

Research Article

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Corresponding author:

Larissa Rosa Oliveira;
Email: larissaro@unisinos.br

New data on South American fur seals and sea lions' occupation of the Wildlife Refuge of Ilha dos Lobos, southern Brazil

Natália Procksch¹, Paulo Henrique Ott^{2,3}, Natalia Bragiola Berchieri⁴, Daniel Danilewicz^{2,5}, Rafael Kenji Horota^{6,7,8}, Murilo Guimarães⁴, Marcelo Zagonel⁶, Maurício Roberto Veronez⁶ and Larissa Rosa de Oliveira^{1,2} 

¹Laboratório de Ecologia de Mamíferos (LEM), Universidade do Vale do Rio dos Sinos (UNISINOS), Av. Unisinos 950, Cristo Rei, São Leopoldo, RS 93022-750, Brazil; ²Grupo de Estudos de Mamíferos Aquáticos do Rio Grande do Sul (GEMARS), Rua Bento Gonçalves, Saldanha da Gama, 937, Torres, RS 95560-000, Brazil; ³Universidade Estadual do Rio Grande do Sul (UERGS), Laboratório de Biodiversidade e Conservação (LABeC), Rua Machado de Assis, 1456, Osório, RS 95520-000, Brazil; ⁴Universidade Federal do Piauí, Departamento de Biologia, Avenida Universitária, lado ímpar, Teresina, PI 64049-550, Brazil; ⁵Instituto Aqualie, Avenida Doutor Paulo Japiassú Coelho, 714, salas 201 e 202, Juiz de Fora, MG 36033-310, Brazil; ⁶Advanced Visualization & Geoinformatics Laboratory (VizLab), Universidade do Vale do Rio dos Sinos (UNISINOS), Av. Unisinos 950, Cristo Rei, São Leopoldo, RS 93022-750, Brazil; ⁷Svalbard (UNIS), University Centre in Svalbard (UNIS), Longyearbyen 9170, Svalbard, Norway and ⁸University of Bergen (UiB), 5007 Bergen, Norway

Abstract

We present the most recent data on the seasonal and spatial occupation of South American sea lions (*Otaria flavescens*) and fur seals (*Arctocephalus australis*) in the Wildlife Refuge of Ilha dos Lobos (WRIL) in southern Brazil throughout the year, based on aerial photographic counts. Thirty-one aerial photographic counts were conducted between July 2019 and November 2020 to assess monthly differences in the abundance of pinnipeds in the WRIL. The results were analysed using a generalized linear model. Spatial analysis was performed using kernel density. Subadult males of South American sea lion were the most abundant pinniped in the WRIL, followed by juveniles of South American fur seal. A juvenile of Southern elephant seal (*Mirounga leonina*) was also recorded. South American fur seals showed a marked seasonality, occurring only between July and October, while South American sea lions occurred year-round. Among the months analysed, September exhibited the highest mean abundance (mean 113.75; SD: ± 8.58), followed by August (mean 103.00; SD: ± 15.69). The pinnipeds were more often concentrated in the northern and central parts of the island. This study reinforces the importance of the WRIL as a haulout site for pinnipeds. Considering the seasonal occupation of the island by South American pinnipeds, monitoring is recommended prior to the development of activities in the area.

Introduction

The presence of pinnipeds on the southern Brazilian coast can be considered seasonal, with the recorded presence concentrated mainly during the non-breeding season. Along this particular stretch of coastline, two South American species, the South American fur seal (*Arctocephalus australis*) and South American sea lion (*Otaria flavescens*), have been recorded annually (Pinedo, 1990; Rosas *et al.*, 1994; Simões-Lopes *et al.*, 1995; Oliveira, 2013; Procksch *et al.*, 2020, 2023), whereas the Antarctic and Subantarctic species, such as Antarctic fur seal (*Arctocephalus gazella*), sub-Antarctic fur seal (*Arctocephalus tropicalis*), leopard seal (*Hydrurga leptonyx*), and southern elephant seal (*Mirounga leonina*) have occasionally been recorded (Oliveira *et al.*, 2001, 2006; Oliveira, 2013; Procksch *et al.*, 2020). Although Brazil has no breeding colonies for any pinniped species, South American fur seals and sea lions are frequently sighted along the southern coast, including at two haulout sites: the wildlife refuge of Molhe Leste of São José do Norte (WRML) and the wildlife refuge of Ilha dos Lobos (WRIL). These are marine protected areas (MPAs) located on the coast of Rio Grande do Sul (Figure 1).

South American pinnipeds found in Brazil arrive from their closest breeding sites in Uruguay and Argentina (Pinedo, 1990; Rosas *et al.*, 1994; Oliveira *et al.*, 2017) after the breeding season, mainly during the austral autumn and spring months (Rosas *et al.*, 1994; Simões-Lopes *et al.*, 1995; Oliveira, 2013; Pavanato *et al.*, 2013; Bombau and Sztteren, 2017; Procksch *et al.*, 2020). Both species have similar reproductive periods during the austral summer, beginning in December and continuing until February for South American sea lions (Campagna, 1985), and from November to mid-January for South American fur seals (Vaz-Ferreira, 1982a; Franco-Trecu *et al.*, 2014). Once the breeding period ends, a small proportion of the population leaves their rookeries and then arrives at the Brazilian haulout sites. This corresponds with the dispersal period after the breeding season, which is the least understood period of their life cycle (Bastida and Rodriguez, 1994; Sanfelice *et al.*, 1999).



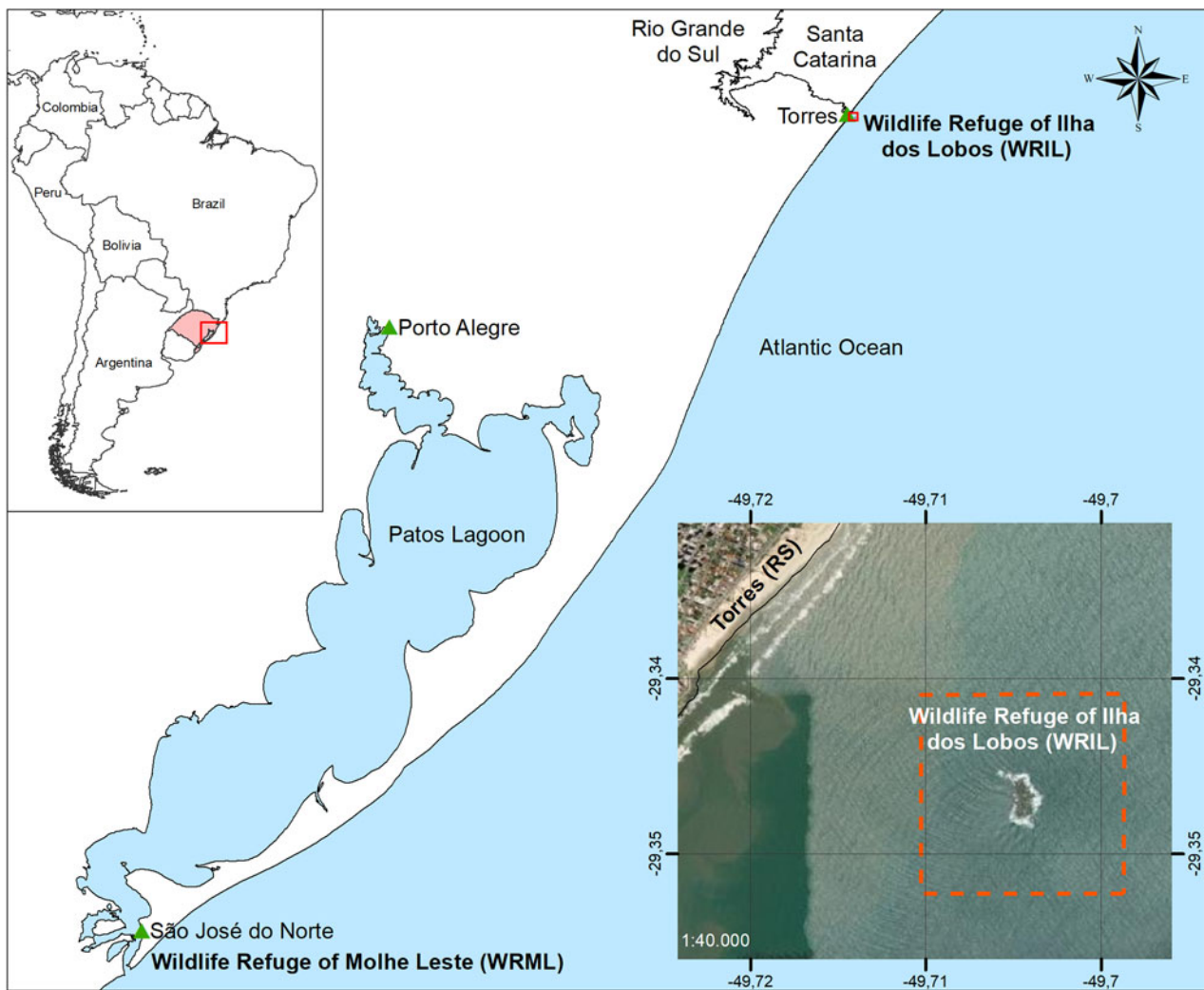


Figure 1. Map of the study area, showing the Wildlife Refuge of Ilha dos Lobos on the southern Brazilian coast.

Pinniped counts conducted around 20 years ago presented information on the seasonal abundance of South American pinnipeds at the WRIL based on land and vessel counts (Sanfelice *et al.*, 1999; Silva, 2004; Pavanato *et al.*, 2013; Silva *et al.*, 2014). The most recently published data on the seasonal and spatial occupation of South American fur seals and sea lions in the WRIL (Procksch *et al.*, 2020) was based on aerial photographic counts conducted from 2010 to 2018, but restricted to July and November of each year. The sampling for this study was opportunistic as it was undertaken during aerial censuses mainly for the southern right whale (*Eubalaena australis*) in the region. This is highly coincident with the breeding and calving season of this baleen whale (Groch *et al.*, 2005; Danilewicz *et al.*, 2017). For that reason, data for the months in which the greatest abundance of pinnipeds are known on the island were evaluated (see Procksch *et al.*, 2020).

In this context, the aim of this study was to describe the seasonal and spatial occupation of the WRIL by South American fur seals and South American sea lions over the entire year through systematic aerial counts. Based on our findings, we provide insights and recommendations on when and where potential human activities could occur, such as marine wildlife tourism and/or on-land research. The findings of this study present relevant information for local managers, stakeholders, and users, considering that the region surrounding the WRIL is subject to human activity (Engel *et al.*, 2014; Pont *et al.*, 2016; Oliveira *et al.*, 2020; Ott *et al.*, 2022). Monitoring

this pinniped haulout site is relevant because this region can act as a gateway for new and emerging pathogens, as well as being a key area for assessing sea level rise in the context of global climate change (Schossler *et al.*, 2018; VanWormer *et al.*, 2019; Procksch *et al.*, 2023).

Methods

This study was based on aerial images taken with an unmanned aerial vehicle (UAV) flying over the WRIL (29°20'S; 49°42'W). The protected area is located at a distance of 1800 m from the city of Torres and consists of a coastal island with an area of 16,966 m², and an additional 500 m around the island, resulting in 142 ha of MPA (Brasil, 1983; Brasil, 2005) (Figure 1).

The aerial images were taken with a DJI Mavic Pro II and DJI Mavic Platinum during 31 flights over the WRIL from July 2019 to November 2020, taking off from Praia Grande, Torres, northern Rio Grande do Sul state, southern Brazilian coast. No flights operated in November 2019 due to bad weather conditions (Table 1). To obtain accurate images of the study area, the UAV with the attached camera was operated at an altitude of approximately 100 m. This altitude was also chosen in order to avoid any impact or disturbance on the pinniped haulout site (adapted from Brazilian legislation for cetaceans – Silva-Jr *et al.*, 2019). Images of the pinnipeds on the WRIL were obtained under the Brazilian Biodiversity authorization and information system, SISBIO license number 54476-4.

Table 1. Number of flights operated per month between July 2019 and November 2020 at the Wildlife Refuge of Ilha dos Lobos, southern Brazil

| | Year | Month | | | | | | | | | | | | Total |
|-------------------|------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | |
| Number of flights | 2019 | - | - | - | - | - | - | 1 | 1 | 1 | 1 | - | 1 | 5 |
| | 2020 | 1 | 2 | 1 | 1 | 4 | 4 | 5 | 3 | 3 | 1 | 1 | - | 26 |
| Total | | 1 | 2 | 1 | 1 | 4 | 4 | 6 | 4 | 4 | 2 | 1 | 1 | 31 |

We used the software ArcMap 10.6.1 to obtain pinniped counts based on the best aerial image obtained during each flight. The individuals were classified according to their species, age, and sex (see details in Procksch *et al.*, 2020). Assessments were based on external morphology, relative size between individuals, behaviour, body colour, size and shape of the head, presence of the mane in males, and its shape and development (Crespo, 1988; Procksch *et al.*, 2020). In this context, South American sea lions were classified into five categories: adult males, subadult males, juveniles, potential adult females, and yearlings (i.e. individuals that will complete their first year of life in the same year that they were observed in the WRIL – King, 1983). The South American fur seals were classified into four categories, based on the descriptions of Vaz-Ferreira (1982a, 1982b), as follows: adult males, subadults, juveniles, and yearlings. The last three categories considered only the age class of individuals because of the difficulty in attributing sex to them from aerial images.

The abundance of each species was plotted and compared monthly from July 2019 to November 2020. For South American sea lions, we assess monthly differences in the number of individuals, since this species was found throughout the year. In the case of South American fur seals, we assess seasons' differences due to their occurrence only in some specific months. We used a generalized linear model with a Poisson error distribution and the number of flights per month as an offset to control for the sampling effort effect for each species. The analyses were performed using the lme4 package (Bates *et al.*, 2005) within R 3.6.0 (www.R-project.org) (R Core Team, 2019).

To test for preferences for habitat use by pinnipeds, we performed a kernel density analysis for each month from July 2019 to November 2020. The best aerial image for each month taken during the 31 flights was georeferenced from the

orthophotomosaic obtained in August 2019. The orthophotomosaic consists of a two-dimensional image in an orthogonal projection of all images, minimizing errors caused by camera distortion (Chandler and Buckeley, 2016; Aires, 2020). The processing of the images and the cartographic product was performed using Agisoft Metashape. To better understand and visualize the spatial distribution of individuals, the island was digitally divided into three sectors (north, centre, and south) of equal area (~10,000 m²), as described by Procksch *et al.* (2020).

The Kernel Density Estimator (KDE) (Silverman, 1986) was used to estimate the density of specimens and to analyse whether pinnipeds in the WRIL exhibited spatial preferences. KDE analyses and maps were generated for each flight using ArcGIS 10.6.1, which were used to identify patterns of spatial distribution in the occupation by pinnipeds in the WRIL.

Results

A total of 1908 records of pinnipeds were observed in the WRIL between July 2019 and November 2020, made up of 1437 (75.32%) South American sea lions, 469 (24.58%) South American fur seals, and two (0.10%) southern elephant seals. Due to the long sample period and the proximity of the months, the same individual may have been registered more than once. The highest monthly abundance of all species occupying the WRIL was in August 2019, with 144 individuals occurring simultaneously, including 94 South American fur seals and 50 South American sea lions (Figure 2). September 2019 and September 2020 were the months with the second highest abundance, with 127 specimens occupying the WRIL. From all aerial photographic counts (i.e., 31 surveys), September had the highest mean abundance (mean 113.75; SD: ± 8.58, $n = 4$, min = 91, max = 127),

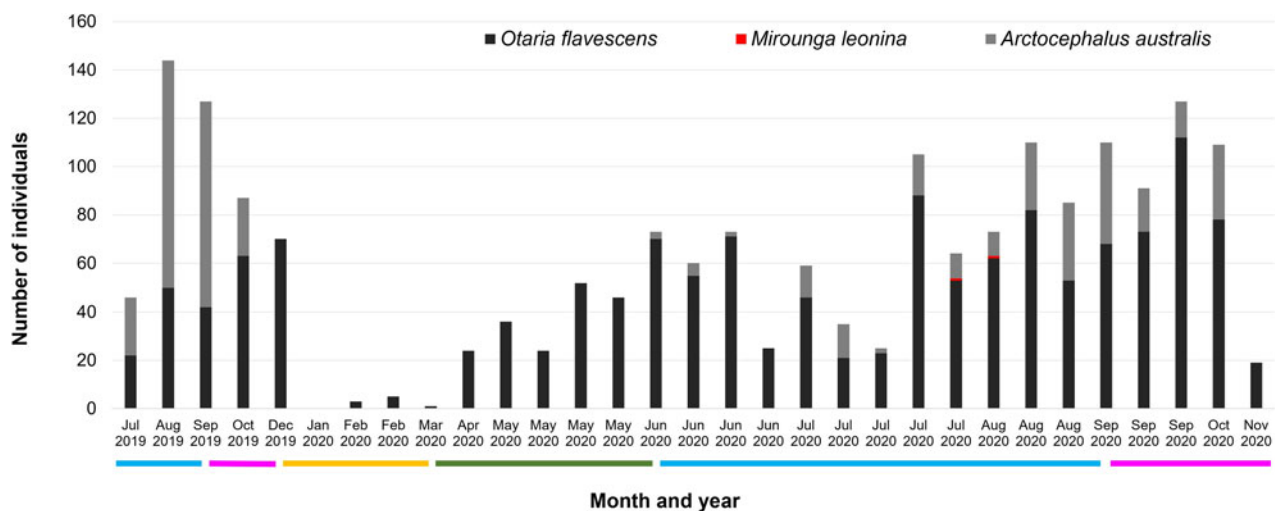


Figure 2. Total number of pinniped individuals found during seasonal occupation of the Wildlife Refuge of Ilha dos Lobos on the southern Brazilian coast between July 2019 and November 2020. The lines indicate the corresponding season. Blue line: austral winter; pink line: austral spring; yellow line: austral summer and green line: austral autumn.

followed by August (mean 103.00; SD: ± 15.69 , $n = 4$, min = 73, max = 144) and October (mean 98; SD: ± 11 , $n = 2$, min = 87, max = 109). June (mean 57.75; SD: ± 11.34 , $n = 4$, min = 25, max = 73) and July (mean 55.67; SD: ± 11.51 , $n = 6$, min = 25, max = 105) showed a similar mean of individuals, followed by May (mean 39.5; SD: ± 6.13 , $n = 4$, min = 24, max = 52) and February (mean 4; SD: ± 1.41 , $n = 2$, min = 3, max = 5). The number of individuals' observer in February, March, April, November, and December can be found in Figure 2.

South American sea lions were present on WRIL in all surveys except in January 2020, when no pinnipeds were recorded. A much stronger seasonal fluctuation in numbers was observed for South American fur seals, with statistical differences in the average number of individuals between seasons (Table 2). This species was recorded only between July and October across the two years. During the 31 surveys, the abundance of South American fur seals was higher than that of South American sea lions on two occasions (August and September 2019). Moreover, the southern elephant seal, *Mirounga leonina*, was recorded only on two occasions: July and August 2020 (Figure 2).

Concerning the sex and age categories over the years for the two main pinniped species, no distribution pattern was found along the studied months. Only one potential female was recorded during a survey in September 2019 for South American sea lions, and the subadult males were predominant ($n = 1237$; 86.08%), followed by adult males ($n = 130$; 9.05%) (Figure 3). Juveniles were observed in 19 of the 31 aerial counts, corresponding to 69 individuals (4.80%), and yearlings were not recorded during this study for this species. For South American fur seals, there was a predominance of juveniles ($n = 396$, 84.43%), followed by subadults ($n = 46$, 9.81%) (Figure 3). Adult males ($n = 6$, 1.28%) and yearlings ($n = 21$, 4.48%) were observed only in five occasions. The two southern elephant seals recorded during the study period (July and August 2020) were juvenile males.

Regarding the spatial occupation of the animals, a total of 1908 individuals were plotted during the 31 surveys. Most of the sightings were recorded in the northern area of the island (1621; 85.10%), followed by the central area (286; 14.88%) and the southern area (1; 0.02%) (Table 3, Figure 4). However, South

American sea lions appeared to form clusters, mainly in the northern part of the island (Figure 4), whereas the spatial occupation of South American fur seals was more dispersed, and in smaller groups mainly occupying the rocks all over the central and northern zones (Figure 4). The only record in the southern area corresponds to a South American fur seal resting on a rock. Both times, the southern elephant seal was recorded, and the individuals were grouped with South American sea lions, resting in the northern and central areas.

Discussion

This study demonstrates that South American sea lions are present throughout the year in the WRIL, although there are fewer individuals during the summer. However, South American fur seals showed a strong seasonal presence, occurring only in the austral winter and spring months. Southern elephant seals are infrequent and can be considered as an occasional visitor to this MPA area.

Although the presence of South American sea lions has been observed across the entire year, the statistical differences between months indicate higher concentrations in winter and spring. This pattern was observed in previous studies conducted in the WRIL, which also reported a higher concentration of South American sea lions during these seasons, with more than a hundred individuals in some observations (Sanfelice et al., 1999; Silva, 2004; Procksch et al., 2020). The number of individuals at the WRIL increases during winter and spring months, because it is the second geographic resting site for pinnipeds along the Brazilian coast, taking into account that these animals came from Uruguay and Argentina, and find as a first haulout site the Wildlife Refuge of Molhe Leste de São José do Norte (WRML), which is located 400 km south of our study area (Rosas et al., 1994). In the WRML they concentrate in autumn and summer months, coinciding with the months of their arrival and departure from the Brazilian coast, respectively. In other words, the sea lions that use both Wildlife Refuges from Ilha dos Lobos and Molhe Leste de São José do Norte seem to exhibit a sequential occupation of these sites, after they leave their Uruguayan and Argentinean

Table 2. GLM model results based on the Poisson distribution for pinniped counts

| Species | Parameter | Estimate | Standard error | z-value | P-value |
|-------------------------|-----------|----------|----------------|---------|-----------------------|
| South American sea lion | Intercept | 3.18 | 0.20 | 15.57 | $<2 \times 10^{-16}$ |
| | August | 0.94 | 0.21 | 4.42 | 9.87×10^{-6} |
| | December | 1.07 | 0.24 | 4.53 | 6.03×10^{-6} |
| | February | -1.80 | 0.41 | -4.39 | 1.14×10^{-5} |
| | January | -19.48 | 2103.36 | -0.01 | 0.99 |
| | July | 0.56 | 0.21 | 2.64 | 0.008 |
| | June | 0.83 | 0.21 | 3.89 | 0.0001 |
| | March | -3.18 | 1.02 | -3.11 | 0.001 |
| | May | 0.50 | 0.22 | 2.27 | 0.02 |
| | November | -2.23 | 0.31 | -0.76 | 0.44 |
| | October | 1.08 | 0.22 | 4.89 | 1.06×10^{-6} |
| | September | 1.12 | 0.21 | 5.29 | 1.12×10^{-7} |
| South American fur seal | Intercept | 0.10 | 0.32 | 0.33 | 0.74 |
| | Spring | 3.45 | 0.33 | 10.54 | $<2 \times 10^{-16}$ |
| | Summer | -15.64 | 715.99 | -0.02 | 0.98 |
| | Winter | 3.09 | 0.32 | 9.64 | $<2 \times 10^{-16}$ |

The intercept for the South American sea lion models corresponds to April and for South American fur seals to autumn.

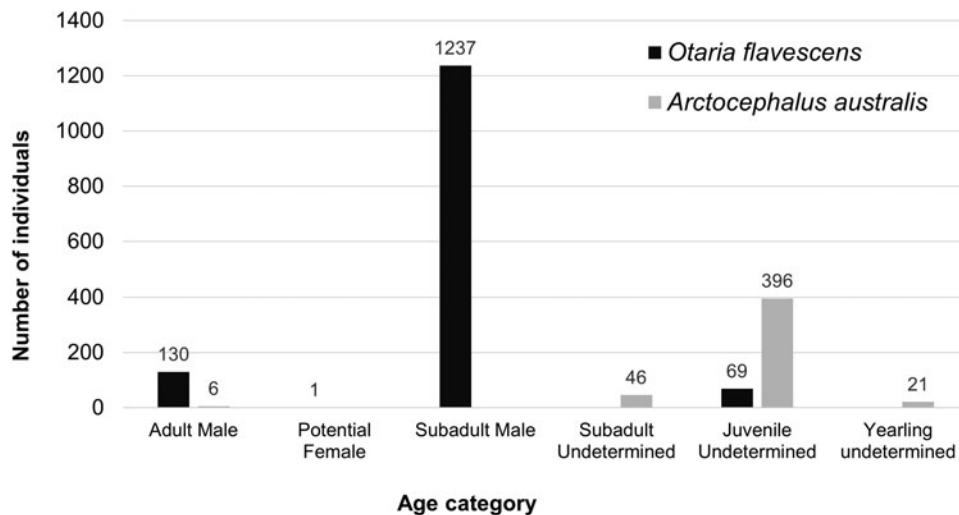


Figure 3. South American sea lions (*Otaria flavescens*) and fur seals (*Arctocephalus australis*) grouped by age categories observed in the Wildlife Refuge of Ilha dos Lobos on the southern Brazilian coast between July 2019 and November 2020.

Table 3. Summary of the spatial distribution of the cumulative records of pinnipeds across the three zones (north, centre, and south) of the Wildlife Refuge of Ilha dos Lobos, southern Brazil, between July 2019 and November 2020

| Taxa | Number of records | North | Centre | South |
|-------------------------|-------------------|---------------|--------------|-----------|
| Pinnipeds | 1908 | 1621 (85.10%) | 286 (14.88%) | 1 (0.02%) |
| South American sea lion | 1437 | 1293 (90.20%) | 144 (9.80%) | – |
| South American fur seal | 469 | 327 (69.72%) | 141 (30.06%) | 1 (0.22%) |
| Southern elephant seal | 2 | 1 (50.00%) | 1 (50.00%) | – |

breeding colonies, characterizing the seasonal movements of South American sea lions (Rosas *et al.* 1994, Silva, 2004; Procksch *et al.*, 2020). Moreover, the present study provides further evidence of the presence of the South American sea lion during the summer months. The presence of a few individuals of this species during this period has been previously reported by Sanfelice *et al.* (1999) and Silva (2004). These combined results indicate that not all individuals depart from the island after the peak of occupation during the winter and spring months.

According to Sanfelice *et al.* (1999), the rare individuals observed during summer corresponded to subadult males. The presence of South American sea lions in summer was also reported by Pont *et al.* (2016) during interviews conducted a decade earlier with local fishermen from Torres and Passo de Torres. Oliveira *et al.* (2020) also confirmed the occurrence of this species in the region during the summer based on records of interactions between South American sea lions and coastal gillnet fisheries in these same communities. The presence of these males throughout the summer in the WRIL could be associated with their non-participation in the reproductive season, possibly because they have not reached the sexual or social maturity to form harems, which means that they did not get females to copulate with (Vaz-Ferreira, 1982b; Grandi *et al.*, 2010).

Although the South American sea lion was the most frequent pinniped recorded on the island, its numbers were surpassed by the South American fur seals on two occasions. This occasional shift in the proportion of the two pinniped species on the island was also recently reported by Procksch *et al.* (2020). In this study, an unexpected number of yearlings of South American fur seals were recorded during September ($n = 199$) and November ($n = 102$) in 2018. According to Procksch *et al.* (2020), the increased abundance of South American fur seals could be related to

population growth or to natural fluctuations in births and survival from year to year in the Uruguayan breeding colonies, which is potentially where the WRIL fur seals come from (Franco-Trecu *et al.*, 2019). To further explore this hypothesis, it is necessary to continue the counts in a network of monitoring sites, including the WRIL and the breeding sites, mainly in Uruguay, which are closest to southern Brazil.

During the 31 aerial photographic counts in this study, southern elephant seals were recorded on only two occasions in the WRIL. Considering the individuals were both categorized as juvenile males, and the temporal proximity of the observations recorded, we believe that these records referred to the same individuals who remained resting on the island during this period. This species is considered less frequent on the Brazilian coast (Pinedo, 1990; Simões-Lopes *et al.*, 1995; Oliveira, 1999; Silva, 2004; Moura *et al.*, 2010) and probably came from the colonies on the Valdés Peninsula, Argentina, the closest southern elephant seal colonies to the Brazilian coast (Lewis, 1996; Moura *et al.*, 2010).

The spatial occupation of the WRIL by pinnipeds occurred mainly in the northern area of the island, in patterns similar to those found by Procksch *et al.* (2020). South American sea lions preferred to stay in groups, forming clusters mainly in the flat areas of the northern area, whereas the fur seals remained dispersed on top of the higher rocks, located both in the north and in the central areas. Vaz-Ferreira (1982b) briefly mentioned that in some Uruguayan islands, South American sea lions select sandy areas, whereas fur seals prefer to occupy areas with higher rocks (Vaz-Ferreira, 1982a). Although the central and southern areas of the WRIL present long periods of surface exposure, both species seem to prefer the northern part of the island, probably because it is the highest area of the relief, making the driest and most protected environment on the island during high tides (Procksch *et al.*, 2023).

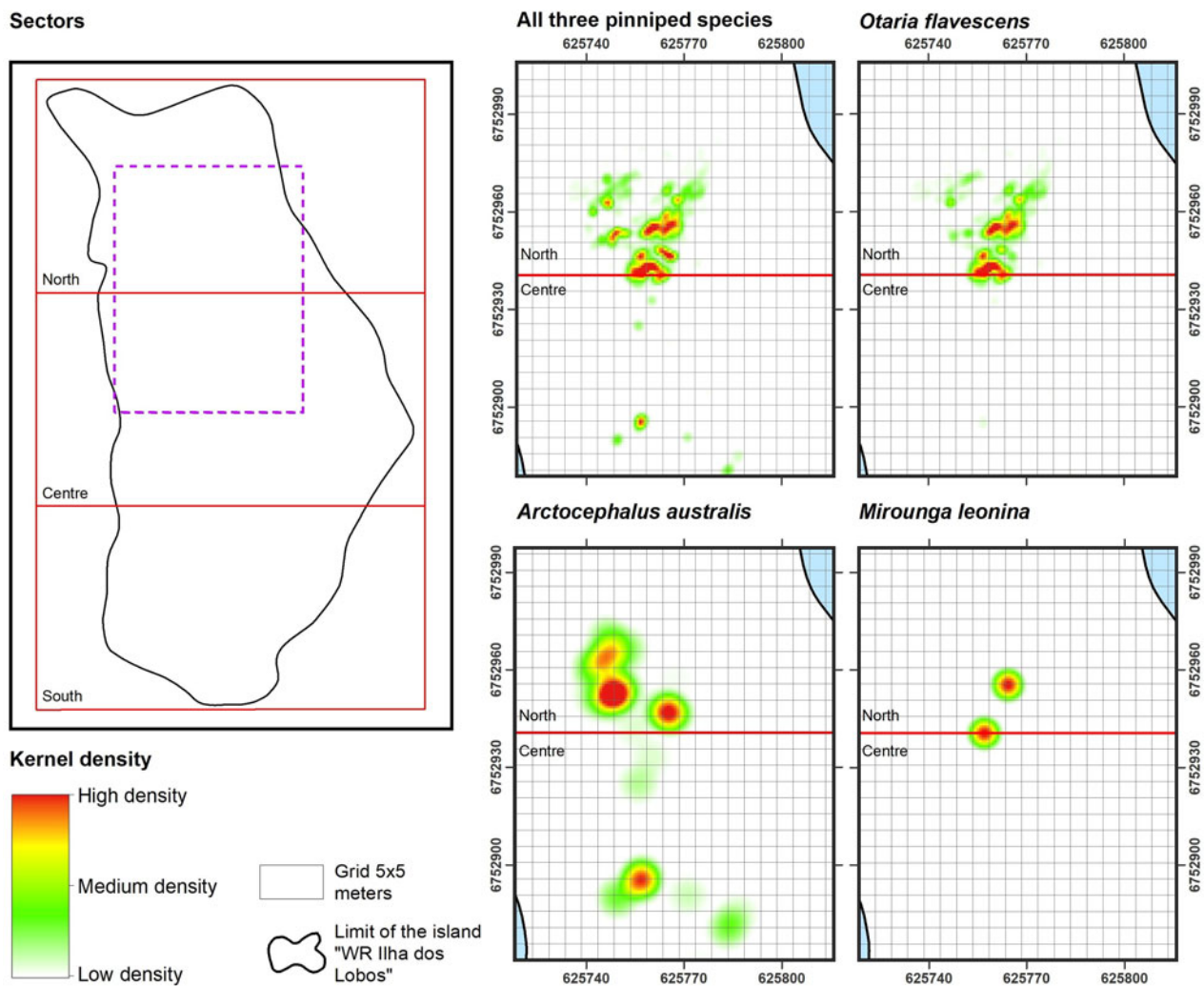


Figure 4. Spatial occupation in the Wildlife Refuge of Ilha dos Lobos by pinnipeds estimated using Kernel Density Analysis for the 31 surveys between July 2019 and November 2020. The emerged area of the island is presented in the left part of the figure and the sectors analysed (north, centre, and south) are shown in red.

These results on the seasonal and spatial occupation of the island allow us to better understand the occurrence of pinnipeds in this MPA throughout the year. The information on monthly abundance can be used to plan management and conservation actions as well as scientific expeditions and the public use of this MPA. In this context, human activities that may be developed in the WRIL, such as research or tourism, should take into account the information on year-round occupation, as well as comply with the guidelines of this MPA. Procksch *et al.* (2020), based on counts conducted exclusively from July to November, recommended that potential activities in the WRIL, such as island-based research, must occur in the summer. However, considering that some South American sea lions occupy the WRIL during the summer, we suggest that prior to the development of any activity, it is imperative to implement a plan for monitoring the presence of pinnipeds with the aim of minimizing any impact on the individuals present.

Finally, our study suggests that continuing studies both in the WRIL and in the breeding colonies of these species, mainly in Uruguay, are needed. These would establish whether the fluctuations in the abundance of pinnipeds observed in the WRIL, especially regarding the high number of yearlings of South American fur seals in some recent years, could be related to fluctuations in the number of births and survival of individuals during their first year of life. Studying the network of monitoring sites covering the Uruguayan breeding sites and Brazilian haulout areas during the same time frame is fundamental to understanding the dynamics

between these habitats. Our data highlight the importance of the WRIL in the life cycle of South American pinnipeds and reinforce the understanding of the uniqueness of this area on the Brazilian coast.

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Conflict of interest. The authors declare no competing interests.

Ethical standards. This study was based on aerial photographic counts with no animal caught or killed during the summarized research. The aerial photographs were collected under Brazilian Biodiversity authorization and information system (SISBIO number 54476-4) and by the Ethics Committee on the Use of Animals provided by University of Vale do Rio dos Sinos (number PPECEUA05.2019) attesting that the authors did not violate any ethical rule for collecting aerial photos.

Data availability. Data will be available through requests and mediate by JMBA editors.

References

- Aires AS (2020) Evaluation of digital outcrop model generation from SFM digital photogrammetry using multiple spherical panoramic images. Trabalho de Conclusão de Curso (Bacharelado em Engenharia Cartográfica e de Agrimensura). Universidade do Vale do Rio dos Sinos, São Leopoldo, BRA.
- Bastida R and Rodríguez D (1994) Hallazgo de un apostadero estacional de lobos marinos de dos pelos, *Arctocephalus australis* (Zimmermann, 1783), en bajos fondos frente a la costa de Mar del Plata (Provincia de Buenos Aires, Argentina). *Anales 4ª Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur*, 1–22.
- Bates D, Maechler M, Bolker B and Walker S (2015) Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67, 1–48.
- Bombau A and Sztren D (2017) Seasonal variability of South American Fur Seals (*Arctocephalus australis*) and sea lions (*Otaria flavescens*) in two haul-outs and interactions with small-scale fisheries off the coast of Montevideo, Uruguay. *Aquatic Mammals* 43, 479–491.
- Brasil (1983) Decreto no. 88.463, de 4 de julho de 1983. Cria a Reserva Ecológica Ilha dos Lobos, e dá outras providências. Diário Oficial da República Federativa do Brasil 129, 12009.
- Brasil (2005) Decreto de 4 de julho de 2005. Presidência da República-Casa Civil- Subchefia para Assuntos Jurídicos. 04 de julho de 2005. Brasília, BRA. Available at https://www.planalto.gov.br/ccivil_03/_Ato2004-2006/2005/Dnn/Dnn10578.htm (Accessed online 18 July 2023).
- Campagna C (1985) The breeding cycle of the southern sea lion, *Otaria byronia*. *Marine Mammal Science* 1, 210–218.
- Chandler J and Buckley S (2016) Structure from motion (SFM) photogrammetry vs terrestrial laser scanning. In Carpenter MB and Keane CM (eds), *Geoscience Handbook*. Alexandria, VA: AGI Data Sheets, Section 20.1. Available at <https://hdl.handle.net/2134/21673> (Accessed online 10 July 2023)
- Crespo EA (1988) *Dinámica poblacional del lobo marino de un pelo Otaria flavescens* (Shaw, 1800), en el norte del Litoral Patagónico (PhD Thesis). Universidad Nacional de Buenos Aires, Buenos Aires, ARG.
- Danilewicz D, Moreno I, Tavares M and Sucunza F (2017) Southern right whales (*Eubalaena australis*) off Torres, Brazil: group characteristics, movements, and insights into the role of the Brazilian-Uruguayan wintering ground. *Mammalia* 81, 225–234.
- Engel MT, Marchini S, Pont AC, Machado R and Oliveira LR (2014) Perceptions and attitudes of stakeholders towards the Wildlife Refuge of Ilha dos Lobos, a marine protected area in Brazil. *Marine Policy* 45, 45–51.
- Franco-Trecu V, Costa P, Scharam Y, Tassino B and Inchausti P (2014) Sex on the rocks: reproductive tactics and breeding success of South American fur seal males. *Behavioral ecology* 25, 1513–1523.
- Franco-Trecu V, Drago M, Grandi MF, Soutullo A, Crespo EA and Inchausti P (2019) Abundance and population trends of the South American Fur Seal (*Arctocephalus australis*) in Uruguay. *Aquatic Mammals* 45, 48–55.
- Grandi MF, Dans SL, García NA and Crespo EA (2010) Growth and age at sexual maturity of South American sea lions. *Mammalian Biology* 75, 427–436.
- Groch KR, Palazzo JT, Flores PAC, Adler FR and Fabian ME (2005) Recent rapid increases in the right whale (*Eubalaena australis*) population off southern Brazil. *Latin American Journal of Aquatic Mammals* 4, 41–47.
- King JE (1983) *Seals of the World*. British Museum of Natural History. Ithaca, New York: Cornell University Press.
- Lewis M (1996) Elefante marino del sur: biología de la especie, descripción general de la agrupación de la Península Valdés y protocolos de trabajo. *Informes Técnicos del Plan de Manejo Integrado de la Zona Costera Patagónica* 16, 1–29.
- Moura J, Di Dario B, Lima L and Siciliano S (2010) Southern elephant seals (*Mirounga leonina*) along the Brazilian coast: review and additional records. *Marine Biodiversity Records* 3, 1–5.
- Oliveira LR (1999) *Caracterização dos padrões de ocorrência dos pinípedes (Carnivora: Pinnipedia) ocorrentes no litoral do Rio Grande do Sul, Brasil, entre 1993 e 1999* (Master Dissertation). Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS), Porto Alegre, BRA.
- Oliveira LR (2013) Carnívoros marinhos. In Weber MM, Roman C and Cáceres NC (eds), *Mamíferos do Rio Grande do Sul*. Santa Maria: Editora UFSM. 405–227.
- Oliveira LR, Danilewicz D, Martins MB, Ott PH, Moreno IB and Caon G (2001) New records of the Antarctic fur seal, *Arctocephalus gazella* (Peters, 1875) to the Brazilian coast. *Com. Museu de Ciência e Tecnologia da PUCRS* 14, 201–207.
- Oliveira LR, Gehara, MCM, Fraga, LD, Lopes, F, Túnez, JI, Cassini, MH, Majluf, P, Cárdenas-Alayza, S, Pavés, HJ, Crespo, EA, García, N, Castro, RL, Hoelzel, AR, Sepúlveda, M, Olavarría, C, Valiati, VH, Quiñones, R, Pérez-Alvarez, MJ, Ott, PH and Bonatto, SL (2017) Ancient female philopatry, asymmetric male gene flow, and synchronous population expansion support the influence of climatic oscillations on the evolution of South American sea lion (*Otaria flavescens*). *PLoS one* 12, e0179442.
- Oliveira LR, Pont, AC, Machado, R, Engel, MT, Ott, PH, Crespo, EA and Marchini, S (2020) Assessing the economic impact caused by South American sea lions based on onboard check versus fishermen's perception: the two sides of the same coin. *Marine Policy* 121, 104193.
- Oliveira LR, Machado R, Alievi MM and Würdig NL (2006) Crabeater seal (*Lobodon carcinophaga*) on the coast of Rio Grande do Sul State, Brazil. *Latin American Journal of Aquatic Mammals* 5, 145–148.
- Ott PH, Brandão MV, Sucunza F and Oliveira LR (2022) O Turismo Embarcado no Refúgio de Vida Silvestre da Ilha dos Lobos, Sul do Brasil: Estado Atual e Perspectivas Futuras. *Gestão do Uso Público: Turismo e Lazer em Áreas Protegidas* 12, 1–24.
- Pavanato H, Silva KG, Estima SC, Monteiro DS and Kinas PG (2013) Occupancy dynamics of South American Sea-Lions in Brazilian Haul-outs. *Brazilian Journal of Biology* 73, 855–862.
- Pinedo MC (1990) Ocorrência de pinípedes na costa brasileira. *Garcia de Orta - Serie de Zoologia* 15, 37–48.
- Pont AC, Marchini S, Engel MT, Machado R, Ott PH, Crespo EA, Coscarella M, Dalzochio MS and Oliveira LR (2016) The human dimension of the conflict between fishermen and South American sea lions in southern Brazil. *Hydrobiologia* 767, 1–16.
- Procksch N, Grandi MF, Ott PH, Groch K, Flores PAC, Zagonel M, Crespo EA, Machado R, Pavez G, Guimarães M, Veronez M and Oliveira LR (2020) The northernmost haulout site of South American sea lions and fur seals in the western South Atlantic. *Scientific Reports* 10, 20008.
- Procksch N, Berchieri NB, Horota RK, Sales V, Ott PH, Danilewicz D, Guimarães TT, Guimarães M, Veronez MR and Oliveira LR (2023) Habitat use by South American fur seals (*Arctocephalus australis*) and sea lions (*Otaria flavescens*) in a marine protected area in southern Brazil. *Marine Policy* 155, 105693.
- R Core Team (2019) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. Auckland, NZ. Available at <https://www.R-project.org/> (Accessed online 04 July 2022).
- Rosas FCW, Pinedo MC, Marmotel M and Haimovici M (1994) Seasonal movements of the South American sea lion (*Otaria flavescens* Shaw, 1800) of the Rio Grande do Sul coast, Brazil. *Mammalia* 58, 51–59.
- Sanfelice D, Vasques VC and Crespo EA (1999) Ocupação sazonal por duas espécies de Otariidae (Mammalia, Carnivora) da Reserva Ecológica Ilha dos Lobos, Rio Grande do Sul, Brasil. *Itheringia Serie de Zoologia* 87, 101–110.
- Schossler V, Simões JC, Aquino FE and Viana DR (2018). Precipitation anomalies in the Brazilian southern coast related to the SAM and ENSO climate variability mode. *Brazilian Journal of Water Resources* 23, e14.
- Silva-Jr JM, Miranda AV, Attademo LFN, Zanoni SA and Luna FO (2019) *Manual de boas práticas em interação com mamíferos marinhos*, 1st edn. Brasília: ICMBio/CMA.

- Silva KG** (2004) *Os pinípedes no Brasil: ocorrências, estimativas populacionais e conservação* (PhD thesis). Fundação Universidade Federal de Rio Grande, Rio Grande, BRA.
- Silva KG, Araújo TG, Crivellaro CVL and Menezes RB** (2014) *Os Mamíferos Marinhos do Litoral do Rio Grande do Sul*, 1st Edn. Rio Grande: NEMA.
- Silverman BW** (1986) *Density Estimation for Statistics and Data Analysis*, 1st edn. London: Chapman & Hall.
- Simões-Lopes PC, Drehmer CJ and Ott PH** (1995) Nota sobre os Otariidae e Phocidae (Mammalia: Carnivora) da costa norte do Rio Grande do Sul e Santa Catarina, Brasil. *Biociências* **3**, 173–181.
- VanWormer E, Mazet JAK, Hall A, Gill VA, Boveng BL, London JM, Gellat T, Fadely BL, Lander ME, Sterling J, Burkanov VN, Ream RR, Brock PM, Rea LD, Smith BR, Jeffers A, Henstock M, Rehberg MJ, Burek-Huntington KA, Cosby SL, Hammond JA, Goldstein T** (2019) Viral emergence in marine mammals in the North Pacific may be linked to Arctic sea ice reduction. *Scientific Reports* **9**, 15569.
- Vaz-Ferreira R** (1982a) *Arctocephalus australis* (Zimmermann): South American fur seal. *Mammals in the Seas, FAO Fisheries Series* **4**, 497–508.
- Vaz-Ferreira R** (1982b) *Otaria flavescens* (Shaw): South American sea lion. *Mammals in the Seas. FAO Fisheries Series* **4**, 477–495.