Guadalupe Fur Seal Population Census and Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean

Preliminary Summary
March 28, 2019 – December 31, 2019

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Cover photo
Four Guadalupe fur seals on a rocky outcrop at the north end of Guadalupe Island, México. Photo credit: J. Bredvik, NAVFAC SW, Environmental Corp. Permit #: SERMARNAT SGPA/DGVS/01643/19, CONANP F00.DRPBCPN.RBIG.0242/2019, and SEMAR 368/19.

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14. ABSTRACT
Guadalupe fur seals are listed as threatened under the U.S. Endangered Species Act and endangered under Mexican law. However, prior to the first year of this study in 2018, the last full census for this species was in 2010, making it difficult to develop current and accurate population estimates and trends. To determine the degree to which this recovering population uses U.S. Navy training and testing ranges in the North Pacific, updated population information for Guadalupe fur seals is needed in addition to tracking at-sea movement patterns using satellite transmitters. Similar to 2018, during the 2019 summer breeding season, direct counts of Guadalupe fur seals were conducted at Guadalupe Island and San Benito Archipelago, México. At San Benito Archipelago, twice as many animals were counted in 2019 relative to 2018, but only approximately 20 mom-pup pairs were observed at this site during both years. In contrast, at Guadalupe Island, approximately the same number of animals were observed in 2018 and 2019, but there were ~3,000 more adult females and ~2,500 fewer pups in 2019 compared with 2018. During the 2019 surveys at Guadalupe Island, we also used a remotely piloted aircraft to collect >12,000 visual and thermal still images as well as 4K video to test the feasibility of using aerial imagery to improve our population estimates and reduce animal disturbance. These images currently are being processed using various tools and techniques. With only two consecutive years of Guadalupe fur seal population monitoring, it is unknown if these 2018-2019 census data reflect interannual fluctuations or longer term abundance trends, and therefore, ongoing annual censuses for this species are needed.

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Abstract

Guadalupe fur seals are listed as threatened under the U.S. Endangered Species Act and endangered under Mexican law. However, prior to the first year of this study in 2018, the last full census for this species was in 2010, making it difficult to develop current and accurate population estimates and trends. To determine the degree to which this recovering population uses U.S. Navy training and testing ranges in the North Pacific, updated population information for Guadalupe fur seals is needed in addition to tracking at-sea movement patterns using satellite transmitters. Similar to 2018, during the 2019 summer breeding season, direct counts of Guadalupe fur seals were conducted at Guadalupe Island and San Benito Archipelago, México. At San Benito Archipelago, twice as many animals were counted in 2019 relative to 2018, but only approximately 20 mom-pup pairs were observed at this site during both years. In contrast, at Guadalupe Island, approximately the same number of animals were observed in 2018 and 2019, but there were ~3,000 more adult females and ~2,500 fewer pups in 2019 compared with 2018. During the 2019 surveys at Guadalupe Island, we also used a remotely piloted aircraft to collect >12,000 visual and thermal still images as well as 4K video to test the feasibility of using aerial imagery to improve our population estimates and reduce animal disturbance. These images currently are being processed using various tools and techniques. With only two consecutive years of Guadalupe fur seal population monitoring, it is unknown if these 2018-2019 census data reflect interannual fluctuations or longer term abundance trends, and therefore, ongoing annual censuses for this species are needed.

Introduction

Guadalupe fur seals (*Arctocephalus townsendi* or *A. philippii townsendi*) primarily use two terrestrial sites, both of which are in México. Greater than 99% of the population breeds on Guadalupe Island. This large oceanic island is located ~300 km offshore off the west coast of the Baja California Peninsula and has a narrow, rugged coastline backed by steep cliffs (highest point ~1,300 m). Guadalupe Island also is ~300 km west-northwest of San Benito Archipelago, which is the main recolonization site for Guadalupe fur seals with <30 births documented each year since the species was rediscovered at this site in 1997 (Maravilla-Chavez and Lowry 1999, Aurioles-Gamboa et al. 2010, Sierra-Rodríguez 2015, Elorriaga-Verplancken et al. 2016). San Benito Archipelago is located on the continental shelf near Punta Eugenia, Baja California Sur and comprised of three small low-lying islands (highest point ~200 m).

Despite federal protection in the U.S. and México over the last four decades, Guadalupe fur seal population monitoring efforts have been infrequent at Guadalupe Island. Prior to 2018, the last full census at this site was in 2010 with 13,327 individuals counted (3,183 of which were pups; Garcia-Capitanachi et al. 2017) and the last pup count was in 2013 (4,924 pups; Garcia-Aguilar et al. 2018). Recent studies have estimated average annual population growth rates of 11% based on total numbers from 1955-2010 (Hernández-Camacho & Trites 2018) and 5.9% based on pups counts from 1984-2013 (Garcia-Aguilar et al. 2018). However, current population estimates and trends are lacking during a period when there has been persistent warm water anomalies in the California Current System that have decreased prey availability and resulted in increased mortality, especially of young animals (Cavole et al. 2016, McClatchie et al. 2016, Morgan et. al 2019, Gálvez et al. 2019, NOAA Fisheries 2019, Sanford et al. 2019).

Population monitoring has been more consistent at San Benito Archipelago with censuses at this site almost every summer since 2007 (no surveys in 2011 and 2016; Aurioles-Gamboa et al. 2010, Sierra-Rodríguez 2015, Elorriaga-Verplancken et al. 2016, Norris & Elorriaga-Verplancken 2019). Guadalupe fur seal abundance peaked at this site in 2009 (5,271 individuals counted) but has since decreased with significant interannual variability (Elorriaga-Verplancken et al. 2016, García-Capitanachi et al. 2017, Norris & Elorriaga-Verplancken 2019).

With insufficient data available on some key aspects of Guadalupe fur seal biology and ecology, the goal of this study is to better understand Guadalupe fur seal abundance, behavior, distribution, and habitat use and determine the degree to which this recovering population uses U.S. Navy training and testing ranges in the North East Pacific. There are two principle components of this multiyear study: (1) updating overall population information for Guadalupe fur seals, and (2) tracking the at-sea movement patterns of this species using satellite transmitters. This is the second year of this project with censuses performed at Guadalupe Island and San Benito Archipelago during the 2019 breeding season. Satellite tags will be deployed on animals at Guadalupe Island in March 2020.

Methods

Study Sites

Guadalupe fur seal population monitoring surveys were conducted at Guadalupe Island, México (29.05ºN, 118.28ºW) and San Benito Archipelago, México (28.30ºN, 115.59ºW; Figure 1) during the 2019 summer breeding season (June-August) because this is when the most animals are found on land (Gallo-Reynoso 1994). Animals are classified into five demographic groups based on morphology and behavior: adult males, subadult males, adult females, juveniles, and pups with an unknown category for individuals that could not be identified (Gallo-Reynoso 1994). Surveys were timed to follow peak pupping season at Guadalupe Island, with most pups born by late July, and to coincide as closely as possible with the timing of our 2018 surveys (11-14 July 2018 at San Benito Archipelago and 30 July-4 August 2018 at Guadalupe Island). As a result, in both years, most adult males already had departed the rookery before we conducted our surveys and are underrepresented in our census data, but adult males represent a small portion of the population.

Direct Counts

Direct counts of Guadalupe fur seals were conducted at San Benito Archipelago from 23-29 July 2019, using the same methodologies as those used in 2018 and previous years (2012-2015 and 2017; Elorriaga-Verplancken et al. 2016, Norris & Elorriaga-Verplancken 2019). Briefly, for the three islands in this archipelago, land-based surveys (walked inland of the animals) were used for all areas of the coastline accessible by foot (all of Middle Island and most of West Island; Figure 1). Surveys from a small boat <50 m from shore were used when land-based surveys were not possible (all of East Island and a small section of West Island). All pup and non-pup counts were performed by the same individual to maintain consistency with previously collected Guadalupe fur seal census data at San Benito Archipelago.

The Guadalupe fur seal population survey was conducted at Guadalupe Island from 8-13 August 2019 with some differences in methodologies from those used in 2018 (Norris & Elorriaga-Verplancken 2019). Land-based survey methods (walked through colony) at Punta Sur (southernmost point) were similar in 2018 and 2019. Boat-based surveys were used for the entire east side of the island and three nearby islets south of Punta Sur; however, because of high northwest winds and swell, we were unable to survey the west side of the island in 2019. In addition, during sections of the boat-based surveys on the east side, the small boat traveled faster (pushed by the winds at the southern end) and farther from the coastline, especially where there were shallow nearshore rocks, in 2019 compared with 2018. All non-pups were counted and classified by the individual with the most experience assigning Guadalupe fur seals to demographic groups during visual surveys. Pups were counted by two other observers, one of which also counted pups at Guadalupe Island in 2018. Similar to 2018, these two observers counted pups along sections of the coast demarcated by visual features, and the highest pup count from the two observers for each section was used. Pup counts were not repeated or averaged when there were significant differences between the two counters as was done in 2018. We recorded substrate type (boulder, high platform, low platform, pebble beach, and wall) during the boat-based counts but did not differentiate between large and medium boulders as was done in 2018.

Aerial Imagery

During the August 2019 surveys at Guadalupe Island, we also used a remotely piloted aircraft (RPA or drone) to test the feasibility of using aerial imagery to improve our counts at Punta Sur to replace or supplement walk-through surveys because these create disturbance for mothers with <1-month-old pups. We also wanted to test if aerial imagery could be used during boat-based surveys to develop substrate-specific correction factors to better account for animals missed from the boat. We used a quadcopter RPA with a built-in 20-megapixel, 84° field-of-view visual camera (DJI Phantom 4 Pro with camera model FC6310, Dajiang Baiwang Technology Co., Shenzhen, China).

Intermittent RPA surveys were flown during boat-based surveys because our battery supply allowed for approximately 3 h of flight time each day (>6 h of total survey time per day; Figure 2, Table 1). These surveys were manually flown using Pix4DCapture Version 4.6.0 (Pix4D, Prilly, Switzerland) because automated flights with directly overhead (*i.e.*, nadir) images were not feasible due to the narrow coastline backed by steep cliffs. Visual images were taken every 9 m initially (oversampling with >4 images per object), but this ground distance was increased to 12 m to give 3-4 images per object and 60-80% front and side overlap between images.

Global positioning system (GPS) coordinates (accuracy generally <10 m) were recorded every 10 min during boat-based surveys and at the start of each survey section with and without RPA flights, which coincided with the end coordinates for the preceding section (Figure 2, Table 1). The start and end of each RPA flight also was marked by a physical feature (*e.g.*, peninsula, large boulder, vegetation, or made-made structure) that could be used to match up direct counts with sections with aerial imagery for the development of boat-based survey correction factors. For each boat-based survey section with and without RPA flights, direct counts were calculated for non-pups on land and in the water because we cannot differentiate among adult males, subadult males, adult females, juveniles, and animals of unknown age/sex class using aerial imagery and for pups on land only because they had not entered the water yet (Table 1).

At Punta Sur, two full RPA surveys were flown at the main peninsula; one while we performed our walk-through survey on 10 August 2019 as animals were disturbed and flushed from crevices (nadir visual images only) and one on 13 August 2019 without any disturbance (nadir and oblique visual images; Figure 3). A full RPA survey also was flown at the west side of Punta Sur on 13 August 2019 without any disturbance (nadir visual images only; Figure 3). These Punta Sur flight plans were developed in DroneDeploy (https://www.dronedeploy.com/) with 75% front and 65% side overlap. Each survey lasted approximately 40 min, requiring three battery changes that were completed as quickly as possible to minimize potential movement of animals between flights. In DroneDeploy, ortho-mosaic images from the visual images were produced for each survey with map resolutions ranging from 0.33-0.37 in/pixel.

Flight altitudes were chosen to minimize animal disturbance while providing sufficient resolution to identify fur seals (Adame et al. 2017, Flores Hernández et al. 2019). On average, the RPA was flown 15-23 m above the animals, which for manual flights was at an altitude of 10-15 m and 15-50° down from a level horizon. Additionally, thermal images were collected every 2 s along with visual imagery for a short partial survey at the main peninsula of Punta Sur and two boat-based survey sections using a FLIR Systems, Inc. Vue Pro Radiometric 640 camera with a 13 mm lens

(https://www.flir.com/). To further test various methodologies for counting fur seals using aerial imagery, during one boat-based survey section, 4K video was collected instead of photographs.

Results and Discussion

Direct Counts

At San Benito Archipelago, twice as many Guadalupe fur seals were counted in 2019 relative to 2018 (Table 2, Figure 4). In 2019, 90% of the fur seal were juveniles, compared with 84% in 2018, but similar to every other survey at this site since fur seals were rediscovered here in 1997, less than 30 mom-pup pairs were observed. Therefore, San Benito Archipelago still is considered a recolonization site rather than an established rookery (Figure 4).

As a result, Guadalupe Island remains the only established rookery (breeding site) for the Guadalupe fur seal population. In 2018 and 2019, approximately the same number of animals were observed at Guadalupe Island (Table 3, Figure 4). In 2018, only ~300 fur seals, 77% of which were juveniles, were counted on the west side of Guadalupe Island, and with the weather conditions in 2019, fewer animals likely were using this side of the island during our surveys. Thus, not surveying the west side of Guadalupe Island in 2019 likely did not significantly change our counts.

In contrast to the 2018 counts, only 41% of the total number of animals observed at Guadalupe Island in 2019 were pups, which is a decrease from 51% during the previous breeding season. Approximately 3,000 more adult females, most of which were in the water (3,668 females in 2019 versus 1,885 females in 2018), and 2,500 fewer pups were observed on the island in 2019 compared with 2018 (Table 3, Figure 4). This resulted in an adult female to pup ratio of 1:0.82 in 2019, whereas the adult female to pup ratio in 2018 was 1:1.29. Approximately 85% of non-pups observed in 2019 were adult females (81% in 2018). Fewer adult males were observed at the island in 2019 relative to 2018, likely because the surveys were conducted slightly later after the peak breeding season, but numbers of juveniles, subadult males, and fur seals of unknown age class and sex were almost identical between years (Table 3).

At Guadalupe Island, boulder is the dominant substrate type, and most pups were found along the northern third of the east side of the island (north of section number 37; Figure 2, Table 1). In contrast, slightly more non-pups, most of which were adult females on land, were distributed along the middle third of the east side of the island (between section numbers 17 and 37; Table 1).

Emigration of animals from Guadalupe Island to San Benito Archipelago that occurred during the first phase of recolonization (Aurioles-Gamboa et al. 2010) may still occur with juveniles displaced to San Benito Archipelago from Guadalupe Island during the breeding season. However, no movements between these two sites were recorded for juvenile fur seals captured at Guadalupe Island and tracked using satellite telemetry instruments through the breeding season (April-September; Norris et al. 2017), and the exchange of Guadalupe fur seals between these two sites remains unknown. Continued population monitoring is necessary to better understand the relationship between Guadalupe fur seal abundance at these two sites.

In terms of overall abundance, fur seal population estimates frequently are extrapolated from pup counts. Newly weaned pups transitioning to independent foraging are extremely vulnerable to environmental perturbations that decrease prey availability. During anomalously warm water years, greater numbers of newly weaned otariid pups strand along the U.S. West Coast in emaciated condition (McClatchie et al. 2016, Melin et al. 2010), and ~97% of the animals included

in the ongoing Guadalupe fur seal Unusual Mortality Event in California have been 9-14 months old (NOAA Fisheries 2019). Fur seal pups that stranded in 2015 (the first year of the Unusual Mortality Event) were born in 2014, and many pinniped females first reproduce at an age of ~5 years old. Therefore, increased pup mortality in 2014-2015 would lead to an approximately 5-year delay in decreased recruitment of breeding females and a corresponding decrease in the number of pups born in 2019. Although there were no pup counts from 2014-2017, from 2018 to 2019, pup counts decreased by 19.2% at Guadalupe Island (Figure 4). This decrease from one year to the next may reflect interannual fluctuations or a longer term decrease in abundance, and ongoing annual censuses are needed to tease apart the drivers of these population trends.

RPA Flights and Aerial Imagery

Greater than 12,000 visual and thermal images were collected during the Guadalupe Island fur seal surveys. Example images from the automated (Punta Sur) and manual (boat-based) RPA surveys are provided in Figures 5 and 6. Currently, these images are being processed, and various tools and techniques to count animals with georeferencing are being explored and tested.

Figures

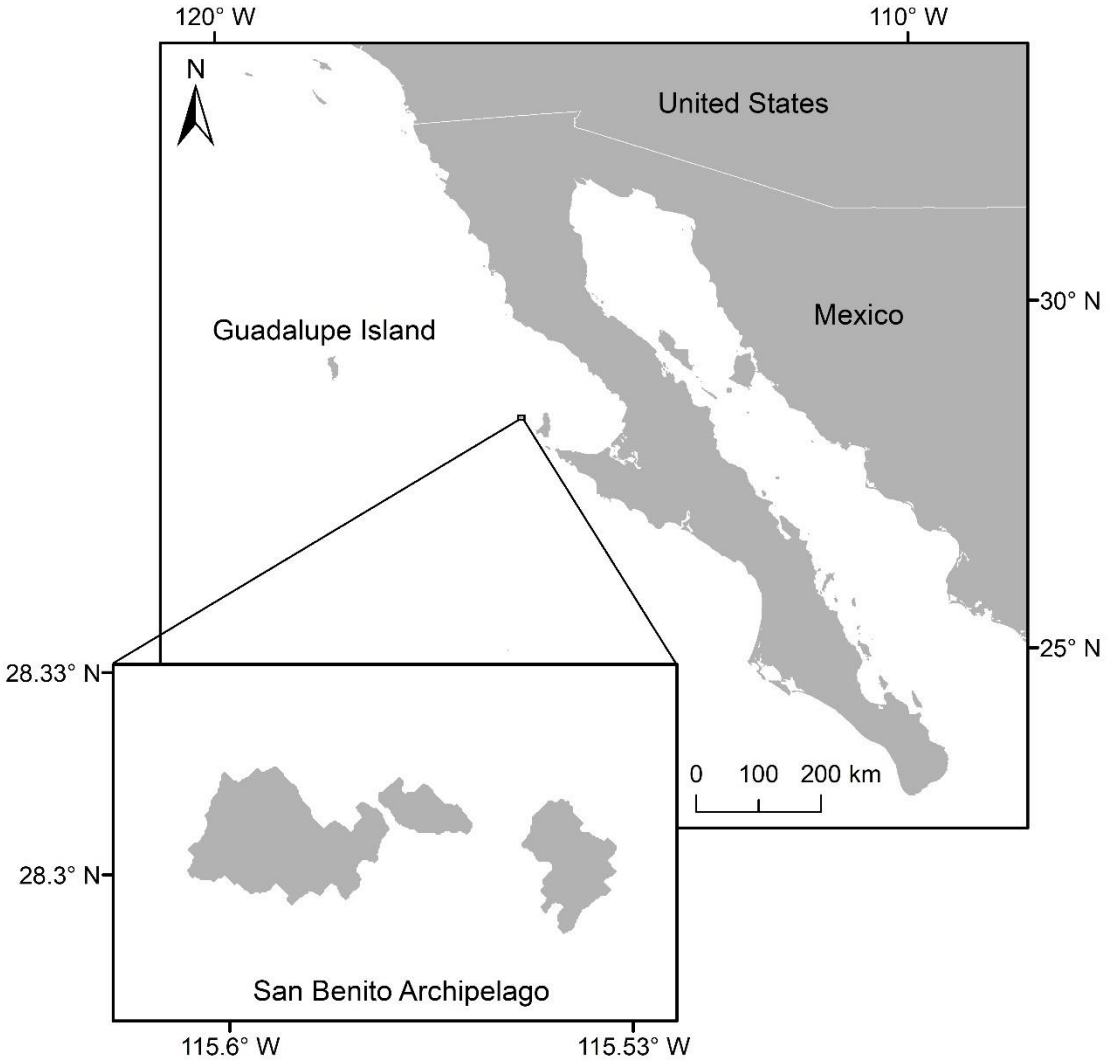

Figure 1. Map of the two study sites, Guadalupe Island and San Benito Archipelago, offshore of the Baja California Peninsula, México.

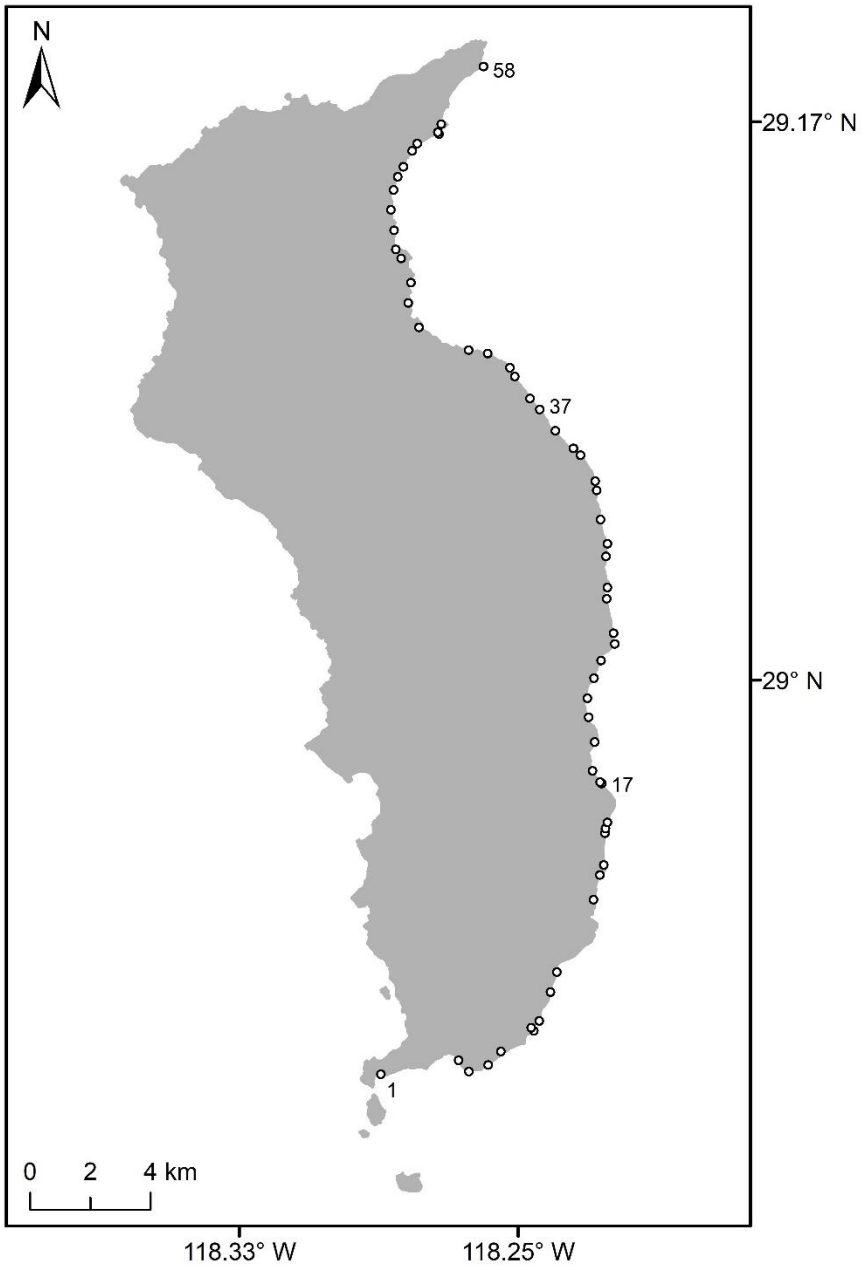

Figure 2. Map of Guadalupe Island with the start of each boat-based survey section with and without drone flights, which coincided with the end coordinates for the preceding section, indicated by the open circles. These surveys were conducted south to north over three days (8 August, 9 August, and 11 August 2019) with the numbers in this map labeling the coordinates at the start of each day (1, 17, and 37) and end of the survey effort (58) and matching the numbers given in Table 1.

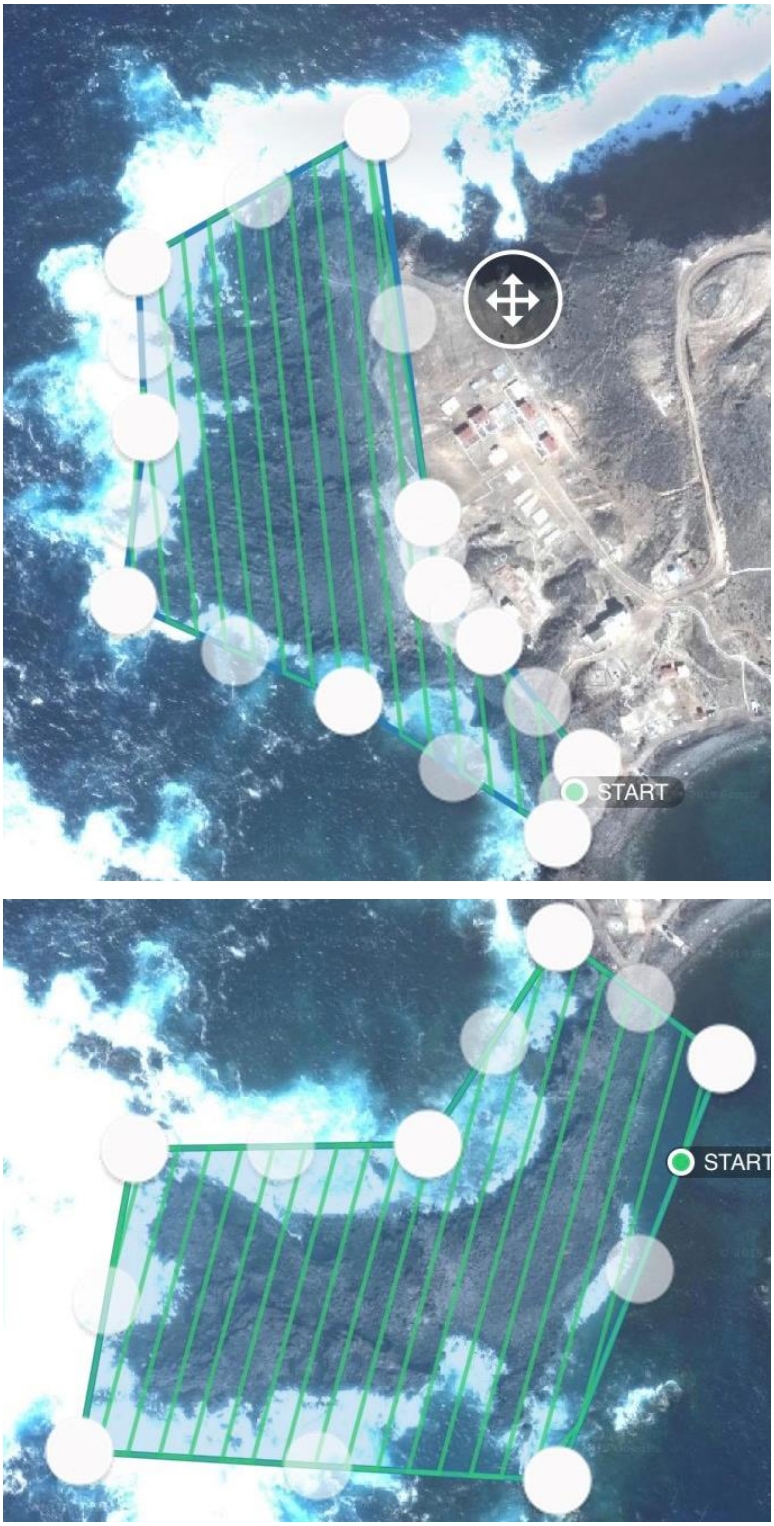

Figure 3. Drone flight plans for the main peninsula (bottom panel) and west side (top panel) of Punta Sur (southernmost point) at Guadalupe Island. Parallel green lines indicate the drone flight path, and white circles represent nodes for creating the transect area (blue/green outline).

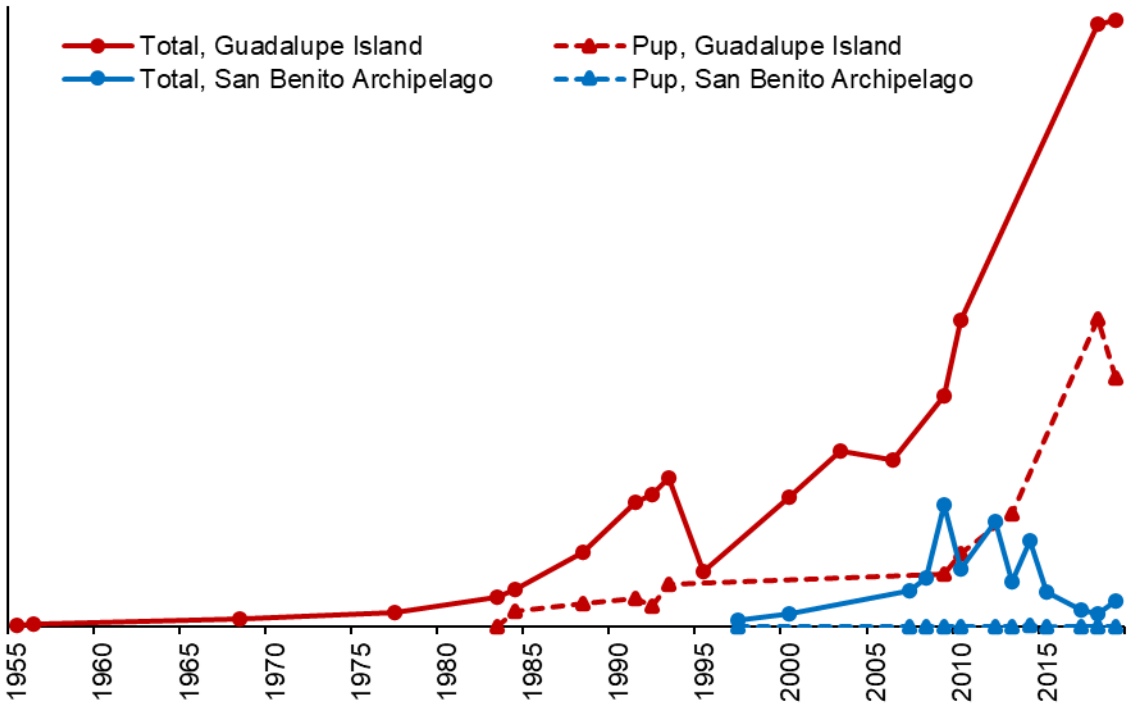

Figure 4. Relative number of Guadalupe fur seals counted (uncorrected) at Guadalupe Island (red) and San Benito Archipelago (blue) during the summer breeding season (June-August) from 1955-2019 for all animals, including pups, (circles and solid lines) and pups only (triangles and dashed lines). Data sources for counts prior to 2019 are provided in Appendix 2. Y-axis labels were intentionally omitted from this report.

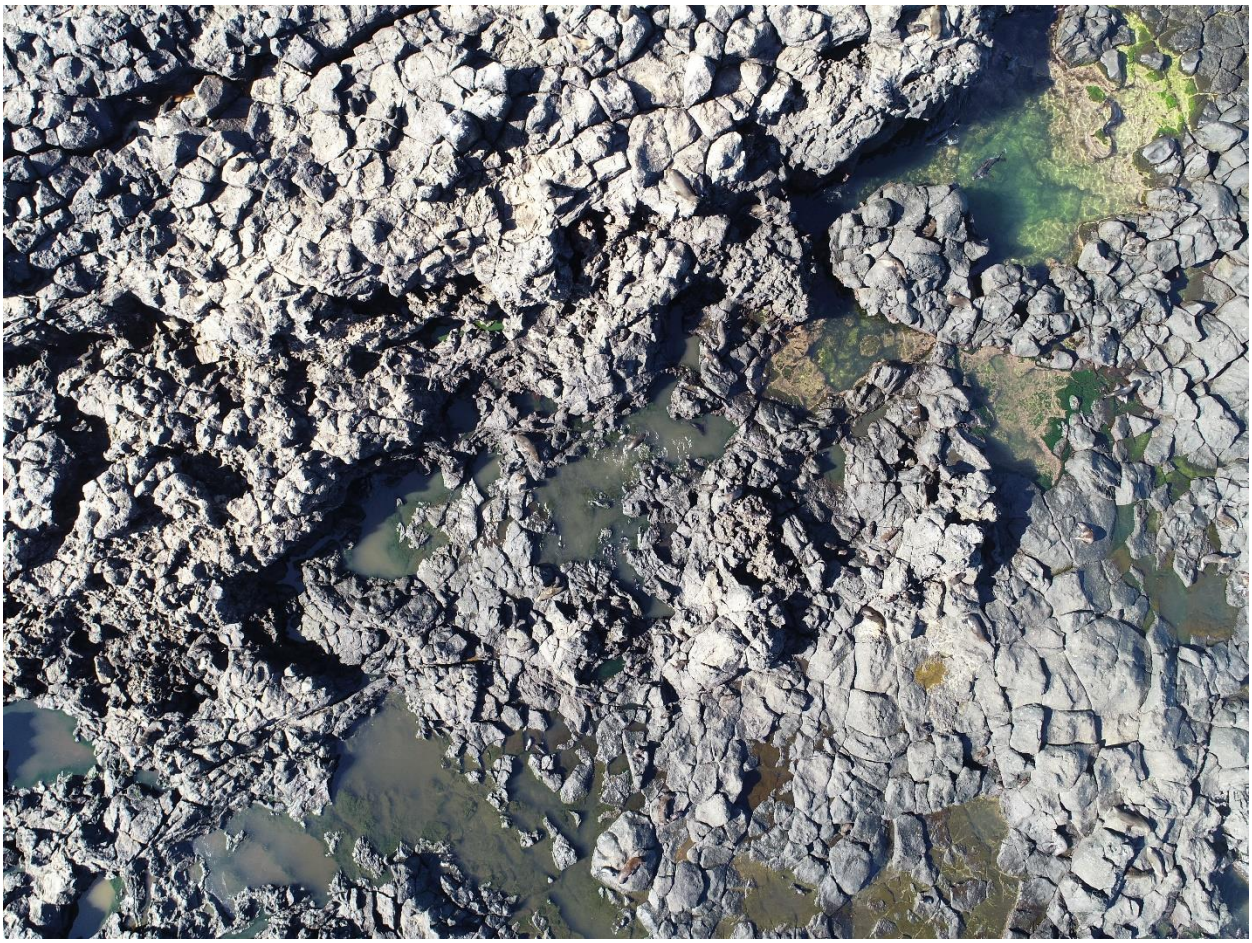

Figure 5. Unedited example of a nadir (*i.e.*, directly overhead) visual image collected during an automated remotely piloted aircraft survey at Punta Sur, Guadalupe Island. The raw high-resolution image can be zoomed to better detect and count fur seals.

Figure 6. Edited examples of oblique thermal (left panel) and visual (right panel) images collected during a manual remotely piloted aircraft (RPA) boat-based survey along the east coast of Guadalupe Island. These images were cropped and zoomed to align the areas captured by the two RPA cameras to demonstrate the utility of having both image types to detect and count fur seals.

Tables

Table 1. Coordinates for the start of each boat-based survey section, which coincided with the end coordinates for the preceding section, with and without drone flights at Guadalupe Island. These surveys were conducted along the east coast from south to north over three days in 2019: 8 August (section # 1-16), 9 August (section #17-36), and 11 August (section # 37-57). Substrate type was recorded for each section as most to least common from left to right in the table: boulder (B), high platform (H), low platform (L), pebble beach (P), and wall (W). Non-pups counted on land and in the water were grouped across adult males, subadult males, adult females, juveniles, and unknown age/sex class categories. All pups were on land. Aerial video was recorded for section 13 (no photographs), and thermal and visual images were collected for sections 44-45.
[table omitted from this report]

Table 2. Number of Guadalupe fur seals observed at San Benito Archipelago during summer 2019. Raw counts (total, uncorrected) were corrected for the number of adult females using the number of pups (1:1 ratio).
[table omitted from this report]

Table 3. Number of Guadalupe fur seals observed at Guadalupe Island during summer 2019. For boat-based surveys, substrate type was recorded. Raw counts (total, uncorrected) were not corrected because more adult females were observed than pups.
[table omitted from this report]

Literature Cited

Adame, K., Pardo, M. A., Salvadeo, C., Beier, E., & Elorriaga-Verplancken, F. R. (2017). Detectability and categorization of California sea lions using an unmanned aerial vehicle. *Marine Mammal Science, 33*, 913-925.

Aurioles-Gamboa, D., Elorriaga-Verplancken, F. R., & Hernández-Camacho, C. J. (2010). The current population status of Guadalupe fur seal (*Arctocephalus townsendi*) on the San Benito Archipelago, Mexico. *Marine Mammal Science, 26*(2), 402-408.

Cavole, L. M., Demko, A. M., Diner, R. E., Giddings, A., Koester, I., Pagniello, C. M., Paulsen, M.L., Ramirez-Valdez, A., Schwenck, S.M., Yen, N.K., & Zill, M. E. (2016). Biological impacts of the 2013–2015 warm-water anomaly in the Northeast Pacific: Winners, losers, and the future. *Oceanography*, *29*(2), 273-285.

Elorriaga-Verplancken, F. R., Sierra-Rodríguez, G. E., Rosales-Nanduca, H., Acevedo-Whitehouse, K., & Sandoval-Sierra, J. (2016). Impact of the 2015 El Niño-Southern Oscillation on the abundance and foraging habits of Guadalupe fur seals and California sea lions from the San Benito Archipelago, Mexico. *PloS one*, *11*(5), e0155034.

Flores Hernández, E. O., Heckel, G., & Pardo Rueda, M. A. (2019). Abundance and terrestrial habitat preferences of the Guadalupe fur seal (*Arctocephalus philippii townsendi*) at Isla Guadalupe, México. 2019 World Marine Mammal Science Conference, 9-12 December 2019. Barcelona, Spain.

Gallo-Reynoso, J. P. (1994). Factors affecting the population status of Guadalupe fur seal, *Arctocephalus townsendi* (Merriam, 1897), at Isla de Guadalupe, Baja California, Mexico. Doctoral dissertation, University of California, Santa Cruz. Santa Cruz, CA.

Gálvez, C., Pardo, M. A., & Elorriaga-Verplancken, F. R. (2019). Impacts of extreme ocean warming on the early development of a marine top predator: The Guadalupe fur seal. *Progress in Oceanography*, 102220.

García-Aguilar, M. C., Elorriaga-Verplancken, F. R., Rosales-Nanduca, H., & Schramm, Y. (2018). Population status of the Guadalupe fur seal (*Arctocephalus townsendi*). *Journal of Mammalogy, 99*(6), 1522-1528.

García-Capitanachi, B., Schramm, Y., & Heckel, G. (2017). Population fluctuations of Guadalupe fur seals (*Arctocephalus philippii townsendi*) between the San Benito Islands and Guadalupe Island, Mexico, during 2009 and 2010. *Aquatic Mammals, 43*(2), 492-500.

Hernández-Camacho, C. J., & Trites, A. W. (2018). Population viability analysis of Guadalupe fur seals *Arctocephalus townsendi*. *Endangered Species Research, 37*, 255-267.

Maravilla-Chavez, M. O., & Lowry, M. S. (1999). Incipient breeding colony of Guadalupe fur seals at Isla Benito del Este, Baja California, Mexico. *Marine Mammal Science*, *15*(1), 239-241.

McClatchie, S., Field, J., Thompson, A. R., Gerrodette, T., Lowry, M., Fiedler, P. C., Watson, W., Nieto, K. M., & Vetter, R. D. (2016). Food limitation of sea lion pups and the decline of forage off central and southern California. *Royal Society Open Science, 3*(3), 150628.

Melin, S. R., Orr, A. J., Harris, J. D., Laake, J. L., DeLong, R. L., Gulland, F. M. D., & Stoudt, S. (2010). Unprecedented mortality of California sea lion pups associated with anomalous oceanographic conditions along the central California coast in 2009. *CalCOFI Reports, 51*, 182-194.

Morgan, C. A., Beckman, B. R., Weitkamp, L. A., & Fresh, K. L. (2019). Recent Ecosystem Disturbance in the Northern California Current. *Fisheries*.

NOAA Fisheries (2019). 2015-2019 Guadalupe fur seal Unusual Mortality Event in California, Oregon, and Washington. Retrieved from: https://www.fisheries.noaa.gov/national/marine-life-distress/2015-2019-guadalupe-fur-seal-unusual-mortality-event-california.

Norris, T. A., & Elorriaga-Verplancken, F. R. (2019). Guadalupe Fur Seal Population Census and Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean, 2018-2019. Technical Report. Prepared for Commander, Pacific Fleet, Environmental Readiness Division. Submitted to Naval Facilities Engineering Command (NAVFAC) Southwest, Environmental Corp, San Diego, CA 9213, under Contract No. N62473-18-2-004. November 2019.

Norris, T., Fauquier, D., Field, C., Whoriskey, S., Gálvez, C., Rowles, T., Viezbicke, J., & Elorriaga-Verplancken, F.R. (2017). At-sea distribution and habitat use of free-ranging and rehabilitated Guadalupe fur seals. 6th International Bio-logging Science Symposium. 25-29 September 2017. Konstanz, Germany.

Sanford, E., Sones, J. L., García-Reyes, M., Goddard, J. H., & Largier, J. L. (2019). Widespread shifts in the coastal biota of northern California during the 2014-2016 marine heatwaves. *Scientific reports*, *9*(1), 4216.

Sierra-Rodríguez G.E. (2015). Recolonización y hábitos alimentarios maternos del lobo fino de Guadalupe (*Arctocephalus philippii townsendi*) del Archipiélago San Benito, BC, México. M.S. thesis, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, La Paz, BCS.

Appendices

Appendix 1. Additional data collection at Guadalupe Island, México in summer 2019.

Forty pups (<1 month old) were captured at Punta Sur during the population survey at Guadalupe Island for ongoing trophic ecology studies (measured, weighed, and a small patch of fur clipped), and all other pinniped species were counted during our surveys at Guadalupe Island and San Benito Archipelago. In addition, three female fur seals satellite tagged in November 2018 were sighted at Punta Sur (main peninsula) on 10 August 2019 (Table S1). Each of these animals was in good body condition, one (tag # 94V) was observed with pup (also in good condition; Figure S1), and the satellite tag of each was not attached. There was very minor guard hair thinning at the satellite tag attachment site, and the hair clipped on the hip for trophic ecology studies had not regrown.

Table S1. Tagging summary for three adult (A) and juvenile (J) female Guadalupe fur seals captured at Guadalupe Island in November 2018 and sighted in August 2019.

Age class	Mass (kg)	Length (cm)	Axillary Girth (cm)	Flipper tag #	Tagging Date	Last transmission date	Transmission duration (d)
J	29.6	128	70	83V	11/16/2018	1/14/2019	59
A	35.7	138	81	94V	11/18/2018	1/18/2019	61
J	36.2	130	79	95V	11/18/2018	2/14/2019	88

Figure S1. Photograph of adult female "94V" that was satellite tagged at Guadalupe Island on 18 November 2018 and observed with her <1-month-old pup on 10 August 2019. The faint mark between her shoulders indicates some minor guard hair thinning and loss where the satellite tag was attached, and the more prominent mark on her hip is where fur was clipped for stable isotope analyses and has not regrown. This female was captured with a 16.7-kg male pup in November 2018, meaning she was pregnant and nursing a pup during the satellite tracking period.

Appendix 2. Data sources for Guadalupe fur seal abundance during the breeding season (June-August) at Guadalupe Island (GI) and San Benito Archipelago (SBA) from 1955-2018.

Year(s)	Island(s)	Source
1955 1956	GI	Hubbs, C. L. (1956). Back from oblivion. Guadalupe fur seal, still a living species. *Pacific Discovery, 9,* 14-21.
1968	GI	Brownell, R. L., Jr., DeLong, R.L ., & Schreiber, R. W. (1974). Pinniped populations at Islas de Guadalupe, San Benito, Cedros, and Natividad, Baja California, in 1968. *Journal of Mammalogy, 55,* 469-472.
1977	GI	Fleischer, L. A. (1978). The distribution, abundance, and population characteristics of the Guadalupe fur seal, *Arctocephalus townsendi* (Merriam 1897). M.S. thesis, University of Washington. Seattle, WA.
1983 1991 1993	GI	Gallo Reynoso, J. P. (1994). Factors affecting the population status of Guadalupe fur seal, Arctocephalus townsendi (Merriam, 1897), at Isla de Guadalupe, Baja California, Mexico. Doctoral dissertation, University of California, Santa Cruz. Santa Cruz, CA.
1984	GI	Seagars, D. J. (1984). The Guadalupe fur seal: a status review. National Marine Fisheries Service, Southwest Region. Administrative Report. SWR-84-6.
1988	GI	Torres-Garcia, A. (1991). Estudio demográfico del lobo fino de Guadalupe (*Arctocephalus townsendi* , Merriam, 1897) en la Isla Guadalupe, BC, México. B.S. thesis, Facultad de Ciencias, UNAM, Mexico City.
1995 2000 2003	GI	Gallo Reynoso, J. P., Le Boeuf, B. J., Figueroa-Carranza, A. L., & Maravilla-Chávez, M.O. (2005). Los pinnípedos de Guadalupe. In: Santos del Prado, K., Peters, E. (eds) Isla Guadalupe. Instituto Nacional de Ecología, Mexico City.
1997	SBA	Maravilla-Chavez, M. O., & Lowry, M. S. (1999). Incipient breeding colony of Guadalupe fur seals at Isla Benito del Este, Baja California, Mexico. *Marine Mammal Science , 15* (1), 239-241.
2000 2007 2008	SBA	Aurioles-Gamboa, D., Elorriaga-Verplancken, F. R., & Hernández-Camacho, C. J. (2010). The current population status of Guadalupe fur seal (*Arctocephalus townsendi*) on the San Benito Archipelago, Mexico. *Marine Mammal Science, 26* (2), 402-408.
2006	GI	Hernández-Montoya, J. C. (2009). Distribución, abundancia y estructura alimentaria del lobo fino de Guadalupe (*Arctocephalus townsendi*) en Isla Guadalupe, México. M.S. thesis, Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, BC.
2009 2010	GI SBA	García-Capitanachi, B., Schramm, Y., & Heckel, G. (2017). Population fluctuations of Guadalupe fur seals (*Arctocephalus philippii townsendi*) between the San Benito Islands and Guadalupe Island, Mexico, during 2009 and 2010. *Aquatic Mammals, 43* (2), 492-500.
2012 2013	SBA	Sierra-Rodríguez G.E. (2015). Recolonización y hábitos alimentarios maternos del lobo fino de Guadalupe (*Arctocephalus philippii townsendi*) del Archipiélago San Benito, BC, México. MSc thesis, Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional, La Paz, BCS.
2013	GI	O. Sosa-Nishizaki (pers. comm.) reported in García-Aguilar, M. C., Elorriaga-Verplancken, F. R., Rosales-Nanduca, H., & Schramm, Y. (2018). Population status of the Guadalupe fur seal (Arctocephalus townsendi). Journal of Mammalogy, 99(6), 1522-1528.
2014 2015	SBA	Elorriaga-Verplancken, F. R., Sierra-Rodríguez, G. E., Rosales-Nanduca, H., Acevedo-Whitehouse, K., & Sandoval-Sierra, J. (2016). Impact of the 2015 El Niño-Southern Oscillation on the abundance and foraging habits of Guadalupe fur seals and California sea lions from the San Benito Archipelago, Mexico. *PloS one , 11* (5), e0155034.
2017	SBA	Elorriaga-Verplancken unpublished
2018	GI SBA	Norris, T. A., & Elorriaga-Verplancken, F. R. (2019). Guadalupe Fur Seal Population Census and Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean, 2018-2019. Technical Report. Prepared for Commander, Pacific Fleet, Environmental Readiness Division. Submitted to Naval Facilities Engineering Command (NAVFAC) Southwest, Environmental Corp, San Diego, CA 9213, under Contract No. N62473-18-2-004. November 2019.