

## Short Note

# Unprecedented Records of Guadalupe and Juan Fernández Fur Seals in the Galapagos Archipelago

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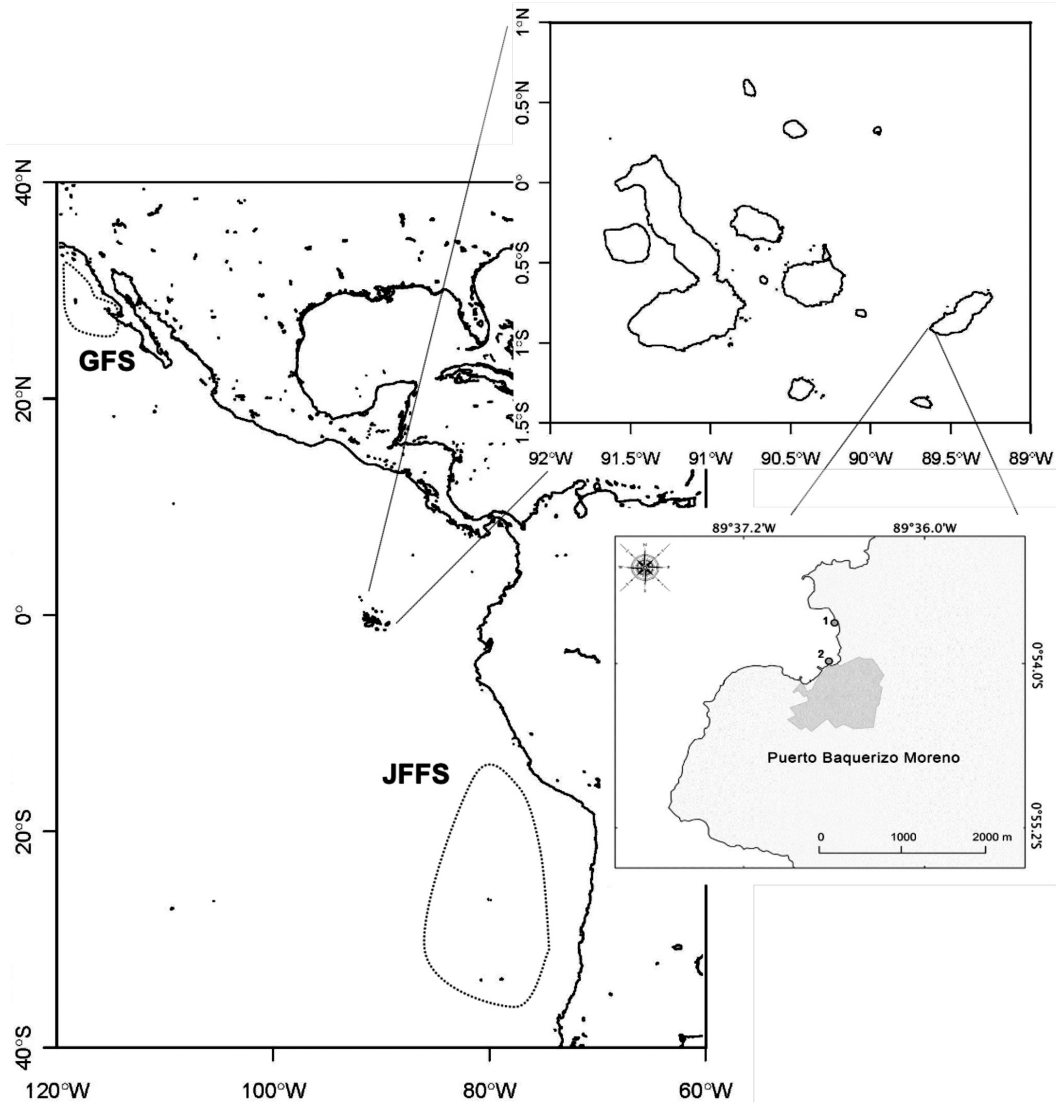
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The Guadalupe fur seal (GFS; *Arctocephalus philippii townsendi*) and Juan Fernández fur seal (JFFS; *Arctocephalus philippii philippii*) have a restricted distribution to islands in the North and South Pacific Ocean, respectively. GFS only breeds in Mexico, concentrating its population on Guadalupe and the San Benito Islands (Figure 1), with a regional abundance of around 40,000 individuals (García-Aguilar et al., 2018; Hernández-Camacho & Trites, 2018), while JFFS is limited to the Juan Fernández Archipelago in Chile (Figure 1), with an estimated population of 20,000 animals (Osman, 2007). Both species were considered extinct by the end of the 1800s because of intense commercial hunting (Townsend, 1931; Hubbs & Norris, 1971). However, a small number of GFS and JFFS were discovered breeding on Guadalupe Island in 1954 and Alejandro Selkirk Island in 1965, respectively (Hubbs, 1956; Bahamonde, 1966). These populations grew slowly and colonized other nearby islands over time (Goldsworthy et al., 2000; Aurióles-Gamboa et al., 2010), surviving in caves or on inaccessible beaches, thereby maintaining their populations and probably facilitating the increase of their genetic diversity (Goldsworthy et al., 2000).

The typical distribution ranges of species are located between 27° and 30° N for GFS and 15° and 40° S for JFFS (Gallo-Reynoso, 1994; Maravilla-Chavez & Lowry, 1999; Osman, 2007; Figure 1). The global distribution of pinnipeds is generally constrained by ocean temperature and its effect on prey availability (Trillmich et al., 1991; Adame et al., 2020). GFS has oceanic habits that normally involve feeding trips of up to 600 km around Guadalupe Island (Gallo-Reynoso et al., 2008). This characteristically wide dispersion may be more pronounced when prey is scarce

due to a decrease in marine productivity, leading to longer foraging trips, which can extend to the Southern Baja California Peninsula (Elorriaga-Verplancken et al., 2016a; Amador-Capitanachi, 2018). JFFS make foraging trips primarily south and east of the Juan Fernández Archipelago to locations up to 837 km toward the coast of Chile (Osman, 2007). Several individuals have been sighted with regularity at Punta San Juan, Peru, which is considered their northern limit (Majluf & Reyes, 1989).

Herein, we report extralimital records of GFS and JFFS in the Eastern Tropical Pacific, which occurred during the incidence of seasonal Humboldt Current near the Galapagos Archipelago when the proliferation of nutrients increases at the base of the region's food marine web (Palacios et al., 2006). During June and July 2019, a sighting of two fur seals on beaches in Puerto Baquerizo Moreno (0° 54' S, 89° 36' W), San Cristóbal Island, Galapagos Archipelago (Figure 1) was reported to the authorities of the Galapagos National Park. Initially, the rangers of the Galapagos National Park assumed these animals were Galápagos fur seals (*Arctocephalus galapagoensis*) because this species normally inhabits the western region of the archipelago (Trillmich, 1987). However, once each animal was captured, some morphological differences from the Galápagos fur seal were observed. Therefore, the animals were recorded as *Arctocephalus philippii* sp., specifically based on their larger body size relative to Galápagos fur seals (Repenning et al., 1971; Brunner, 2003) and morphological traits such as the bulkier nose relative to the head size and larger size of the pectoral flippers that are typical of JFFS (Maritza Sepulveda & Fernando Elorriaga-Verplancken, pers. comm., July 2019). On 24 June 2019, a subadult male fur



**Figure 1.** Geographic location of the Guadalupe fur seal (GFS; *Arctocephalus philippii townsendi*) and the Juan Fernández fur seal (JFFS; *Arctocephalus philippii philippii*). The dotted lines west of Baja California–Mexico and around Juan Fernández–Chile Islands represent the home range of both species. (1) Playa de Oro and (2) Playa Mann (Puerto Baquerizo Moreno) in San Cristóbal Island, Galapagos Archipelago, are also indicated.

seal measuring 1.6 m in total length and 70 kg in weight was captured (sample 1; Figure 2) on Playa de Oro, San Cristóbal Island, Galapagos. Based on body condition, it was determined to be healthy and not emaciated. A skin sample (sample 1) was taken and preserved in a 1.5 mL microcentrifuge tube with ethanol (95%) for genetic analysis. Later, on 12 July 2019, another subadult male fur seal measuring 1.5 m in total length and 60 kg in weight was captured (sample 2; Figure 3) on Playa

Mann (located less than 1 km from the Playa de Oro), San Cristóbal Island, Galapagos. The fur seal showed an apparent good body condition and normal resting behavior. A skin sample (sample 2) was also taken for genetic analysis. Both animals stayed on the beaches for 2 d and then departed; they were not seen again.

To evaluate the field identifications, we extracted genomic DNA from the two skin tissue samples using a guanidine thiocyanate protocol



**Figure 2.** Subadult male JFFS in Playa de Oro rocks, Galapagos Islands. Note the pointed snout and the large size of the pectoral fins in relation to the body—typical morphological characteristics of this species. © Photos courtesy of Leandro E. Vaca



**Figure 3.** Subadult male GFS in Playa Mann, Galapagos Islands. Note the long snout typical of the species as well as the large body size relative to Galápagos fur seals. © Photos courtesy of Benjamín Ayala-Jahnel

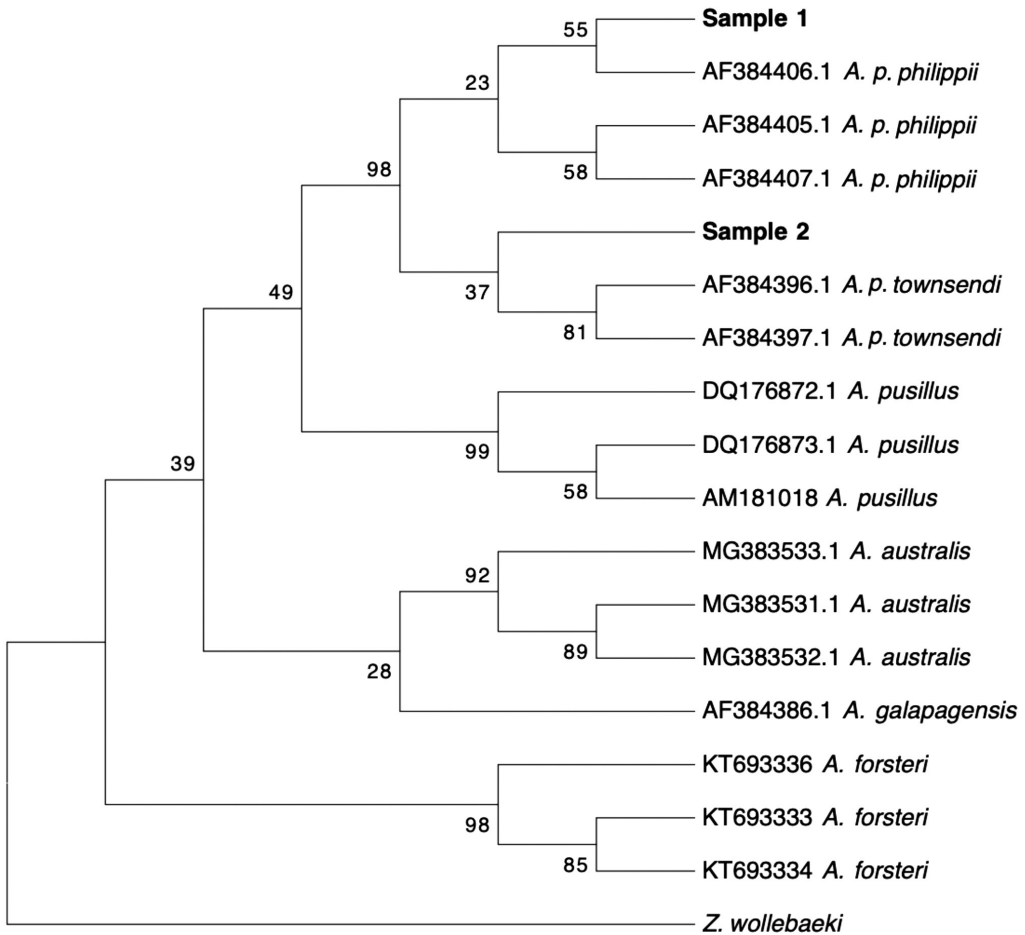
(Chomczynski, 1993). We determined DNA concentrations spectrophotometrically (Epoch Microplate Spectrophotometer; BioTek, Winooski, VT, USA) and electrophoretically to verify DNA integrity using agarose gel electrophoresis (0.8% agarose in  $1\times$  TBE buffer). Polymerase chain reaction (PCR) was carried out to amplify the mitochondrial Control Region (CR) using light strand T-Thr (5'- TTCCCCGGTCTTGTAAC-3') and heavy strand T-Phe (5'- AITTCAGTGTCTTGCTTT-3') primers (Hoelzel & Green, 1992; Hoelzel et al., 1993). Reactions were carried out in a total volume of 25  $\mu$ l containing 2.5  $\mu$ l PCR buffer (10 $\times$ ), 2.5  $\mu$ l MgCl<sub>2</sub> (50 mM), 2.5  $\mu$ l 10 mM deoxynucleotide triphosphates (dNTPs), 1.5  $\mu$ l each of the Forward and Reverse primers, each at 10  $\mu$ M, 0.15  $\mu$ l Taq DNA polymerase (5 Units), and 0.5  $\mu$ l of diluted DNA (at a concentration of 10 to 25 ng/ $\mu$ l). PCR cycling conditions consisted of an initial denaturation at 94°C for 5 min, 30 cycles at 94°C for 2 min, 50°C for 2 min, and 70°C for

45 min. Finally, an extension of 70°C for 7 min was performed. PCR products were cleaned up using ExoSap and sequenced at Macrogen (Seoul, South Korea). A Maximum Likelihood (ML) phylogenetic tree was constructed using default settings of the software *Mega 7* (Hoelzel & Green, 1992), with the CR sequences amplified in this study, plus sequences from several fur seals: *A. philippii philippii* ( $n = 3$ ), *A. philippii townsendi* ( $n = 2$ ), *A. australis* (South American fur seal;  $n = 3$ ), *A. galapagoensis* (Galápagos fur seal;  $n = 1$ ), *A. forsteri* (New Zealand fur seal;  $n = 3$ ), and *A. pusillus* (Cape fur seal;  $n = 3$ ) downloaded from Genbank. A sequence of Galápagos sea lion (*Zalophus wollebaeki*) was used as an outgroup. Node supports were estimated from non-parametric bootstrap values (1,000 pseudoreplicates; Sokal & Rohlf, 1995).

A total of 900 base pairs (bp) were obtained for the mitochondrial DNA (mtDNA) Control Region, and 293 bp were used for the phylogeny construction to match the Genbank sequences' length. We

detected 89 variable sites, 65 of which were parsimony informative. The phylogenetic tree produced under the Maximum Likelihood criterion shows a well-supported clade that includes both JFFS and GFS samples. Within this clade, sample 1 groups within the JFFS subclade, and sample 2 groups with the GFS subclade (Figure 4). These results support the morphological data and suggest the presence of foreign JFFS and GFS in the Galapagos Archipelago. In recent years, the recurrence of pinnipeds from the Southern Hemisphere (e.g., South American fur seal and southern elephant seal [*Mirounga leonina*]) in the tropical regions has become common (Villegas-Zurita et al., 2016; Páez-Rosas et al., 2018; Elorriaga-Verplancken et al., 2020); however, sightings of native pinnipeds from the Northern

Hemisphere have been rare. Prior to these sightings, the northernmost vagrant JFFS recorded was reported on 4 July 2007 in Buenaventura Port (3° 53' N, 77° 4' W) on the central-south coast of Colombia (Avila et al., 2014); while the southernmost GFS record (a stranding event) was reported in Oaxaca, Mexico (15° 58' N, 97° 32' W) in October 2012 (Villegas-Zurita et al., 2015). We hypothesize that the GFS observed in the Galapagos Archipelago travelled about 4,250 km from the nearest probable origin in San Benito Islands, Mexico (Figure 1). This distance, traveled by this GFS, is the longest documented dispersal by an otariid to date, overtaking the southernmost record of the Steller sea lion (*Eumetopias jubatus*) that traveled about 3,500 km south from its typical geographic range to Colima,



**Figure 4.** Phylogenetic tree resultant from Maximum Likelihood analysis based on the mtDNA Control Region. Bootstrap values are shown in each branch.



Mexico (18° 51' N, 103° 58' W) from July to November 2008 (Ceballos et al., 2010).

Both sightings reported in this study involve remarkable migrations. However, the GFS record is an unprecedented event because long otariid migrations are generally associated with the incidence of cold marine currents (e.g., Humboldt Current) or anomalous oceanographic events like El Niño–Southern Oscillation (ENSO) (Elorriaga-Verplancken et al., 2016b; Páez-Rosas et al., 2017)—characteristics that would not be favorable for GFS given its home range (Gallo-Reynoso et al., 2008). Both factors promote conditions that facilitate pinniped mobility and the consumption of food resources because they increase foraging grounds beyond the typical limits, thus allowing individuals to reach extreme sites (Páez-Rosas et al., 2018). Based on the Southern Oscillation Index (SOI) values from National Oceanic and Atmospheric Administration (NOAA) Regions 1 and 2, slightly negative or neutral conditions persisted during the months of May to July 2019 (SOI average:  $-0.07$ ; data obtained from [www.ncdc.noaa.gov/teleconnections/enso/indicators/soi](http://www.ncdc.noaa.gov/teleconnections/enso/indicators/soi)). Due to the neutral SOI values, coupled with the specimens' good body condition, oceanographic anomalies are not likely to be a direct factor explaining these sightings.

In the Tropical Eastern Pacific, there is a regional difference with respect to marine productivity. The Galapagos Archipelago exhibits high annual productivity, whereas the rest of the region exhibits a lower mean productivity (Palacios et al., 2006). These conditions are caused by the incidence of the cold Humboldt or Peru Current that flows north along the western coast of South America, producing upwelling that induces phytoplankton blooms and a highly productive habitat (Schaeffer et al., 2008). Therefore, the JFFS migration might be favored by the oceanographic dynamics of the region. In the case of GFS, the migration to the Galapagos Archipelago is not related to the influence of the Humboldt Current or oceanographic anomalies but, rather, might be a consequence of an increase in the dispersal capacity of the species or an erroneous foraging trip. The accumulative effect of climate change and the increasing frequency of El Niño and La Niña events in the last decades (Freund et al., 2019) cannot be ignored as a possible factor that has altered dispersal patterns of these species and their potential prey (Páez-Rosas et al., 2017, 2018). Changes in sea surface temperature directly influence prey distribution and abundance and, consequently, predator foraging ranges (Ochoa-Acuña & Francis, 1995; Elorriaga-Verplancken et al., 2016b), which could somehow explain the unusual sightings documented in this study.

The effects of environmental variability on the pinnipeds could lead to these species increasing their home range and feeding areas. These conditions associated with favorable oceanographic events would lead to the extralimital distribution of individuals from increasing populations to facilitate survival under the effects of climate change. This is the first GFS record in the Southern Hemisphere and has important biogeographical implications for our knowledge of pinnipeds.

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