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Four decades of pinniped records on the coast of São Paulo state, Southeastern Brazil (1981–2023)

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Abstract

Beach monitoring is an essential method for documenting marine mammal strandings, and gathering valuable information on individual and population dynamics. This study reports occurrences of pinniped strandings along the coast of São Paulo state (23-25° S), Southeastern Brazil, with the aim of updating species records, analyzing seasonal, annual, and spatial stranding patterns and identifying the sex and maturity class of the individuals. Data were collected between 1980 and 2023, initially through sporadic records and non-systematic monitoring. From 2015 onward, data were systematically collected via daily monitoring conducted by the Santos Basin Beach Monitoring Project (PMP-BS). Throughout the study period, a total of seven species were recorded in the state, representing both the Otariidae and Phocidae families: South American sea lion (*Otaria flavescens*), South American fur seal (*Arctocephalus australis*), Subantarctic fur seal (*Arctocephalus tropicalis*), Antarctic fur seal (*Arctocephalus gazella*), southern elephant seal (*Mirounga leonina*), leopard seal (*Hydrurga leptonyx*), and crabeater seal (*Lobodon carcinophaga*). The findings revealed that immature males of South American fur seal and mature males of Subantarctic fur seal were the most frequently encountered individuals. Strandings occurred year-round, with the highest number of occurrences observed in winter, the only season during which all listed species were recorded. Furthermore, the southern coast of São Paulo state exhibited the highest concentration of strandings. This study represents the first detailed account of pinniped records along the São Paulo coast.

Keywords:
Atlantic Ocean, extralimital, long-term monitoring, Otariidae, Phocidae, stranding

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Introduction

Monitoring marine mammal strandings along the coast has proven to be an effective method for understanding species occurrence, distribution, and population dynamics (Prado et al., 2016; Warlick et al., 2018). This approach, which is relatively simple and cost-effective compared to aerial and shipboard surveys, allows the maintenance of a robust database if long time series are maintained (Pyenson, 2010; Pavanato et al., 2013; Prado et al., 2016). Additionally, it provides valuable information about various aspects of individuals within the monitored area, including age class, sex (Chadwick et al., 2023), health status (Arbiza et al.,

2012; Sacristán et al., 2021; Duarte-Benvenuto et al., 2022), diet (de Lima et al., 2024), and movements (Procksch et al., 2020).

The coast of São Paulo (19°45′ S - 25°18′ S), southeastern Brazil, had not been consistently monitored until the establishment of the Santos Basin Beach Monitoring Project (PMP-BS) in 2015, under the federal environmental licensing framework. Since then, monitoring activities have included daily transects conducted by land or water, depending on distance and accessibility challenges (Petrobras, 2019). Prior to this, marine mammal research and rehabilitation institutions recorded occasional strandings, often based on reports from collaborators.

Daily monitoring provides access to remote areas with low human activity, likely leading to a higher number of strandings being recorded. While it has limitations in improving the detection of oceanic species, especially those that rarely wash ashore or are found in an advanced state of decomposition, it remains highly valuable for documenting fresh specimens and responding more quickly and efficiently to live stranding events, particularly those involving pinniped species, which are often found alive.

In Brazil, eight species of pinnipeds have been recorded, including four species from the Otariidae family: South American sea lion (*Otaria flavescens*), South American fur seal (*Arctocephalus australis*), Subantarctic fur seal (*Arctocephalus tropicalis*), Antarctic fur seal (*Arctocephalus gazella*); and four species from the Phocidae family: Southern elephant seal (*Mirounga leonina*), leopard seal (*Hydrurga leptonyx*), crabeater seal (*Lobodon carcinophaga*), and Weddell seal (*Leptonychotes weddellii*) (Castello & Pinedo, 1977; Pinedo, 1990; Pinedo et al., 1992; Rosas et al., 1992; Magalhães et al., 2003; Mayorga et al., 2016; Frainer et al., 2017). The first three cited Otariidae species are the most frequent species along the Brazilian coast (Moura & Siciliano, 2007; Moura et al., 2011; Prado et al., 2016).

While there are no pinniped breeding colonies in Brazil, two significant haul-out sites exist in Rio Grande do Sul (~30º S), primarily inhabited by juvenile and older male South American sea lions: the Wildlife Refuge (WR) Molhe Leste and WR Ilha dos Lobos (Pavanato et al., 2013; Procksch et al., 2020). Due to the presence of these haul-out areas and the proximity of breeding colonies in neighboring countries, particularly for South American fur seal and South American sea lion, most pinniped records are concentrated in higher latitudinal regions. Rio Grande do Sul and Santa Catarina are the Brazilian states with the highest occurrences of pinnipeds (Silva, 2004).

Moreover, it is noteworthy that several pinniped species from Patagonian, Subantarctic, and Antarctic regions have been documented near the Equatorial Atlantic waters. For example, in addition to the more common reports of pinnipeds in the southeastern region (Moura & Siciliano, 2007; Siciliano et al., 2020), there are records of fur seals as far north as the São Pedro and São Paulo Archipelago (00°56′ N; 29°22′ W) (Milmann et al., 2019; Sousa-Lima et al., 2022), and along the northeastern Brazilian coast, in the states of Bahia (12° S) and Sergipe (11° S) (Velozo et al., 2009; Siciliano et al., 2016), Alagoas (9º S) (Ximenez, 1980), Pernambuco (7° S), Rio Grande do Norte (5° S) (SIMMAM, 2024), and Maranhão (2º S) (G1, 2020). Additionally, a Southern elephant seal was sighted in the Fernando de Noronha Archipelago (3º S) (Lodi & Siciliano, 1989), and a Weddell seal was recorded at Trindade Island (20°31′ S; 29°19′ W), (Frainer et al., 2017). All of these reports fall outside the typical range of these species, and such long-distance movements are often associated with foraging behavior. They may also be influenced by abiotic factors such as ocean currents, productivity, sea surface temperature, and climate patterns, which could be undergoing shifts due to climate change (Oliveira, 1999; Oliveira et al., 2001, 2024).

Considering the reports of pinniped species at lower latitudes, this paper aims to document their occurrence along the tropical coast of São Paulo (23–25º S). It describes the species characteristics and statistically analyzes seasonal, annual, and spatial stranding patterns. The findings can improve monitoring efforts and animal rescue strategies, increase understanding of stranding patterns, and provide insights into potential long-term changes in these coastal ecosystems.

Material and Methods

Study area

The São Paulo coastline has a humid tropical climate, with high temperatures and no distinct dry season, influenced by the nearby Serra do Mar, which causes year-round precipitation (CETESB, 2023). This coastline is complex, encompassing diverse natural environments such as beaches, rocky shores, mangroves, lagoons, and sandbanks. The northern São Paulo coastline features small crescent-shaped sandy beaches interspersed with rocky shores. The central coastline has long, less indented beaches with low topographic gradients, forming wide coastal plains. There are

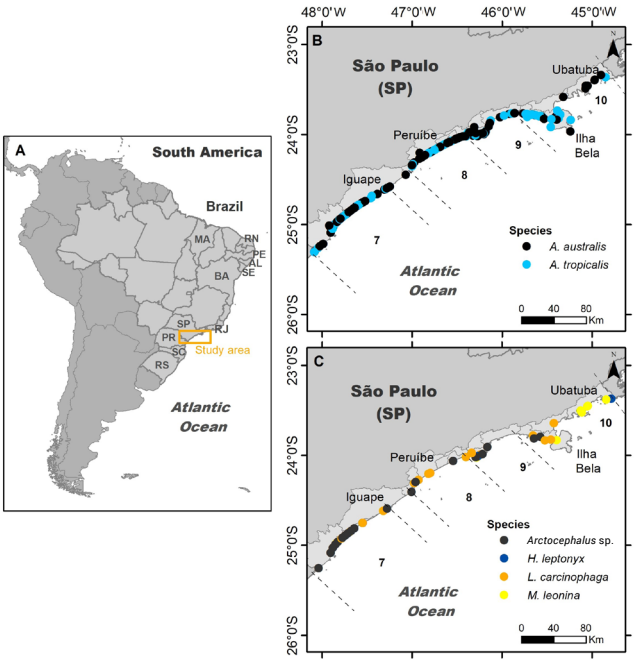

Figure 1. (A) Map of South America highlighting Brazil, the study area, and the states referenced in this study: AL = Alagoas, BA = Bahia, MA = Maranhão, PR = Paraná, PE = Pernambuco, SC = Santa Catarina, SP = São Paulo, SE = Sergipe, RN = Rio Grande do Norte, and RS = Rio Grande do Sul. (B) Stranding locations of the most frequently recorded pinniped species. (C) Stranding locations of less frequently recorded pinniped species along the São Paulo coast from 1981 to 2023. The map also indicates the PMP-BS transects, with coastal cities represented in light gray.

dissipative, high-energy beaches oriented NE-SW and, in the municipalities of Santos, São Vicente, and Guarujá, the coastline forms a large coastal embayment with a N-S orientation. The southern coastline has high-energy dissipative beaches oriented NE-SW, with large, nearly uninterrupted beach arcs about 70 km long, and the area is open to high-energy wave systems from the S-SSE (Souza, 2012).

The study area covers the entire coast of São Paulo, from Cananéia (25°01'28" S, 47°55'56" W) to Ubatuba (23°26'02" S, 45°05'09" W) (Fig. 1). The total linear coastline has 407.56 km and the surveys during the years from 2015 to 2023 were realized according to the PMP-BS transects: 07 - Cananéia to Iguape (118.47 km); 08 - Peruíbe to Praia Grande (77.02 km); 09 - São Vicente to Bertioga (62.61 km); and 10 - São Sebastião to Ubatuba (149.46 km). Between transects 07 and 08, there is a gap referring to the rocky coast of the Juréia-Itatins Ecological Station.

Data collection and analysis

Before 2015, monitoring efforts were sporadic, with most stranding notifications coming from collaborators and locals (Period I: 1981-2014). From August 2015 to December 2023 (Period II: 2015-2023), records were collected through daily monitoring surveys of the entire coastline.

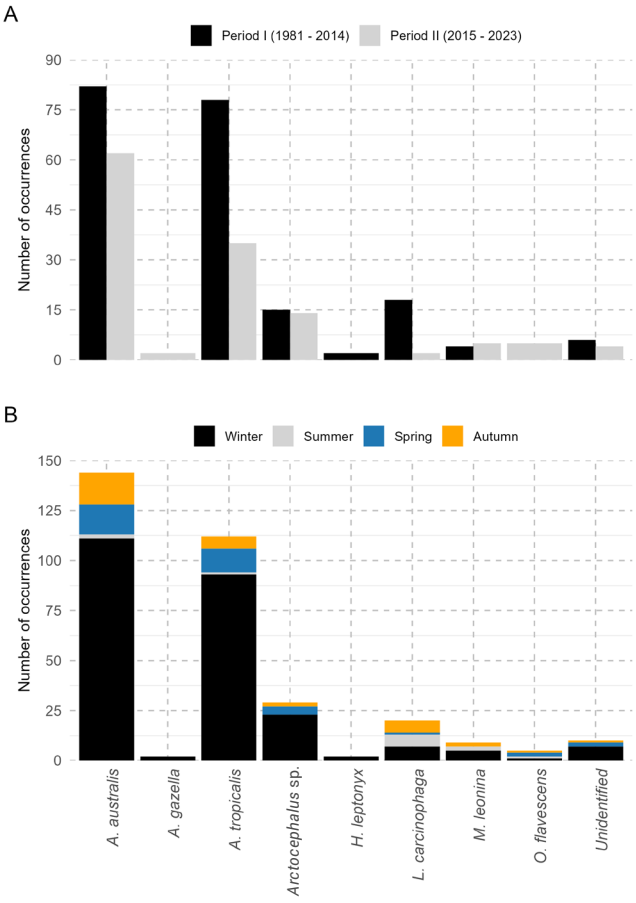

Figure 2. (A) Records of pinnipeds in the state of São Paulo in periods without systematic monitoring (1981-2014) and with regular monitoring by the Santos Basin Beach Monitoring Project/PMP-BS (2015-2023); (B) Number of occurrences of pinniped species for each season from 1981 to 2023.

Records were obtained from private and public databases of researchers and institutions, including the Aquatic Biota Monitoring Information System (SIMBA) and daily surveys were conducted by four different institutions: Instituto Argonauta, Gremar, Instituto Biopesca and Instituto de Pesquisas Cananéia. The data collection protocol included: species identification, date, geographical location, sex, standard body length, maturity class, human interaction evidence and decomposition state, evaluated according to Geraci & Lounsbury (2005): 1 = alive; 2 = fresh carcasses; 3 = carcasses with minimal autolysis; 4 = advanced decomposition; 5 = mummified or skeletal remains. Since age estimations are unavailable, sexual maturity was estimated based on standard length (Supplementary Material 1).

To determine whether there were seasonal trends in the occurrences of the pinnipeds, the data were categorized into four austral seasons: summer (22 December – 20 March); autumn (21 March – 20 June); winter (21 June – 22 September); and spring (23 September – 21 December).

Differences in strandings and species frequency between PMP-BS years and seasons were investigated using the chi-square test on the R statistical environment (version 2022.02.0). Due to the lack of systematization in Period I, along with inconsistencies in data collection and missing information on species, age, and sexual maturity, statistical analyses were conducted solely on data from Period II. The year 2015 was excluded from the analysis due to data collection beginning in August of that year. Regarding spatial distribution, maps showing stranding occurrences per species group were generated in ArcMap 10.8.1 using data from Periods I and II.

Results

Pinniped occurrence and distribution

Between 1981 and 2023 (Periods I and II), 366 strandings involving seven different pinniped species were recorded along the São Paulo coast, spanning from Cananéia to Ubatuba. Of these, 32 were resightings and were excluded from the data analysis.

During Period I (1981-2014), 205 individuals of the following species were recorded: South American fur seal (n = 82; 40%), Subantarctic fur seal (n = 78; 38.05%), crabeater seal (n = 18; 8.78%), Southern elephant seal (n = 4; 1.95%) and leopard seal (n = 2; 0.97%) (Fig. 2A). Some individuals could not be identified at the family or species level (n = 21; 10.25%), but most belonged to the genus *Arctocephalus* (n = 15). During Period II (2015-2023), 129 individuals were recorded, with South American fur seal (n = 62; 48.6%) and Subantarctic fur seal (n = 35; 27.13%) remaining the predominant species. Additionally, South American sea lion (n = 5; 3.88%); Southern elephant seal (n = 5; 3.88%); Antarctic fur seal (n = 2; 1.55%); crabeater seal (n = 2; 1.55%), and unidentified individuals (n = 18; 13.95%) were observed (Figs 2A and 3). The majority of unidentified individuals belong to the genus *Arctocephalus* (n = 14), similar to the previous period.

In both periods analyzed, South American fur seal was the most frequently recorded species, accounting for 43% of all pinniped strandings in the state of São Paulo over the entire period from 1981 to 2023. The proportion between South American fur seal and Subantarctic fur seal varied significantly over the years.

Figure 3. Examples of species of pinnipeds in São Paulo state: A) *Arctocephalus tropicalis* (1992); B) *Arctocephalus australis* (2000); C) *Arctocephalus gazella* (2021); D) *Lobodon carcinophaga* (2021); E) *Mirounga leonina* (2022); and F) *Otaria flavescens* (2022). Photo credits: Fernando Siqueira Alvarenga (A, B), IPeC (C), Instituto Argonauta (D, E), and Gremar (F).

However, the average for Period II is 2:1, respectively, similar to the average in the years with the highest number of strandings (2018 and 2020).

Among the recorded strandings, 12 lacked geographical coordinates and were excluded from the map: 11 from Period I (5.3%) and one from Period II (1%). Strandings varied according to sectors during Period II (χ^2 = 63.651, df = 3, p-value < 0.001) and were more frequent at higher latitudes, particularly along the central and southern coast of the state (transect 7 – 9) (Table 1; Fig. 1B and 1C). No visually significant differences in stranding distribution were observed among species, except for the Southern elephant seal, which was more frequently recorded along the northern coast, though with a low overall occurrence (n = 9), with seven cases in transect 10.

Seasonal and interannual variation of pinnipeds

Considering both periods, the majority of strandings were recorded during winter (n = 251; 75.15%), although a significant number of pinnipeds also stranded in spring and autumn (Fig. 2B). Analysis for Period II showed a significant difference between the seasons (χ^2 = 142.22, df = 3, p-value < 0.001). Winter was the only season in which all species were recorded. Notably, crabeater seals had a higher number of occurrences in summer. Of the 20 total occurrences of crabeater seal, 30% occurred in summer (n = 6), 30% in autumn (n = 6), 5% in spring (n = 1), and 35% in winter (n = 7) (Fig. 2B).

During Period I and Period II, it was observed that in certain years, there was a higher number of stranding records compared to the annual average for pinnipeds (mean = 14.3 strandings/year, considering Period II) (Fig. 4). There appears to be a trend of stranding peaks occurring after intervals of time, ranging from 5 to 10 years. Chi-square analyses were used to compare the number of animals recorded per year during Period II, confirming significant variation across the years (χ^2 = 73.547, df = 7, p < 0.001), with a particularly high number of strandings in 2018 (n = 45; 35.7% of the records between 2016 and 2023) (Fig. 4A). This pattern mirrors the records for South American fur seal (χ^2 = 57.426, df = 7, p < 0.001) and Subantarctic fur seal (χ^2 = 26.235, df = 7, p < 0.001), which were the most frequently found species, with 2018 and 2020 being the peak year for strandings of both species (Fig. 4B and C). Fig. 4D showed a different pattern for the other less frequent species recorded.

Sex and maturity class of frequent species

Considering the records where sex and maturity class could be determined, most South American fur seal individuals were immature males (Fig. 5A, B), while Subantarctic fur seals predominantly consisted of mature males (Fig. 5C, D). In Period I (1981-2014), a large percentage of South American fur seals (81.7%) and Subantarctic fur seals (66.7%) were recorded without identification of sex and maturity class. However, in Period II (2015-2023), the number of individuals with undetermined sex decreased, with only 35.5% of South American fur seals and 14.3% of Subantarctic fur seals lacking sex identification. The proportion of males to females for both species during Period II is approximately 2:1. Regarding maturity class, this information was absent in 9.7% of South American fur seal records and 8.6% of Subantarctic fur seal records.

Table 1. Comparison of the strandings occurred in periods I and II by transect and carcass code. The total numbers are presented alongside their respective percentages in relation to the total for each period. Absent data were not provided in the table.

	Period I (1981-2014)	Period II (2015-2023)	Total
Transect	**Strandings**		
7 (Cananéia - Iguape)	48 (23.4%)	70 (54.3%)	118
8 (Peruíbe - Praia Grande)	68 (33.2%)	27 (20.9%)	95
9 (São Vicente - Bertioga)	44 (21.5%)	10 (7.8%)	54
10 (São Sebastião - Ubatuba)	34 (16.6%)	22 (17%)	56
Code	**Strandings**		
1 - alive	173 (84.4%)	80 (62%)	253
2 - fresh	7 (3.4%)	3 (2.3%)	10
3 - minimal autolysis	2 (0.9%)	5 (3.9%)	7
4 - advanced decomposition	11 (5.4%)	30 (23.3%)	41
5 – mummified	3 (1.5%)	11 (8.5%)	14

Of the 38 records involving less frequent species, 23 lacked standard length information, preventing maturity class determination. For the Antarctic fur seal, two males were recorded, one mature and one immature. For the crabeater seal, there was one mature individual, seven immatures, and 12 undetermined (five females, three males, and four unclassified). Southern elephant seal records included three mature individuals and six undetermined (one female, five males, and three unclassified). South American sea lion records consisted of two mature individuals and three undetermined (all males). The leopard seal was recorded twice, with one female and one undetermined individual, both lacking maturity class information.

Stranding conditions and monitoring data collection

A notable characteristic of pinniped strandings in this study is that most animals were found alive (n = 253), accounting for 75.7% of cases throughout the entire period, representing the majority in both periods (Table 1). Of the 253 animals found alive, 28.5% (n = 72) died, and 14.2% (n = 36) lacked information regarding care and final destination, with these cases occurring during Period I. Of the 145 living animals, 48.3% (n = 70) remained at the stranding location without requiring veterinary intervention, 23.5% (n = 34) received veterinary treatment after being captured and transported to a rehabilitation center, 15.2% (n = 22) were treated in the field, 6.9% (n = 10) were relocated to a safer place without veterinary intervention, 5.5% (n = 8) lacked detailed records of the procedures they received, and 0.6% (n = 1) was transferred to captivity (zoo/aquarium).

Considering the strandings of dead animals (n = 79), the majority of carcasses (51.9%) were classified as code 4, indicating an advanced state of decomposition (n = 41) (Table 1). Within the total count, nine individuals lacked code information (4.4%). Only two reports from Period I lacked information on whether the animal was found alive or dead. Of the dead animals recorded, only nine cases (2.7%) involved interactions with human activities, such as fishing interactions, aggression, ingestion of solid waste, or entanglement. Among these, fishing interactions were the most common, accounting for five cases (55.5% of the recorded interactions). Regarding data collection, during Period II, 62 stranding cases (48%) were reported during regular beach monitoring, while 66 were reported by collaborators and local people (51.2%), with only one record lacking this information. Among the collaborators' reports, 86.4% (n = 57) were of animals found alive.

Discussion

Pinniped occurrence and distribution

The species identified in this study are consistent with those previously recorded along the Brazilian coast (Pinedo et al., 1992). The South American fur seal is the most frequently observed species along the coast of São Paulo, followed by the Subantarctic fur seal. These findings are consistent with those of Oliveira et al. (2014) in Santa Catarina and Oliveira & Vigário (2008) in Paraná. In Santa Catarina, both species together accounted for more than 40% of the records, while in Paraná, they comprised 95.08% of the individuals.

On the coast of Rio Grande do Sul, a higher occurrence of the South American fur seal was also documented, but followed by the South American sea lion (Oliveira, 1999; Prado et al., 2016). Oliveira (1999) recorded 102 (68%) individuals of South American fur seal, 33 (22%) individuals of South American sea lion, and 11 (7.33%) individuals of Subantarctic fur seals on the northern coast of Rio Grande do Sul, between 1982 and 1998 (16 years), while Prado et al. (2016) found approximately 60% of South American fur seal (3,419) of the total number of pinniped strandings evaluated between 1979 and 2013 (34 years), followed by South American sea lion (n = 2,049; 36%) and Subantarctic fur seal (n = 219; 3.84%).

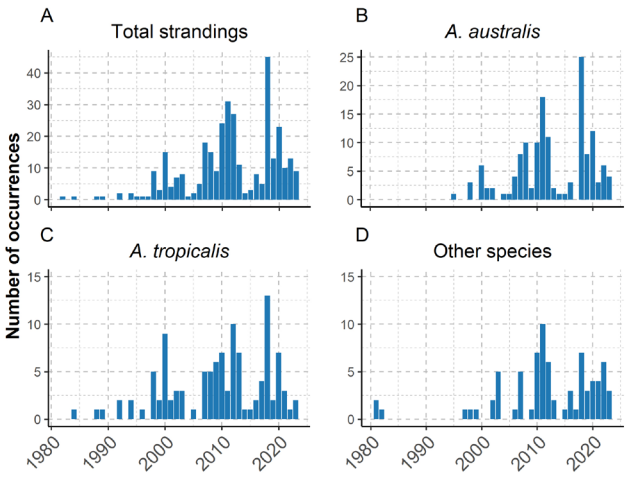

Figure 4. (A) Total number of pinniped strandings recorded in São Paulo state from 1981 to 2023. (B) Strandings of *Arctocephalus australis*. (C) Strandings of *A. tropicalis*. (D) Other pinniped species combined, recorded between 1981 and 2023.

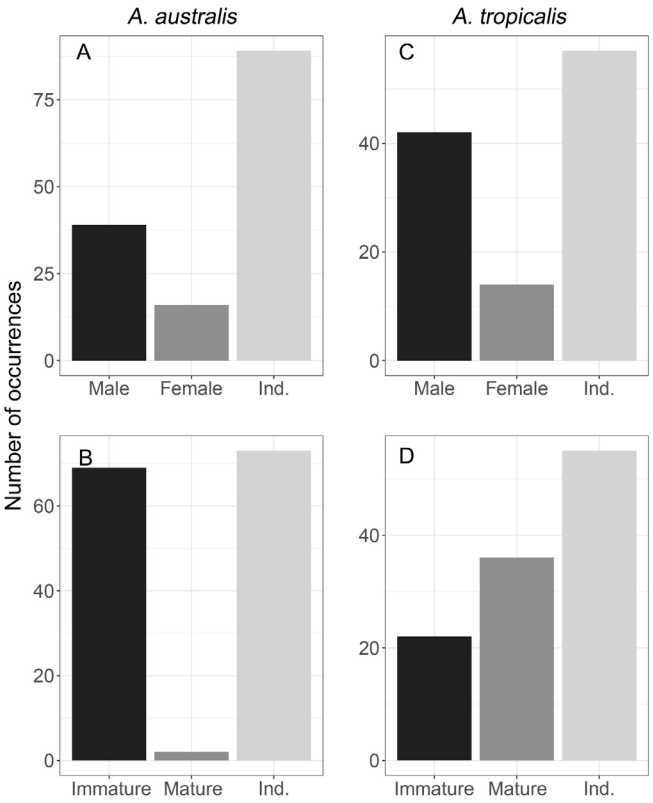

Figure 5. (A) Sex and (B) maturity class of *Arctocephalus australis* and *A. tropicalis* (C, D) recorded in the state of São Paulo between 1981-2023. Ind. = Indeterminate.

The South American fur seal and South American sea lion have breeding colonies extending from Peru to Uruguay (Bastida et al., 2007; Túnez et al., 2008). The higher occurrence of juvenile South American fur seals along the southeastern Brazilian coast is likely related to the dispersal of yearlings born the previous year, as suggested by Prado et al. (2016). These records may also be linked to the proximity of their breeding colonies to the Brazilian coast, which could facilitate the arrival of these individuals compared to other pinniped species, such as Subantarctic fur seals, which are likely from Gough, Tristan da Cunha, and other islands north of the Antarctic Convergence (Ferreira et al., 2008).

In the case of the Subantarctic fur seal, which is one of the species with the greatest dispersions in the Southern Hemisphere, their appearance on the Brazilian coast may be related to their behavior and movement patterns (Arnould, 2009). Based on the literature review and current data, this species appears to follow a pattern opposite to that of the South American fur seal, with its proportional occurrence related to total stranding numbers increasing as latitude decreases in Brazil - Rio Grande do Sul: 3.84% (Prado et al., 2016); Northern of Rio Grande do Sul: 7.33% (Oliveira, 1999); Santa Catarina: 15.35% (Oliveira et al., 2014); São Paulo: 38.05% in Period I and 27.13% in Period II. Additionally, the Subantarctic fur seal was the most recorded species in Rio de Janeiro, accounting for nearly 50% of the records (Moura et al., 2011). Oliveira et al. (2014) had already suggested a latitudinal shift in the proportion of occurrences of both species along the Brazilian coast.

Despite the presence of colonies in Uruguay and the existence of haul-out sites, the occurrence of the South American sea lion at lower latitudes in Brazil is very rare. Stranding occurrences begin to decrease in Santa Catarina (11.6%), and the species was not reported in Paraná (Oliveira & Vigário, 2008). There have been sporadic occurrences of the species on the coast of Rio de Janeiro (Moura et al., 2011) and the first record in the present study occurred in 2022, followed by two additional individuals in the same year and other two in 2023. Only one of these individuals was alive.

It is possible that the species exhibits a more restricted movement pattern compared to the fur seal species. However, the movement patterns of male South American sea lions vary across the distribution area. While in some regions sea lions show strong colony fidelity (Baylis et al., 2017), in others pre-reproductive males exhibit large-scale movements, visiting multiple haul-out sites. Giardino et al. (2016) recorded one individual reaching Brazil, 1,600 km from northern Argentina, and juveniles in central Chile can cover distances exceeding 2,000 km (Hückstädt et al., 2014). In the Falkland/ Malvinas Islands, foraging trips are short (127 km over ~4 days), though some individuals travel much farther, such as one male that undertook an 800 km journey (Baylis et al., 2017).

Thus, it seems that sea lions are also capable of traveling long distances, although these may be shorter than those covered by species of *Arctocephalus*, or they may disperse to other areas at lower latitudes. Telemetry studies are recommended to better understand the movement and occurrence of these animals in Brazil.

The low number of records of Antarctic fur seal was expected, as this species occurs only sporadically in Brazil (Pinedo et al., 1992; Silva, 2004). The first record of the species in Brazil dates back to 1984 (Pinedo & Marmontel-Rosas, 1987), followed by a second record in 1994 (Oliveira, 1999), both on the coast of Rio Grande do Sul, and a few others reported by Prado et al. (2016). Additionally, misidentifications remain a challenge, as Antarctic fur seal is easily confused with South American fur seal. This may explain why records are recent (2021), appearing in Period II, when animal handling and sample collection became more frequent.

Among the Phocidae family, the crabeater seal had the highest occurrence rate in São Paulo, followed by the Southern elephant seal and leopard seal. The crabeater seal was the only phocid species recorded in Paraná (Oliveira & Vigário, 2008). In Rio de Janeiro, the Southern elephant seal was the most frequently recorded phocid species, accounting for 20% of the records, followed by the crabeater seal and the leopard seal (Moura et al., 2011). The same pattern was observed in Rio Grande do Sul (Prado et al., 2016), but each species representing less than 0.1% of the pinniped records. In Santa Catarina and northern Rio Grande do Sul, the Southern elephant seal was the only phocid species recorded (Oliveira, 1999; Oliveira et al., 2014).

Regarding the distribution of strandings, most occurrences were concentrated in the southern region of São Paulo (transect 7), mainly for Period II, likely because it is closer to breeding colonies than the northern region. No distinct pattern was observed between the two fur seal species, despite the higher occurrence of Subantarctic fur seals in Rio de Janeiro (Moura et al., 2011), which, if following the same trend, would suggest a higher number of strandings in northern São Paulo. The Southern elephant seal was the only species with a more concentrated distribution in the northern part of the state and also showed a

significant occurrence in Rio de Janeiro (Moura et al., 2011). This pattern suggests that specific factors may favor the presence of this species in the region, even though phocid strandings are generally associated with erratic movements (Silva, 2004).

Although there are no ecological differences between the PMP-BS sectors that would justify a direct comparison, information on stranding distribution is essential for determining effort allocation and logistical requirements for stranding response. These data play a crucial role in project management, aiding in the optimization of resources and operational planning.

Seasonal and interannual variation of pinniped occurrence

Most pinniped records occurred during winter, followed by spring, autumn, and summer. These results are similar to studies conducted in southern Brazil (Oliveira, 1999; Oliveira et al., 2014; Prado et al., 2016), coinciding with the post-weaning and post-reproductive period. Except for the South American fur seal and the Subantarctic fur seal, the crabeater seal and the South American sea lion were the only species recorded in all seasons.

A comparison of records between periods I and II highlights the importance of daily monitoring. Over one third of the occurrences were documented within just eight years (2015–2023), compared to the 34-year span of Period I (1981–2014). Additionally, since resightings were recorded in Period II, it is likely that they also occurred in Period I, though record tracking was not yet implemented at that time. This underscores the value of systematic and long-term monitoring in improving our understanding of species' stranding patterns and minimizing potential discrepancies caused by the documentation of rare or atypical species in the region (Prado et al., 2016).

By analyzing the interannual variation, it is possible to note a stranding pattern similar to that observed in Santa Catarina (Oliveira et al., 2014) and Rio Grande do Sul (Oliveira, 1999; Prado et al., 2016; Oliveira et al., 2024), characterized by years with few records followed by peaks and subsequent decreases in strandings. The years with the highest records were 2018, 2011, and 2012, respectively, with observed interval peaks in 2007-2008, 2010-2013, and 2018-2022. Some of the years with higher occurrences overlap with those observed in other studies, such as 2008 and 2010, which were also noted by Oliveira et al. (2014) in Santa Catarina, and 2011, which recorded one of the highest stranding rates in Rio Grande do Sul. Furthermore, when considering only the South American fur seal, 2007 was also a year of high occurrence in the south (Prado et al., 2016). Additionally, the years with few records also overlap with those in other studies, with 2005 being a year with low stranding rates in other regions (A. Oliveira et al., 2014; Prado et al., 2016; C. Oliveira et al., 2024).

Despite the discrepancy in the number of records between the two periods, with a clear increase in data collection during Period II, the stranding pattern has remained consistent since the late 1990s. Records show a gradual increase, peaking at intervals of 5 to 10 years before declining again. One possible explanation is that, although systematic and daily monitoring was implemented by PMP-BS in 2015, the establishment of marine fauna research institutions in São Paulo in the mid-2000s played a crucial role in ensuring data collection along the coast. Even without a structured monitoring effort, these institutions contributed to a stranding database through opportunistic records, often triggered by public reports, allowing for the characterization of a regional stranding pattern.

An increasing population growth rate could account for the rise in South American fur seal strandings observed in more recent years (Franco-Trecu et al., 2019). However, significant fluctuations between years suggest that other factors are likely involved. While there is a general upward trend, some years show higher birth numbers and these fluctuations may correspond with variations in stranding occurrences, as observed in other studies (Prado et al., 2016). However, since some species, such as the Subantarctic fur seal, have a higher occurrence of adults, other factors are likely influencing these extralimital movements.

Initially, it was hypothesized that the El Niño-Southern Oscillation (ENSO) influenced the occurrence of Subantarctic fur seals along the Brazilian coast (Oliveira, 1999). However, Prado et al. (2016) and Oliveira et al. (2024) found no evidence of ENSO affecting species dispersal and stranding rates. Oliveira et al. (2024) linked the presence of Subantarctic fur seals on the southern Brazilian coast to low Chlorophytes concentrations at their breeding colonies, suggesting that individuals travel beyond their usual range when productivity is low. Additionally, breeding colonies are believed to be affected by anomalies in the Antarctic and Subantarctic fronts, as well as extreme weather events. Therefore, a combination of environmental factors may be a key driver of their dispersal (Oliveira et al., 2024).

The action of marine currents is commonly associated with marine animal strandings, such as Magellanic penguins (*Spheniscus magellanicus*)(Brusius et al., 2021) and pinnipeds (Oliveira et al., 2024). The Falkland/Malvinas Current reaches lower latitudes and penetrates deeper into the Brazilian continental shelf in winter mainly towards the southern coast of the country (Olson et al., 1988). There are traces of permeation of its cold waters on the coast from São Paulo to the south of Rio de Janeiro (Silva Jr et al., 1996), possibly facilitating the dispersal of Antarctic and Subantarctic species toward these latitudes.

Another possible route discussed for the arrival of the Subantarctic fur seal on the southeast coast of Brazil involves the influence of the South Atlantic Anticyclonic System in association with the Benguela, South Equatorial, and Brazil currents (Oliveira et al., 2024). However, it is uncertain whether this route can be extrapolated to other species or if it significantly influences occurrences on the São Paulo coast. Future telemetry research is strongly recommended to better understand the dispersal routes of different pinniped species.

Sex and maturity class

The high number of recorded males among immature South American fur seals and adult Subantarctic fur seals aligns with data from Rio Grande do Sul, Santa Catarina, Paraná and Rio de Janeiro (Oliveira, 1999; Oliveira & Vigário, 2008; Moura et al., 2011; Oliveira et al., 2014; Oliveira et al., 2024). Based on age analysis, Oliveira (1999) found that most South American fur seals were less than a year old, followed by adults and juveniles, whereas 60% of the recorded Subantarctic fur seals were adults over seven years old. This pattern may be associated with the proximity of reproductive colonies, as there are South American fur seal breeding colonies in Uruguay (Franco-Trecu et al., 2010; Arbiza et al., 2012). In contrast, the closest Subantarctic fur seal breeding colony to the Brazilian coast is Gough/Tristan da Cunha Island (~

4,200 km), north of the Antarctic Convergence (Jefferson et al., 1993; Ferreira et al., 2008), and for this reason we hypothesize that immature individuals of this species have lower probability of surviving the long-journey to the coast of São Paulo compared to adults, or immature South American fur seals.

Regarding sex, more males were recorded for all species. The male-to-female ratio for the two most frequently recorded fur seal species was approximately 2:1. Other studies have found a more pronounced disparity, with ratios of 3.2 for South American fur seal and 2.7 - 2.8 for Subantarctic fur seal males for each female (Oliveira, 1999; Oliveira et al., 2024). Males of both species exhibit longer dispersal movements, as females are spatially restricted to colony areas while nursing their young for extended periods (9–12 months) (Franco-Trecu et al., 2010; Oliveira et al., 2024).

Notably, most records of South American and Subantarctic fur seals lacked sex and maturity class information in Period I. However, this percentage dropped considerably in Period II, highlighting the importance of a well-trained team and daily monitoring.

Stranding conditions and monitoring data collection

Strengthening monitoring efforts is essential, particularly for the well-being of debilitated animals, as over 70% of the records involved live animals. Furthermore, a notable proportion of stranded animals required veterinary treatment or other forms of intervention by the team. Veterinary care has been facilitated since 2015 with the establishment of rehabilitation and stabilization centers along the São Paulo coast under the PMP-BS initiative (Petrobras, 2019). Systematic monitoring is an important strategy for assessing the health status of both wildlife and the environment, contributing to public health and the conservation of species.

Amidst the array of emerging public health challenges, Highly Pathogenic Avian Influenza (HPAI) has emerged as a critical concern, necessitating vigilant monitoring, particularly within pinniped South American populations (Plaza et al., 2024). This virus has been reported in South America since late 2022, with its initial record in a *Thalasseus acuflavidus* in Brazil in May 2023 (Reischak et al., 2023). Positive cases of HPAI were identified in South American sea lion in the states of Rio Grande do Sul and Santa Catarina, as well as in South American fur seal in Rio Grande do Sul (CIDASC, 2023; MAPA, 2024) in October 2023. In Rio Grande do Sul, the outbreak in 2023 has led to unusual mortality events in both species, primarily affecting sea lions, albeit only a limited number of specimens were tested (SEAPI, 2023; de Lima et al., 2025). Notably, during this period, both occurrences of South American sea lions in October 2023 in São Paulo were recorded on the southern coast with one case testing positive for HPAI on Ilha Comprida (MAPA, 2024). Given the frequent presence of pinnipeds in São Paulo state, particularly recent and increasing strandings of sea lions, coupled with the looming threat of HPAI, we strongly recommend massive testing of potentially contaminated animals to promptly detect and mitigate future outbreaks.

In addition, despite daily monitoring efforts, collaborators and civil society play a significant role in reporting live individuals, likely because debilitated animals attract attention and encourage public mobilization (Petrobras, 2023). This underscores the importance of ongoing participatory social communication (Dias et al., 2021) and active engagement with collaborators. These efforts help ensure timely assistance and improve the survival rates of stranded animals in weakened conditions.

Conclusion

Data quality and accuracy improved in Period II compared to Period I, considering the time frame, along with improved identification of individuals' maturity class and sex. This underscores the importance of consistent and systematic monitoring efforts in collecting robust data, ensuring timely veterinary care for live animals, and assessing wildlife and environmental health. Such efforts contribute not only to species conservation but also to public health safety. Additionally, encouraging information sharing by collaborators remains crucial, as these reports account for a significant portion of recorded occurrences.

The species composition observed in both periods remained similar, with a higher number of strandings recorded in the southern part of São Paulo state. Immature South American fur seals were the most frequently stranded individuals, followed by adult male Subantarctic fur seals. Overall, the stranding patterns along the São Paulo coast closely resemble those reported in Paraná, Santa Catarina, and Rio Grande do Sul in terms of annual variations, seasonality, sex, and maturity class. Climatic factors likely influence these strandings by increasing species dispersal into the region. Given the imminent effects of climate change, particularly global warming, continued monitoring of pinniped strandings is essential for detecting potential shifts in occurrence and understanding their implications for species conservation.

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Supplementary material

Supplementary Material 1- Summarized information for size at sexual maturity for pinniped species found in the coast of São Paulo.