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New non-breeding colonies of the South American fur seal in central Chile. Is the distribution in the southeastern Pacific waters extending?

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The South American fur seal (SAFS), *Arctocephalus australis* (Zimmermann, 1783) (Fig. 1), is a top marine predator with an estimated population of 219,000 individuals (Cárdenas-Alayza *et al.*, 2016), which are distributed along the southwestern Atlantic and the southeastern Pacific coasts of South America. In the Atlantic Ocean, a total of 45,600 individuals have been recorded in Uruguay (Franco-Trecu *et al.*, 2019), although another abundance estimate for the Uruguayan coast is of about 130,000 individuals (Crespo *et al.*, 2015; Franco-Trecu, 2015; Cárdenas-Alayza *et al.*, 2016). At least 20,000 individuals have been recorded in Argentina (Crespo *et al.*, 2015); between 18,000-20,000 individuals have been recorded in the Malvinas/Falkland Islands (Strange, 1992) and there is an undetermined vagrant population in Brazil (Oliveira, 2013). In the Pacific Ocean the distribution is discontinuous, with a gap that extends along the coast of Chile from 29°02'S to 43°36'S (Fig. 2). The population reaches 86,000 individuals on the coasts of Chile and Peru, of which 20,900 individuals have been recorded for the Peruvian/northern Chile population^{1,2}, while the population of southern Chile has an estimated size of 65,100 individuals (Torres *et al.*, 2000).

Two evolutionary units have been evidenced in the SAFS, through analysis of the size and shape of the skull (morphometric and traditional geometric) (Oliveira *et al.*,



Figure 1. South American fur seal (*Arctocephalus australis*). Photo credit: L. René Durán.

2008). Genetic data and reproductive patterns indicate that currently the Peruvian and Uruguayan populations are reproductively isolated (Majluf, 1987; Oliveira *et al.*, 2008; Cárdenas-Alayza, 2012; Franco-Trecu *et al.*, 2014; Pavés *et al.*, 2016) and that the southern Chile and Atlantic populations share several haplotypes (Crespo *et al.*, 2015; Rodrigues *et al.*, 2018) and synchrony in the reproductive period (Pavés *et al.*, 2016), suggesting a connection between these populations. There is enough evidence (morphometric, genetic and from life history features) to consider the Peruvian/northern Chile and the southern Chile/Atlantic populations as different evolutionary units or even subspecies (Oliveira and Brownell, 2014).

¹Instituto del Mar del Peru (IMARPE). (2013) *Anuario científico y tecnológico* (Vol. 13). Callao, Perú. 214 pp.

²Majluf, P. (1998) Effects of the 1997/1998 El Niño on pinnipeds in Peru. In Abstracts, 8a. Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur y 2do. Congreso de la Sociedad Latinoamericana de Especialistas en Mamíferos Acuáticos (SOLAMAC), 25–29 October 1998, Olinda, PE, Brazil. 120 pp.

The ENSO event that occurred from 1997 to 1998 in northern Peru caused a high rate of SAFS pup and juvenile mortality, as well as female mortality, as a consequence of longer foraging trips². According to Oliveira *et al.* (2006), the Pacific population of SAFS is well-adapted to ENSO events, but the increase in strength and frequency of events similar in magnitude to the 1997-1998 event could severely impact the local population. The SAFS Peruvian population experienced a genetic bottleneck that could be a result of synergic climatological and anthropogenic effects (Oliveira *et al.*, 2009). Climate change and its influence on ENSO events (NCDC-NOOA, 2004; Collins *et al.*, 2010) is a key phenomenon that would model the top predator species abundance and would explain shifts in the distribution range of marine mammals (Simmonds and Isaac, 2007).

During the eighteenth century, numerous whaling and sealing ships caught thousands of marine mammals in the Southern Hemisphere, among them the South American sea lion (SASL, *Otaria byronia*), the SAFS and the southern elephant seal (*Mirounga leonina*), obtaining fur and oil. The hunting activity continued until the beginning of the nineteenth-century. According to historical evidence, more than 400 European and American ships were dedicated to the killing of fur seals in Mocha (38°23'S) and Santa María (37°01'S) islands, the Juan Fernández Archipelago (33°38'S), San Félix (26°17'S) and San Ambrosio (26°20'S) islands off central Chile, and along the coast of southern Patagonia (55°58'S), the Malvinas/Falkland Islands (51°34'S) and Staten Island (54°45'S) (Sielfeld *et al.*, 1977; Torres *et al.*, 2000). Moreover, the Diego Ramírez Islands (56°30'S), Staten Island and other neighboring islands of the Cape Horn Archipelago were considered the main hunting grounds in the southern tip of the South American continent according to other reports (Martinic, 1987). The levels of sealing during those centuries considerably reduced the populations and consequently the activity ceased in the middle of the nineteenth century (Martinic, 1987). Fur seals were driven almost to extinction along the South American coast and Antarctic Peninsula during these centuries³ (Bonner, 1982; Mayorga, 2016; 2017). This heavy hunting of SAFS is reflected today in the relatively low abundance throughout the distribution range.

The aim of this study is to show new distribution and abundance records of the SAFS in the gap of distribution, between 29°02'S and 43°36'S, as a consequence of the colonization process of animals from the Peruvian and southern Chile populations.

Aerial censuses were performed in Chile during the austral summer (17 February to 14 March) and winter (1 to 4 July) of 2015, between 32°12'S and 39°24'S. Aerial

censuses were also performed between 41°44'S and 44°55'S during the austral summer (13 February, 28-29 February, 15 February and 12 February of the years 2013, 2016, 2017 and 2018, respectively). The summer survey dates coincided with the post-reproductive period of the species whereas the winter survey coincided with the foraging season (Pavés and Schlatter, 2008). Both geographical areas were surveyed synoptically for a study of abundance of the SASL in the main reproductive colonies of the Southeastern Pacific Ocean. The surveys were carried out by air (Cessna 172), because the geographical areas present limited access by ground and sea. Digital photographs were taken, using CANON 7D, 40D and Rebel XT digital cameras with objectives of 70-200 F / 4 L IS, 100-400 F / 4.5-5.6 IS and 28-135 F / 3.5-5.6 IS, respectively. The CANON camera 7D has a GPS CANON GP-E2 that connects directly to the camera, and the geo-referencing process executed by this device was recorded in the metadata of each photograph. The aerial photographs were taken at 70 to 250 masl, depending on the meteorological and topographical conditions, at 60 to 90 kn, according to Aguayo and Maturana (1973). Three independent observers counted the total of individuals and categorized them into functional age classes. Stranding records of live SAFS from the National Fishing and Aquaculture Service (SERNAPESCA)⁴ from 2009 to 2016 were included to complement the research sightings within the gap. We followed previous considerations to define the type of colony as breeding (presence of newborn pups) or non-breeding (absence of newborn pups) (Sepúlveda *et al.*, 2001; 2011; Grandi *et al.*, 2008); whereas a haul-out site was defined by a single individual seen resting at a location. Based on secondary characteristics indicated by Bininda-Emonds and Gittleman (2000) and Lindenfors *et al.* (2002), individuals in the colonies and haul-out sites were categorized by three independent trained observers as adult males, adult females and juveniles. When it was not possible to classify an individual, it was categorized as indeterminate. All the data were combined to create distribution maps of the total sightings using ArcGis 10.2®.

Our results showed two non-breeding colonies and 12 haul-out sites along the gap of distribution in the Pacific coast of Chile. The two non-breeding colonies, Isote del Trabajo (38°25'S) and Isote Quechol (38°26'S), were found in adjacent islets of the Mocha Island National Reserve (38°22'S) in the Biobío Region, central Chile (Fig. 2). These new non-breeding colonies (Figs. 2, 3) consisted of 43 individuals during the austral winter of 2015, of which 27 (2±0 adult males, 23±1 adult females and 2±1 juveniles) were recorded in Isote del Trabajo and 16 (3±0 adult males and 13±0 adult females) in Isote Quechol.

During the 2016 summer survey, an indeterminate sea lion was observed in the Punta Chaiguaco haul-out site

³Ponce de León, A. (2000) *Taxonomía, sistemática y sinopsis de la biología y ecología de los pinípedios de Uruguay. Sinopsis de la biología y ecología de las poblaciones de lobos finos y leones marinos de Uruguay. Pautas para su manejo y Administración. Parte I, Biología de las especies, Uruguay*. Proyecto URU/92/003.

⁴Stranding records from SERNAPESCA include stranded (dead) and sightings of live marine mammals. Obtained from SIAC-SERNAPESCA on 06 February 2017.

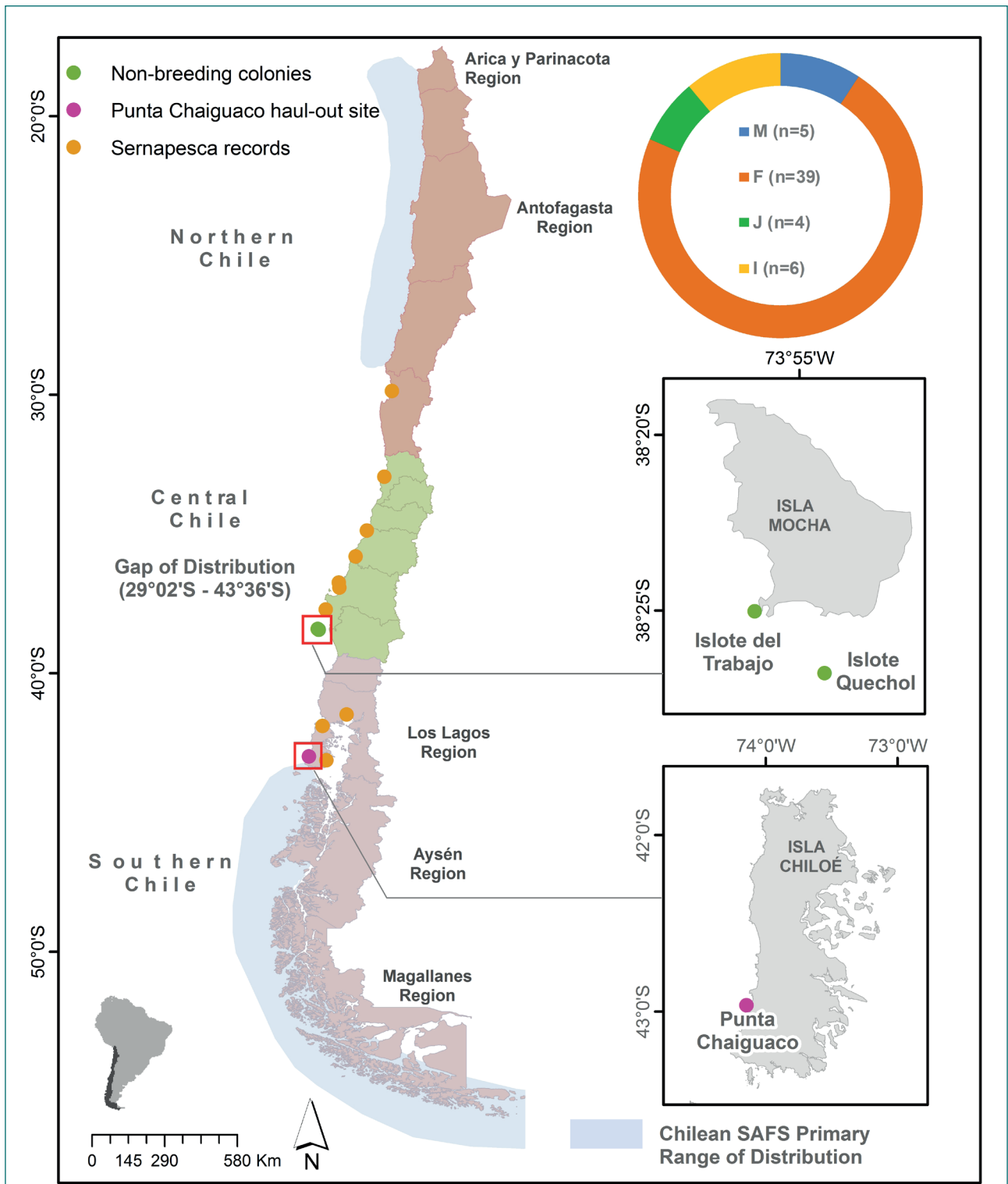


Figure 2. Sightings of South American fur seal (*Arctocephalus australis*) between 2009 and 2018 from aerial censuses and SERNAPESCA stranding records inside the gap of distribution in the southeast Pacific coast of Chile. Age classes: M= Adult Males, F= Adult Females, J= Juveniles, I= Indeterminates).

(42°59'S) (Fig. 2) among a group of SASL juvenile females in the Chiloé Archipelago, southern Chile. This sea lion appeared to be morphologically different from a SASL or a SAFS. Potentially, the specimen is a hybrid sea lion (SASL and SAFS), characterized by a different kind of fur,

prominent flipper and larger external ear in comparison to SASL individuals that inhabit this rookery⁵ (Fig. 4); however, this cannot be confirmed without genetic evidence.

⁵A. Aguayo, pers. comm. 23 November 2018, Instituto Antártico Chileno (INACH), Punta Arenas, Chile.

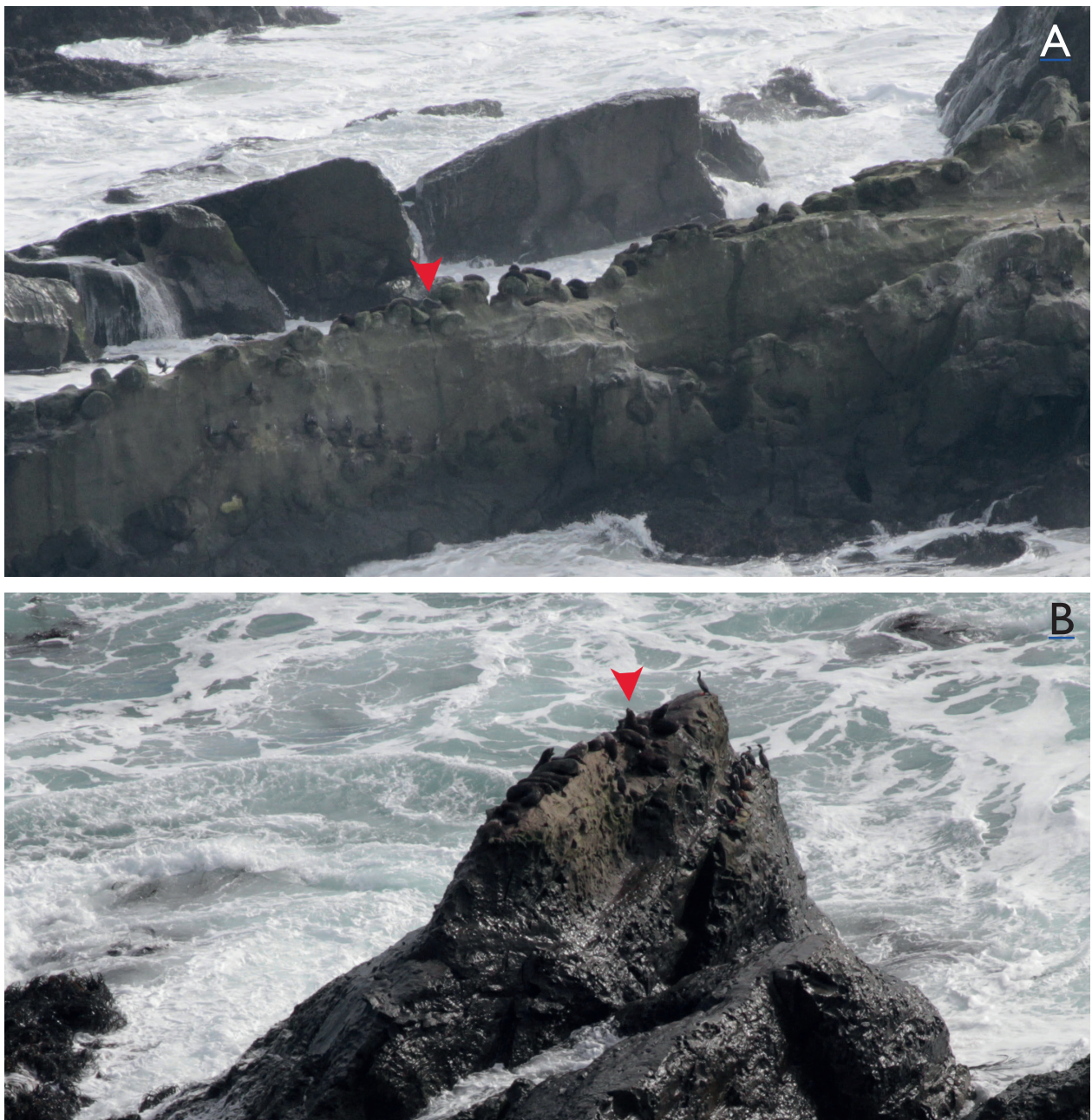


Figure 3. New non-breeding colonies of the South American fur seal (*Arctocephalus australis*) in central Chile (a) Islote del Trabajo (38°25'S) and (b) Islote Quechol (38°26'S). Both colony sightings were performed on 01 July 2015 between 12:00 and 13:00 (austral winter). Arrowheads indicate females. Photo credit: L. René Durán.

From SERNAPESCA records, a total of 10 SAFS were registered in ten haul-out sites. Among the fur seals sighted only two were registered in the Chiloé Archipelago, at Pupelde (41°53'S) and Quellón (43°07'S); whereas the other eight fur seals were found in mainland coast haul-out sites (Fig. 2).

In summary, we registered a total of 54 SAFS along the Chilean distribution gap. Most of the SAFS were recorded during the austral winter ($n = 48$; 89%) with lower proportions in the summer ($n = 4$; 7%), spring ($n = 1$; 2%) and autumn ($n = 1$; 2%) seasons. The individuals were categorized as adult males ($n = 5$; 9%), adult females ($n =$

39; 72%), juveniles ($n = 4$; 8%) and indeterminates ($n = 6$; 11%) (Fig. 2). The other fur seals sighted in haul-out sites appeared solitary; all of them were resting and returned alone or by rescue action (performed by SERNAPESCA Officials) to the marine environment (Table 1).

The distribution of SAFS in their northern range in Chile was reported for first time in 1982 in the Antofagasta Region (23°35'S) and subsequently corroborated by the sightings of a number of individuals in Punta Comache (21°11'S) in the same year and 20 individuals in Punta Patache (20°51'S) in 1984, likely as result of dispersal activity from colonies in



Figure 4. Sighting of an indeterminate sea lion (probably a hybrid specimen between a South American fur seal, *Arctocephalus australis*, and a South American sea lion, *Otaria byronia*), in Punta Chaiguaco haul-out site during the austral summer of 2016. The individual appeared between a group of five juvenile females of South American sea lions. Arrowhead indicates the purportedly hybrid specimen. Photo credit: L. René Durán.

southern Peru (Torres, 1985). Later, a synoptic census in the same geographic area during the summer of 1996 registered 20 haul-out sites (comprising 1,598 individuals), with Punta Pichalo (19°31'S) being the only breeding colony (with 38 pups), suggesting that the population was in a process of gradual colonization towards the south⁶. Nowadays, the northern population of SAFS showed an increase in the number of breeding colonies (n= 3) and total number of SAFS (5,378 individuals) in the last census carried out during the summer of 2007. Among these, Punta Pichalo (19°31'S) and Punta Campamento (23°04'S) stand out as the largest breeding grounds of SAFS in northern Chile (76 and 210 pups registered, respectively)^{2,7}.

The high rates of mortality and the dispersion of individuals towards the south before the 1982-1983 ENSO climatological event have contributed to the presence and increased numbers of SAFS in northern Chile, making this species a possible biological indicator (Torres, 1985). However, the strong 1997-1998 ENSO caused a considerable decline in the Peruvian population of SAFS (72%), mostly because of starvation due to low availability of anchovies in Peru and a subsequent migration of individuals to the south searching for food⁸ (Stevens and Boness, 2003).

⁶Sielfeld, W., Amado, N., Peredo, R., Vargas, M., Guerra, C., Malinarich, A., Acuña, E., Cerda, G., Bolvarán, A., Durán, L.R., Aguayo, A., Sepúlveda, M., Palma, F., Veloso, X., Guerra, Y., Grau, R. and Galáz, J.L. (1997) *Monitoreo de la pesquería y censo del lobo marino común en el litoral de la I-IV Regiones*. Proyecto Fondo de Investigación Pesquera FIP 95-28.

⁷Bartheld, J., Pavés, H., Contreras, F., Vera, C., Manque, C., Miranda, D., Sepúlveda, D., Artacho, P. and Ossman, L. (2008) *Cuantificación poblacional de lobos marinos en el litoral de la I a VI Región*. Informe Final Proyecto FIP N° 2006-50.

The increase in population, natality and number of breeding colonies suggest population growth in southern Chile. Sielfeld *et al.* (1977) considered the population status of SAFS in the Magallanes Region in at least 88,200 individuals. Summer censuses performed in the Los Lagos and Aysén regions showed a population increase from 2,828 (two breeding colonies) in 1998 to 5,524 (four breeding colonies) individuals in 2007, finally reaching a total of 9,595 individuals (six breeding colonies) in 2012^{9,10,11}.

The SAFS population growth and range extension in central Chile documented here is likely to be the result of a combination of factors, such as ENSO events promoting dispersal from affected areas, the recovery process at population level after cessation of sealing, and favorable physical environmental conditions, all of which could be propitiating an extension of their range and consequently filling the gap in their distribution in central Chile. A similar situation is likely occurring in the Atlantic Ocean, where the occurrence of SAFS in the Argentinian Patagonia has been historically registered in Islote Lobos (41°24'S) and the recent presence of SAFS has been reported in San Matías Gulf (Svendsen *et al.*, 2013). This also indicates an analogous situation on the Pacific coast, which is currently facing imminent population growth and the presence of a natural corridor between distant SAFS colonies established in northern and southern Chile.

The possible hybrid individual reported in Punta Chaiguaco rookery matches with the adult hybrid female described by Franco-Trecu *et al.* (2016) in Lobos Island (Uruguay). This in turn suggests that SAFS and SASL in southern Chile are sharing habitat and colonies within the distribution gap, promoting the hybridization among species.

It is important to emphasize that the presence of SAFS in the Playa Amarilla (32°57'S), Pelluhue (35°48'S), Playa Ramuncho (36°45'S) and Punta Chaiguaco (42°59'S) haul-out sites (Table 1) in summer raises the possibility that subadults disperse to feed after the breeding season from nearby colonies (Szteren, 2015). The presence of SAFS has been previously reported in the Chiloé Archipelago: Playa Pumillahue (41°56'S) and Metalqui Island (42°11'S). Among these, the case of Metalqui Island stands out, where in 1977 SAFS females and pups were sighted, presenting exceptionally

⁸Arias-Schreiber, M. and Rivas, C. (1998) *Distribución, tamaño y estructura de las poblaciones de lobos marinos (Arctocephalus australis y Otaria byronia) en el litoral Peruano*, en noviembre 1996 y marzo 1997. Informe Progresivo del Instituto del Mar del Perú, Callao, Perú.

⁹Oporto, J., Brieva, L., Navarro, R. and Turner, A. (1999) *Cuantificación poblacional de lobos marinos en la X y XI Regiones*. Informe Final Proyecto FIP 97-44.

¹⁰Oliva, D., Sielfeld, W., Sepúlveda, M., Pérez, M.J., Moraga, R., Urra, A., Schrader, D., Pavés, H. and Buscaglia, M. (2008) *Plan de acción para disminuir y mitigar los efectos de las interacciones del lobo marino común (Otaria flavescens) con las actividades de pesca y acuicultura*. Informe final Proyecto FIP 2006-34.

¹¹Oliva, D., Sepúlveda, M., Durán, L.R., Urra, A., Sielfeld, W., Moraga, R., Pavés, G. and Muñoz, L. (2012) *Cuantificación poblacional de lobos marinos en las Regiones X-XI y propuesta de escenarios de manejo*. Informe Final Proyecto FAP ID 4728-46-LP11.

Table 1. Summary of sightings of South American fur seal (*Arctocephalus australis*) along the southeast Pacific coast of Chile, SAFS gap of distribution (29°02'S - 43°36'S), from 2009 to 2018 per haul-out sites and non-breeding colonies. Age classes: M= Adult Males, F= Adult Females, J= Juveniles, I= Indeterminate). Locations arranged from north to south.

Location	Habitat	Season	Fur seals sighted	GPS coordinates
Caleta San Pedro	Sandy beach	Winter	1 (F)	29°52'S; 71°16'W
Playa Amarilla	Rocky	Summer	1 (I)	32°57'S; 71°32'W
Duao	Rocky	Spring	1 (F)	34°53'S; 72°10'W
Pelluhue	Sandy beach	Summer	1 (I)	35°48'S; 72°34'W
Playa Ramuncho	Sandy beach	Summer	1 (I)	36°45'S; 73°11'W
San Vicente	Sandy beach	Autumn	1 (I)	36°56'S; 73°09'W
Playa Larga de Lebu	Sandy beach	Winter	1 (I)	37°43'S; 73°39'W
Isote del Trabajo	Rocky islet	Winter	27 (M=2, F=23, J=2)	38°25'S; 73°56'W
Isote Quechol	Rocky islet	Winter	16 (M=3, F=13)	38°26'S; 73°54'W
Pelluco	Sandy beach	Winter	1 (J)	41°29'S; 72°54'W
Pupelde	Wetland	Winter	1 (F)	41°53'S; 73°46'W
Punta Chaiguaco	Rocky	Summer	1 (I*)	42°59'S; 74°15'W
Quellón	Sandy beach	Winter	1 (J)	43°07'S; 73°37'W

* Possible hybrid individual between a SASL (South American sea lion) and a SAFS (South American fur seal).

different characteristics from those of SASL, such as greyish-brown fur, thin head and body and protruding ears clearly visible (Saavedra, 1980). The fact that from 1977 to the present SAFS individuals (even pups) have been recorded frequently in the geographical area means that the species previously inhabited the archipelago successfully, which could now be leading to a recolonization process from Guafo Island, the largest breeding colony of the species in southern Chile (Paves and Schlatter, 2008).

During the winter season, 89% of individuals (only adult male and female) arrive at the gap area. Szteren (2015) recorded an abundance of SASL and SAFS in poorly known sites along the Uruguayan coast. Interestingly, at Las Pipas non-breeding colony, subadult males, females and juveniles were the predominant age classes of SAFS. The maximum abundance was found in winter, declining in number abruptly during spring and remaining very low in summer, suggesting that animals may be migrating from breeding areas to these locations, probably to use them as resting grounds near feeding areas. Our results suggest the dispersion of mature individuals during the foraging season to Chilean middle latitudes. The SAFS sightings inside the gap of distribution showed a preference for rocky islets (Fig. 3; Table 1), such as the case of Isote del Trabajo and Isote Quechol (both adjacent to Mocha Island), to establish colonies during the austral winter (post-reproductive season). These rocky islets present the topographic characteristics previously described for SAFS colonies (Stevens and Boness, 2003). Forty-three individuals congregated these two islets combined, which may be considered as a composed non-breeding colony (since

these are located at a distance of less than a mile), fulfilling the assumption stipulated by Grandi *et al.* (2008) for a non-breeding colony.

The Pleistocene glaciations could have played a deterministic role in the living conditions of SAFS. The genealogical relationship between haplotypes revealed a pattern of phylogeographic structure with two main haplogroups corresponding to the main breeding areas of the SAFS (Peru and Uruguay). Significant genetic differences have been determined from these results, which suggest a long period of isolation between the Pacific and Atlantic populations, which in turn could have shaped the current SAFS distribution and the reproductive colonies in the Chilean territory (Túnez *et al.*, 2013).

The establishment of new non-breeding colonies and haul-out sites in central Chile would not be a surprise and could foster new breeding colonies inside the gap of distribution in the future. It is likely that the current abundance status of the SAFS is a result of the heavy sealing activity carried out during the end of the eighteenth and the first half of the nineteenth centuries (Martinic, 1987), when the capture reached more than 800,000 furs (Bonner, 1982)² and Guafo Island was one of the sealing locations (Mayorga, 2017). Today, we believe that SAFS are reaching Mocha Island in central Chile as a resting or feeding ground, a location that the species used to inhabit in the past (Sielfeld *et al.*, 1977; Torres *et al.*, 2000) and which could have been the northern limit of the South Pacific population of SAFS.

Here we present the first observations during the last decade of solitary individuals and aerial graphic records of

two non-breeding colonies inside the gap of distribution in central Chile. Although Reppenning *et al.* (1971) described an erroneous continuous distribution of SAFS in Chile, our study shows that currently this pattern could be getting closer to becoming real. Also, current data suggest that the Guafo Island population belongs to the same lineage and has radiated from the Atlantic population, presenting an amphi-oceanic distribution (Rodrigues *et al.*, 2018). This in turn suggests that the Mocha Island individuals arrive from Guafo Island due to the historical sealing background and are recolonizing the area. However, the Peruvian/northern Chile population will probably continue to be reproductively isolated (Oliveira and Brownell, 2014). Therefore, it is important to continue monitoring this area with standard effort throughout the entire year, and to continue surveying the Magallanes Region; to assess the population trend within the gap of distribution and the southern population abundance of SAFS, and to define the best strategies to ensure its correct conservation and future research of its ecology.

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