 19th centuries due to the value of their fur led to the species' apparent extinction (Townsend, 1931). It is estimated that, prior to exploitation, the population of this species was between 100,000 and 200,000 individuals (Hubbs, 1979), and some evidence suggests that it could have been distributed from Monterey Bay, California (around the 36° N and 121° W) down to the Revillagigedo Islands, Mexico (18° 46.489' N, 110° 58.681' W), including Guadalupe Island (28° 59.157' N, 118° 13.834' W), Cedros Island (28° 11.828' N, 115° 13.001' W), and the San Benito Archipelago (28° 18.173' N, 115° 34.119' W) (Hamilton, 1951; Fleischer, 1987; Hanni et al., 1997). The sighting and hunting of a few individuals on Guadalupe Island in 1926 suggested the return of the species; however, it was not reported again until 1954 (Hubbs, 1956).

Once protection for this species was established in the 1920s (NOM-059-SEMARNAT-2010; Gallo-Reynoso, 1994), its recovery began until it reached its overall current abundance of ~40,000 individuals (García-Aguilar et al., 2018), including its reappearance in 1997 at one of its former breeding sites, the San Benito Archipelago (Maravilla-Chávez & Lowry, 1999). GFSs occupy this site seasonally, with higher density during the summer and an almost complete absence during the winter (Hambrecht et al., 2016). Pups are born during summer, with a lactation period of 9 to 10 mo, with weaning taking place in March or April (Pierson, 1987; Gallo-Reynoso, 1994). Since the maximum number of pups recorded at San Benito Archipelago is not above 30 per breeding season (Elorriaga-Verplancken et al., 2016b), the only well-established and recognized reproductive colony for the GFS is Guadalupe Island (Gallo-Reynoso, 1994).

Mexican environmental authorities had listed the GFS as an endangered species (NOM-059-SEMARNAT-2010); however, recent information on population increases has led the International Union for Conservation of Nature (2015) to list it as a Species of Least Concern. According to Sierra (2015) and Elorriaga-Verplancken et al. (2016b), the dynamics of this species' recovery is still inconclusive as the ongoing recolonization process at San Benito still lacks the "maturity" (i.e., consistent breeding activity) characteristics of a secondary colony (Roux, 1987). Additionally, Weber et al. (2004) reasoned that the success of the GFS recovery will probably be linked to food availability and not to factors such as genetic variability. Even though there is a reduction in genetic diversity for the GFS, it is not as significant as in other species (i.e., the northern elephant seal [*Mirounga angustirostris*]) that went through a similar population process.

GFSs feed mainly on different squid species (Gallo-Reynoso & Esperon-Rodríguez, 2013; Amador-Capitanachi et al., 2017). This species has oceanic habits that normally involve feeding trips of up to 600 km over 2 wks in duration around Guadalupe Island (Gallo-Reynoso et al., 2008). This characteristic of wide dispersion could be more pronounced when prey availability is scarce due to a decrease in primary production, leading to GFSs increasing their search effort (i.e., longer feeding trips) and, in extreme cases, resulting in individuals with malnutrition or even sequential mass mortality events (Lander, 2000; Gálvez, 2015; Villegas-Zurita et al., 2015; Elorriaga-Verplancken et al., 2016a, 2016b; NOAA Fisheries, 2018).

The lack of knowledge on the GFS, compared to other pinnipeds, and the effects of oceanographic anomalies on their population growth, point to the need to obtain and evaluate new information, documenting the presence of this species in offshore areas of the Mexican Central Pacific (MCP) where it has not officially been reported.

A total of 16 marine mammal research surveys were conducted during 2010 to 2015, encompassing an area of around 76,000 $km^2$ (16.5° to 20.5° N, 108° to 103° W) in the MCP (Figure 1). For each ~7 d survey, two observers with experience to search for and identify marine mammals were located on both sides of the highest platform of

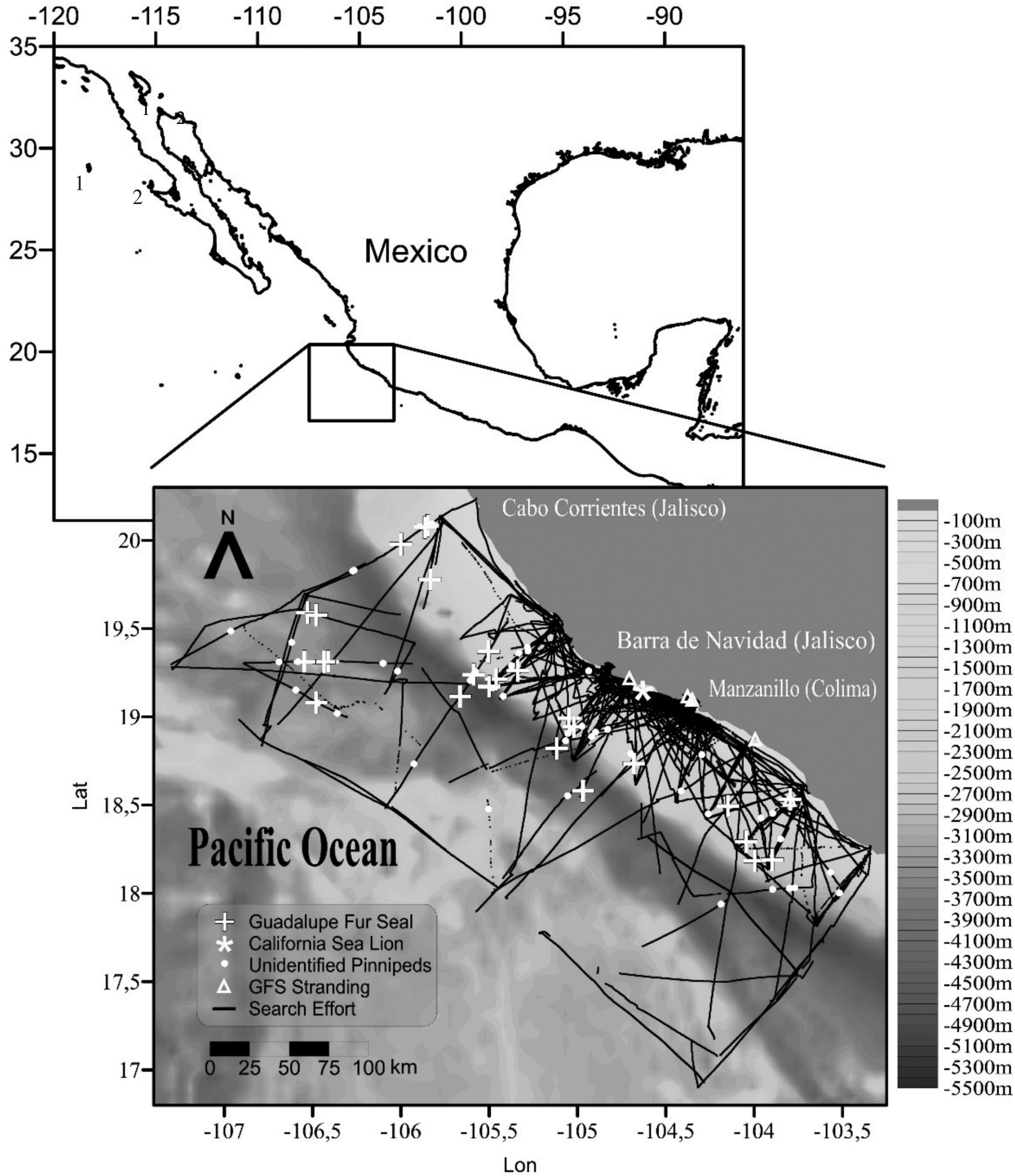


**Figure 1.** Study area in the Mexican Central Pacific (MCP) and geographical location of Guadalupe fur seals (GFSs, *Arctocephalus philippii townsendi*) sighted at sea or recorded stranded on beaches, unidentified pinnipeds (UPs), and California sea lion (*Zalophus califonianus*). (1) Guadalupe Island and (2) San Benito Archipelago, where GFSs have most frequently been recorded, are indicated on the enlarged area, gray-scale map.

a ship (around 5 m above sea, medium level). An independent observer located on the central part of the platform detected sightings omitted by the other observers, while another person recorded the information. All observers used Fujinon 7×50 binoculars. Non-systematic transects were recorded using a Garmin GPSMAP 76CS geo-positioner. When a pinniped was sighted, we approached it to identify the species and to record its geographic position, as well as the date, time, sighting number, number of individuals, particular observations of the sighting, and environmental observations (e.g., sea state in Beaufort scale, wind intensity and direction, etc.). Occasionally, photographs of the pinnipeds observed were obtained with a Canon EOS 60D digital camera, equipped with a 100-300 mm lens. Photographs were analyzed to positively identify the individuals as GFSs by three people using *ACDsee Pro*, Version 3, considering distinctive morphological characteristics of the species (especially compared with the California sea lion [*Zalophus californianus*] morphology as per Reeves et al., 2002) such as small body in relation to large anterior fins, abundant dark grey fur, long or pointed snout, and horizontal orientation of the pinnae. Pinnipeds whose species could not be identified by expert observers, nor photographed in high quality, were classified as "unidentified pinnipeds" (UP).

The position of sightings was described in relation to an interpolated depth from a bathymetry map obtained from the National Geographic Data Center (NGDC, National Oceanic and Atmospheric Administration) and the distance to the coast calculated using *Surfer*, Version 11. Additionally, sightings in waters less than 200 m deep were classified as a *continental shelf zone*, and those in waters more than 200 m deep were classified as a *slope canyon zone*. Sightings registered during surveys conducted in November through March were classified as *cold season*, and those conducted in April through October were classified as *warm season*.

To avoid potential biases due to differences in sampled tracks, all sightings from each survey were standardized based on effort, calculating the total sighting rate by zone and season using the following equation:

$$Sighting\ rate = \frac{number\ of\ sightings}{search\ effort\ (km)} \quad (1)$$

To detect significant differences in effort surveys and sighting rates, non-parametric (Kruskal-Wallis [*KW*] test) or parametric (Student's *t* test) statistics were employed, depending on normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test) of the data. These analyses were carried out at a $p = 0.05$ significance level (Zar, 1996) using *R*, Version 2.

A total of 17,103.1 km were traveled searching for pinnipeds in the MCP region; this searching effort was variable among the 16 surveys conducted mostly due to climatic factors and to logistics. There were significant differences in effort and number of sightings per survey ($t_{1,15}$ = 13.96, $p < 0.001$), although no overall trend (as per lack of linear correlation; $t_{1,15}$ = 1.40, F = 1.98, $p = 0.18$). A total of 80 individuals were counted

**Figure 2.** Juvenile Guadalupe fur seals in waters from the Mexican Central Pacific (*Photo credit:* Grupo Universitario de Investigación de Mamíferos Marinos [GUIMM], Universidad de Colima)

during 71 sightings (Figure 1): 34 individuals were identified as GFSs during 29 sightings, and 46 individuals from 42 sightings were UPs. We also confirmed an additional sighting of one California sea lion (CSL). All recorded GFSs ($n$ = 34) were apparently juveniles or subadult males, henceforth referred to as "immature" (Figure 2).

The average GFS sighting rate (0.0029 ind/km) was slightly lower than the UP sighting rate (0.0046 ind/km). The highest GFS sighting rate occurred during December 2012 (0.0049 ind/km), and the highest UP sighting rate occurred during November-December 2011 (0.0102 ind/km) (Table 1).

The sighting rate of GFSs and UPs were higher in oceanic regions (0.006 and 0.015 ind/km, respectively). These GFSs were observed at an average distance of 68.4 km from the coast (range: 12 to 151 km) over waters 2,602 m deep on average (range: 708 to 4,522 m) (Table 1). The distance from the coastline and depth of GFS sightings were not significantly different from those of UP sightings ($KW_{1,72}$ = 0.012, $p$ = 0.91 and $KW_{1,72}$ = 0.127, $p$ = 0.0721, respectively). Moreover, the single CSL sighting occurred in the coastal region (sighting rate = 0.0008 ind/km), over shallow waters of the continental shelf (~100 m; Figure 1). No statistical test was performed in this case because a unique CSL sighting was unrepresentative, but differences in the distance from the coastline and depth were evident in comparison with those from GFS and UP sightings.

To know if there was a relationship between GFS and UP sighting rates with the regional temperature variability, the occurrence of thermal anomaly events (El Niño or La Niña) in the Pacific Ocean during the study period was identified based on the El Niño Oceanic Index (trimestral ERSST .v3b average) for Region 3.4 (5° N to 5° S, 120° to 170° W). This information was extracted from the NOAA-Climate Prediction Center webpage (www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.html).

**Table 1.** Survey date, effort (km), and sightings of pinnipeds in the Mexican Central Pacific during 2010 to 2015. GFS = Guadalupe fur seal (*Arctocephalus philippii townsendi*); UP = unidentified pinniped; CSL = California sea lion (*Zalophus californianus*); SR = sighting rate (individuals/km), with SR for continental shelf and slope canyon, respectively, in parentheses.

| Survey | Effort | GFS | SR | UP | SR | CSL | SR |
|---|---|---|---|---|---|---|---|
| Jan 2010 | 1,539.9 | 5 | 0.0032 (0-0.0032) | 8 | 0.0051 (0-0.0051) | -- | -- |
| May/June 2010 | 1,425.0 | -- | -- | -- | -- | -- | -- |
| Oct 2010 | 1,428.1 | -- | -- | -- | -- | -- | -- |
| March 2011 | 1,123.4 | -- | -- | -- | -- | 1 | 0.00089 (0.00089-0) |
| Nov/Dec 2011 | 1,360.6 | 5 | 0.0036 (0-0.0036) | 14 | 0.0102 (0.0021-0.014) | -- | -- |
| Feb/March 2012 | 1,147.0 | 2 | 0.0017 (0-0.0017) | 5 | 0.0043 (0-0.0043) | -- | -- |
| June/July 2012 | 977.5 | -- | -- | -- | -- | -- | -- |
| Oct 2012 | 1,179.9 | -- | -- | -- | -- | -- | -- |
| Dec 2012 | 1,418.8 | 7 | 0.0049 (0-0.0049) | 4 | 0.0028 (0-0.0028) | -- | -- |
| March 2013 | 508.0 | 1 | 0.0019 (0-0.0019) | 2 | 0.0039 (0-0.0039) | -- | -- |
| June 2013 | 873.5 | -- | -- | -- | -- | -- | -- |
| Nov 2013 | 922.4 | -- | -- | -- | -- | -- | -- |
| March 2014 | 863.3 | 3 | 0.0034 (0-0.0034) | 2 | 0.0023 (0-0.0023) | -- | -- |
| Nov 2014 | 638.4 | 1 | 0.0015 (0-0.0015) | 1 | 0.0015 (0-0.0015) | -- | -- |
| March 2015 | 855.9 | 4 | 0.0046 (0-0.0046) | 6 | 0.0070 (0-0.0070) | -- | -- |
| Nov 2015 | 841.2 | 1 | 0.0011 (0-0.0011) | -- | -- | -- | -- |
| Total | 17,102.9 | 29 | -- | 42 | -- | 1 | -- |

As a second analysis, the sea surface temperature (SST) anomalies were assessed for MCP localities. Satellite images of monthly SST averages (11µ nighttime–4 km) downloaded from the Ocean Color Web (gsf NASA) were used. *SeaDAS*, Version 7.3.1 was used to crop the study area and extract the statistics of the SST (i.e., average, maximum, minimum, and variance) for the months corresponding to the surveys (Table 1). Monthly SST climate images (11µ nighttime–4 km) were also obtained for the study area; data from these images were subtracted from the SST using *SeaDAS*, Version 7.3.1. Statistical data were extracted from the database of these images to identify the local anomaly. The relationship between calculated temperature anomalies and GFS–UP sightings was tested using a multiple correlation ($R^2$) test at a significance level of $p$ = 0.05 utilizing *R*, Version 2.

There were two periods with El Niño conditions (2010 and 2014-2015) and two with La Niña conditions (2010-2011 and 2011-2012) in Region 3.4 of the Pacific Ocean. Four surveys were conducted when there were positive temperature anomalies (January 2010, November 2014, March 2015, and November 2015), and four were conducted when there were negative temperature anomalies (October 2010, March 2011, November-December 2011, and February-March 2012) (Table 2). Nevertheless, SST anomalies in Region 3.4 were not correlated with the overall pinniped sighting rate nor with separate sighting rates of GFSs and UPs in the MCP ($F_{1,14}$ = 1.722, $R^2 multiple$ = 0.0002, $R^2 adjusted$ = -0.0711, $p$ = 0.953; Table 2). There were only significant differences between the overall pinniped sighting rate (GFSs and UPs) and the SST anomaly when it was calculated locally for the MCP ($t_{2,15}$ = -3.068, $p$ = 0.007).

Records of dead pinnipeds in the MCP were obtained from direct observations during surveys and from stranding events that we attended in the area after being alerted by local authorities. Collected data on such events were species, date, time, location, geographical position, age category (e.g., juvenile or adult), sex, and animal condition code (i.e., [1] alive, [2] fresh dead, [3] moderate decomposition, [4] advanced decomposition, and [5] mummified/skeletal). Photographs were also taken to corroborate the species and features of the animal condition. Five dead individual pinnipeds were recorded on beaches (Tecomán, Armería, Manzanillo, and Melaque) from Colima and Jalisco states, and all of them were identified as GFSs. Three of these individuals were subadult males as they all measured approximately 2 m in length and, thus, were not large enough to be considered adults (Table 3). Four individuals were found in an advanced state of decomposition.

**Table 2.** Sea Surface Temperature (SST) anomalies in El Niño Region 3.4, with information from the NOAA-Climate Prediction Center. ¤ = positive anomalies (El Niño), * = negative anomalies (La Niña), and SR = overall sighting rate of all pinnipeds (GFSs and UPs) estimated during surveys conducted in the Mexican Central Pacific during 2010 to 2015.

| Survey date | SST anomalies | SR |
|---|---|---|
| Jan 2010 | 1.6¤ | 0.0084 |
| May/June 2010 | -0.4 | -- |
| Oct 2010 | -1.5* | -- |
| March 2011 | -0.9* | 0.0008 |
| Nov/Dec 2011 | -1* | 0.0139 |
| Feb/March 2012 | -0.5* | 0.0061 |
| June/July 2012 | 0.1 | -- |
| Oct 2012 | 0.6 | -- |
| Dec 2012 | -0.3 | 0.0077 |
| March 2013 | -0.4 | 0.0059 |
| June 2013 | -0.3 | -- |
| Nov 2013 | -0.3 | -- |
| March 2014 | -0.5 | 0.0057 |
| Nov 2014 | 0.7¤ | 0.0031 |
| March 2015 | 0.6¤ | 0.0116 |
| Nov 2015 | 2.5¤ | 0.0011 |

One was alive but emaciated (Figure 3a) and was found dead the next day. These mortality events occurred during fall and spring of 2010 to 2016. We were able to analyze stomach contents for only one individual (the first one; Table 3). It contained fish remains (bones and scales). Moreover, live pinnipeds were also recorded near the Colima coast during our study period; all of these were identified as GFSs. One was observed in December 2011 resting on one of the buoys at the entrance of the commercial port of Manzanillo. This individual was not emaciated, but it looked fatigued (as it was not moving when our boat came closer). Another was observed resting for a couple of days on the rocky zone of La Audiencia Beach in Manzanillo during September 2014. A third individual was observed resting on the breakwater of the Tepalcates Channel in January 2016 (Figure 3b). It should be noted that the latter two GFSs were emaciated, weak, and seemed ill. These records occurred at the same time as the mortality events and sightings at sea.

A large proportion of our sightings at sea (60%) were classified as UPs; however, there is a high probability that most of these individuals were GFSs due to their sightings' date, depth, and distance from the coast corresponding to those identified GFSs that are more oceanic than other predominantly

**Table 3.** Mortality events of Guadalupe fur seals in the Mexican Central Pacific during 2010 to 2016; Uk = Unknown.

| Event | Date | Site | Geographic position | Age class | Sex | Observations |
|---|---|---|---|---|---|---|
| 1 | 19 Oct 2012 | Miramar Beach, Manzanillo, Colima | 19° 07.062 104° 23.17 | Adult (1.99 m) | Male | Good body condition and advanced decomposition, with remains of fish in stomach content |
| 2 | 21 Nov 2014 | El Paraíso Beach, Armería, Colima | 18° 55.87 104° 05.07 | Subadult | Male | Emaciated, alive, with hemorrhage in snout; it died a few hours after the stranding. |
| 3 | 22 Nov 2014 | Tecomán coasts | 18° 32.009 103° 47.71 | Subadult | Male | Floating dead; advanced decomposition |
| 4 | 24 Oct 2015 | Melaque Beach, Jalisco | 19° 14.06 104° 44.33 | Probable subadult | Uk | Advanced decomposition; it stranded after a meteorological event (Hurricane "Patricia"). |
| 5 | 26 Feb 2016 | Cuyutlán Beach, Armería, Colima | 18° 55.016 104° 03.41 | Uk | Uk | Advanced decomposition |

coastal species such as the CSL (Aurioles-Gamboa & Camacho-Ríos, 2007). There are two other fur seal species (Galapagos fur seal [*A. galapagoensis*] and South American fur seal [*A. australis*]) that have been recorded in the southern Mexican Pacific but very rarely. In fact, only five solitary individuals of both species were sighted in the last 20 years (Aurioles-Gamboa et al., 2004; Medrano et al., 2008; Villegas-Zurita et al., 2016; Páez-Rosas et al., 2018); hence, we assumed that these two species were absent from the region during the surveys.

The presence of GFSs in our study region (i.e., an area so distant from their most frequent locations around Guadalupe Island and the San Benito Archipelago; Gallo-Reynoso, 1994; Maravilla-Chávez & Lowry, 1999) is possible due to the species' great capacity for movement (Gallo-Reynoso et al., 2008) that is characterized as being more horizontal (up to ~11° and ~12° in latitude and longitude, respectively) than vertical displacement (towards deeper layers of the water column) (Aurioles-Gamboa & Camacho-Ríos, 2007; Gallo-Reynoso et al., 2008). The distance between our study area and Guadalupe Island is around 1,500 to 1,600 km, which is greater than the maximum distances (up to 600 km) reported by geo-location tags from GFS adult females (Gallo-Reynoso et al., 2008). However, in our case, the sightings involved apparently immature individuals that have already been recorded as solitary individuals in areas far away from those where they are usually distributed (Elorriaga-Verplancken et al., 2016a; Villegas-Zurita et al., 2016; Audley et al., 2017).

Recent research using stable isotope analysis provided evidence for a probable foraging segregation between young GFSs from San Benito that occupied a southern foraging ground and mature individuals from Guadalupe Island that apparently used a northernmost area (Amador-Capitanachi et al., 2017). Our study provides evidence that at least a small portion of the GFS population moves towards southern latitudes such as the MCP, especially within the period preceding the breeding season (summer), which might suggest segregation between immature and more mature seals (e.g., adult females) that could use northernmost foraging grounds or to be closer to breeding sites.

The location of GFSs in the study area might be linked to the presence of a submarine canyon where teutophagous cetaceans have been recorded in recent years (Ortega-Ortiz et al., 2014). Our sightings might be associated with such potential foraging behaviour based on the observation that GFS diet is composed mostly of squid (Gallo-Reynoso & Esperón-Rodríguez, 2013; Amador-Capitanachi et al., 2017). However, we do not rule out the possibility that GFSs would use other food resources, such as fish, as was observed in the stranded GFS in 2012 in accordance with Gallo-Reynoso & Esperón-Rodríguez (2013) who report about 10 species of fish taken by GFSs. This finding and the lack of relationship between our data and climatic anomalies support the importance of the MCP region for foraging activities, at least on a seasonal basis, of different marine mammal species such as GFSs.

Unfortunately, there are no data on pinniped sightings in our study area during the years or decades prior to 2010. Therefore, it is not possible to assess a historical trend of GFS sightings for the region. However, we assume that a gradual phenomenon took place, similar to that reported for other latitudes such as California where GFS records have become more frequent since 1980 at islands such as San Miguel (34° 2.161' N, 120° 21.575' W) and Los Farallones (37° 41.063' N, 123° 0.763' W) (Stewart et al., 1987, 1992; Hanni et al.,

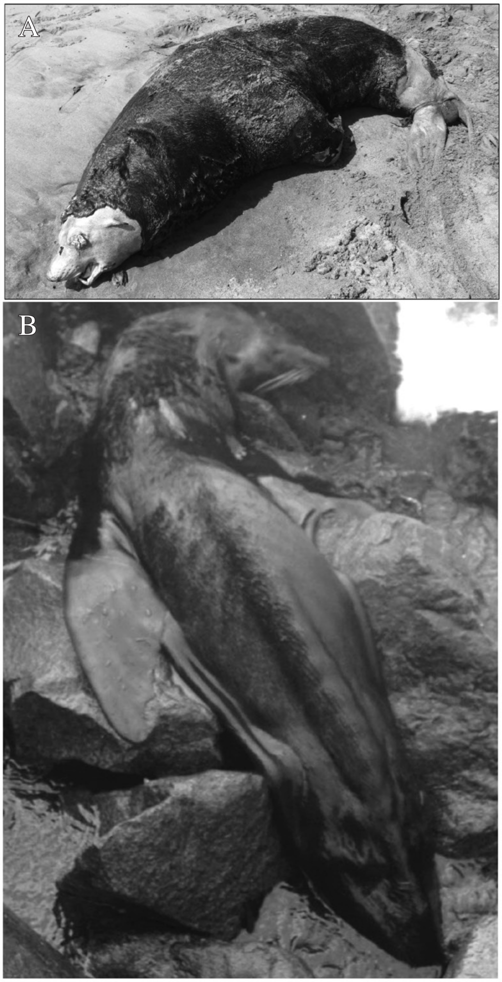


**Figure 3.** Stranded Guadalupe fur seals: (A) An adult male stranded in a state of advanced decomposition on Miramar Beach, Colima, 19 October 2012; and (B) an emaciated adult individual resting on Tepalcates Channel breakwater in Colima, 12 January 2016. (*Photo credit:* Grupo Universitario de Investigación de Mamíferos Marinos [GUIMM], Universidad de Colima)

1997). The first record of GFS recolonization at the San Benito Archipelago occurred in 1997, with approximately 300 individuals (Maravilla-Chávez & Lowry, 1999); whereas in recent years (2014), up to almost 4,000 individuals have been counted (Elorriaga-Verplancken et al., 2016b).

The present study shows the potential for GFSs to disperse far away from their main reproductive colony, which can be related to their successful species recovery. This species was observed during several seasons in the MCP region, with no significant relationship with regional oceanographic temperature anomalies. The Revillagigedo Archipelago (probably Socorro Island) has been suggested as part of the historical GFS distribution prior to exploitation (Townsend, 1924; Hamilton, 1951). These islands are located approximately 500 km west from our survey region. Based on our findings and due to this relatively short distance, we suggest that the GFS recolonization of these southern islands could occur in the future if the current population growth rate (5.9% per year; García-Aguilar et al., 2018) continues. However, it will be highly important to assess the impact of persisting oceanographic anomalies, like the North Pacific Heatwave (Kintisch, 2015), which have caused mortality events of GFSs in southern California between 2015 and 2018 (NOAA Fisheries, 2018), on dispersal scenarios like the one presented herein and on the overall GFS population.

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