



Macroscopic lesions in free-living seabirds found stranded on beaches: impacts of environmental imbalance and anthropogenic changes

Lesões macroscópicas em aves marinhas de vida livre encontradas encalhadas em praias: impactos do desequilíbrio ambiental e das alterações antropogênicas

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ABSTRACT: Seabirds are one of the most endangered groups of birds in the world, and identifying aggression factors and injuries is complex and often impractical. The aim of this study was to describe lesions found at necropsy in free-living seabirds that were stranded and dead on the beaches of the north coast of the state of Rio de Janeiro, Brazil. During the 17 months of the study, 154 birds were necropsied, with an average of 9 per month. The birds belonged to four orders, and trauma was the most common injury. Injuries to the glenohumeral joint occurred in 16.9% of cases, with a predominance of dislocations. Garbage was found in the stomachs of six birds. Seabirds are constantly exposed to aggressive factors, one of the main ones being human interaction. As a result, the death of free-living seabirds in the Lagos region is common, frequent, and constant throughout the year, occurring more frequently on the beaches of Armação de Búzios. The main injuries found at necropsy are single or multiple fractures and joint injuries such as dislocation, laceration, and rupture of tendons and ligaments. Cachexia, pulmonary edema, hemorrhage, and ingestion of garbage occur less frequently but also occur continuously. The negative influence of man-made environmental changes is one of the main causes of death and is a worldwide concern for the preservation of these animals.

Keywords: vessel collision; human interference; seabird pathology.

RESUMO: Aves marinhas são um dos grupos de aves mais ameaçados do mundo, e a identificação de fatores de agressão e lesões é complexa e muitas vezes impraticável. O objetivo deste estudo foi descrever as lesões encontradas em necropsias de aves marinhas de vida livre que encalharam e morreram nas praias do litoral norte do estado do Rio de Janeiro, Brasil. Durante os 17 meses do estudo, 154 aves foram necropsiadas, com uma média de 9 por mês. As aves pertenciam a quatro ordens, e o trauma foi a lesão mais comum. Lesões na articulação glenoumeral ocorreram em 16,9% dos casos, com predominância de luxações. Lixo foi encontrado no estômago de seis aves. As aves marinhas estão constantemente expostas a fatores agressivos, sendo um dos principais a interação humana. Como resultado, a morte de aves marinhas de vida livre na região de Lagos é comum, frequente e constante ao longo do ano, ocorrendo com maior frequência nas praias de Armação de Búzios. As principais lesões encontradas na necropsia são fraturas simples ou múltiplas e lesões articulares, como luxação, laceração e ruptura de tendões e ligamentos. Caquexia, edema pulmonar, hemorragia e ingestão de lixo ocorrem com menos frequência, mas também de forma contínua. A influência negativa das alterações ambientais provocadas pelo homem é uma das principais causas de morte e uma preocupação mundial para a preservação desses animais.

Palavras-chave: colisão de embarcações; interferência humana; patologia de aves marinhas.

INTRODUCTION

There are about 359 species of seabirds (Dias *et al.*, 2019), and this is one of the most threatened groups of birds in the world (Croxall *et al.*, 2012). These animals are constantly exposed to stressors such as predation, climate change (Afán *et al.*, 2019), competition with native species, changes in foraging areas or migration due to anthropogenic action, capture by fishing, and human disturbance (Christensen-Dalsgaard *et al.*, 2022; Croxall *et al.*, 2012; Dias *et al.*, 2019; Garcês *et al.*, 2021).

Human activity alters the environment in different ways, thereby causing an imbalance in marine biodiversity and harming animal welfare (Christensen-Dalsgaard *et al.*, 2022; Garcês *et al.*, 2021; ICMBio, 2018; Maree *et al.*, 2014). Moreover, the constant search for

improvements, technological advances, and the optimization of cities has boosted this change (Bárcia, 2020). The sighting of seabirds near vessels is common (Christensen-Dalsgaard *et al.*, 2022; Dias *et al.*, 2019; Maree *et al.*, 2014); this occurrence contributes to collisions with vessels or to disorientation and sensory irritation due to excessive noise from machinery and artificial lighting (Bodey *et al.*, 2014). In tropical regions, stranding can also be aggravated by storms and increasingly warm waters, which reduce the amount of prey and, consequently, food intake (Tavares; De Moura; Siciliano, 2016), leading these birds to look for fish near fishing boats.

Free-living seabirds suffer from pollution, such as the discharge of substances from boats into the sea, like engine oil (Bodey *et al.*, 2014). Pollutants can cause direct damage, mainly to the gastrointestinal mucosa

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(Simpson; Fisher, 2017), ranging from bleeding to ulcers, or indirect damage, resulting in malabsorption of nutrients and subsequent progressive weight loss (Jansson *et al.*, 2018; Siebert *et al.*, 2012; Simpson; Fisher, 2017).

The mortality of free-living seabirds is unpredictable and a global concern (Christensen-Dalsgaard *et al.*, 2022). The high variability of aggression factors demonstrates the vulnerability of these species in a polluted and unbalanced ecosystem (Croxall *et al.*, 2012; Garcês *et al.*, 2021). Identifying the offending agents and how they act is complex and often unfeasible (Afán *et al.*, 2019; Croxall *et al.*, 2012), but it is extremely necessary (Christensen-Dalsgaard *et al.*, 2022). However, the scarcity of scientific studies on the diseases that affect these birds (Garcês *et al.*, 2018) compromises the assessment of risk factors. Understanding the injuries that occur in these birds is the best way to understand and anticipate the aggressions and to plan appropriate treatment and management. The aim was to describe lesions at necropsy of free-living seabirds found stranded and dead on the beaches of the north coast of the state of Rio de Janeiro (RJ), Brazil.

MATERIAL AND METHODS

Ethical procedures

All procedures were authorized by the Federal Government through the Biodiversity Information and Authorization System (No. 56807-4) and by the Fluminense Federal University Animal Use Ethics Committee (No. 905).

Retrospective study

We analyzed seabird necropsy records from August 2016 to December 2017, archived by the company Scitech® - Ciência e Tecnologia Ambiental. Data on the date of stranding and death, the city and beach where the bird was found, the type and anatomical location of the lesion, and the presence or absence of garbage in the stomach were recorded on individual forms.

Prospective study

In November and December 2017, 18 free-living seabirds of both sexes and all ages were necropsied. These animals were found stranded dead on the beaches of the mesoregions Norte Fluminense (Campos dos Goytacazes and Macaé) and Baixadas Litorâneas and were collected by the company Scitech®.

The necropsy procedure followed the method described by Ytrehus and Work (2019) and Christensen-Dalsgaard *et al.* (2022). Photographic and descriptive records of all injuries were made for each individual. The assessment of injuries considered musculoskeletal, tendon, and ligament integrity and the presence or absence of hemorrhage and edema and was compared to that described for wild (Kinne, 1985) and domestic animals (Zachary, 2017).

Study area and origin of seabirds

All the free-living seabirds were found stranded and dead on the beaches of the Norte Fluminense and Baixadas Litorâneas mesoregions in the state of Rio de Janeiro. These regions include the municipalities of Campos dos Goytacazes, Cardoso Moreira, São Fidelis, São Francisco de Itabapoana, São João da Barra, Carapebus, Conceição de Macabu, Macaé, Quissamã (mesoregion Norte Fluminense) and Casimiro de Abreu, Rio das Ostras, Silva Jardim, Araruama, Armação de Búzios, Arraial do Cabo, Cabo Frio, Iguaba Grande, São Pedro da Aldeia, and Saquarema (mesoregion Baixadas Litorâneas).

Statistical analysis

The data were tabulated, and a descriptive analysis was performed. The chi-squared test was used to assess independence between variables, with a significance level of 5%.

RESULTS AND DISCUSSIONS

During the study period, 154 free-living seabirds were necropsied, an average of almost 9 per month. The birds belonged to the orders Procellariiformes (43.5%), Suliformes (33.8%), Charadriiformes (21.4%), and Sphenisciformes (1.3%). The most abundant species (39.6%) was *Puffinus puffinus*. The period with the highest frequency of stranding events was between August and December, and the lowest frequency occurred between January and July. Different findings were reported by Mariani *et al.* (2019), who studied the stranding of seabirds on the coast of northeastern Brazil and observed the orders Procellariiformes, Suliformes, Charadriiformes, and Sphenisciformes, with a higher frequency of the species *Calonectris borealis*. In addition, they described that the period with the most stranding events was from March to June (fall). Interestingly, the present study showed a higher number of stranding events in the spring.

Among the animals, 88 (57.2%) were female, 60 (38.9%) were male, and the sex was not recorded in 6 of them (3.9%). There was a predominance of females in the species *P. puffinus*, *Larus dominicanus* and *Fregata magnificens* and of males in the species *Sula leucogaster* (Table 1). A positive association ($p = 0.000$) was found between sex and the species of bird stranded: females of *P. puffinus*, *L. dominicanus* and *F. magnificens* and males of *S. leucogaster* were more susceptible to stranding in the period and region under study.

Most birds (40.9%) were found on the beaches of the municipality of Armação de Búzios, with Rasa beach having the highest number of birds (24.7%). *P. puffinus* was found on the beaches of Armação de Búzios, while *S. leucogaster* and *L. dominicanus* were found in Cabo Frio. *F. magnificens* was more frequent in Macaé. More details are shown in Figure 1. A positive association was found between the stranding site and the most frequently stranded species ($p = 0.000$).

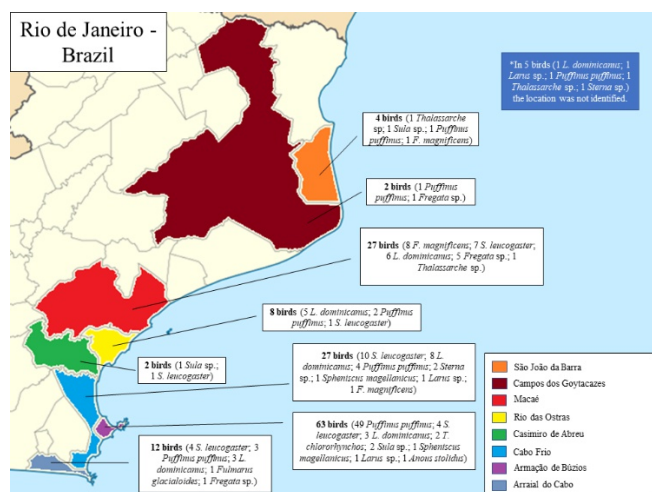
The analysis showed a significant association between the sex and species of the stranded birds, especially females of *P. puffinus*, *L. dominicanus*, and *F. magnificens* and males of *S. leucogaster*, indicating that

Table 1 – Species and number of male and female seabirds stranded on different beaches in the Região dos Lagos, RJ, Brazil.

Species/Genus	Sex			
	N/D	F	M	Total
<i>Thalassarche</i> sp.	1	2	0	3
<i>T. chlororhynchos</i>	0	1	1	2
<i>Sula</i> sp.	0	2	2	4
<i>S. leucogaster</i>	1	7	21	29
<i>Sterna</i> sp.	0	2	1	3
<i>Spheniscus magellanicus</i>	0	2	0	2
<i>Puffinus puffinus</i>	2	35	24	61
<i>Larus</i> sp.	0	3	0	3
<i>L. dominicanus</i>	0	17	9	26
<i>Fulmarus glacialisoides</i>	1	0	0	1
<i>Fregata</i> sp.	0	7	1	8
<i>F. magnificens</i>	1	9	1	11
<i>Anous stolidus</i>	0	1	0	1
Total	6	88	60	154

Legend: N/D – not determined; F – female; M – male.

Figure 1 – Number of birds found stranded per city on the north coast of Rio de Janeiro, Brazil.



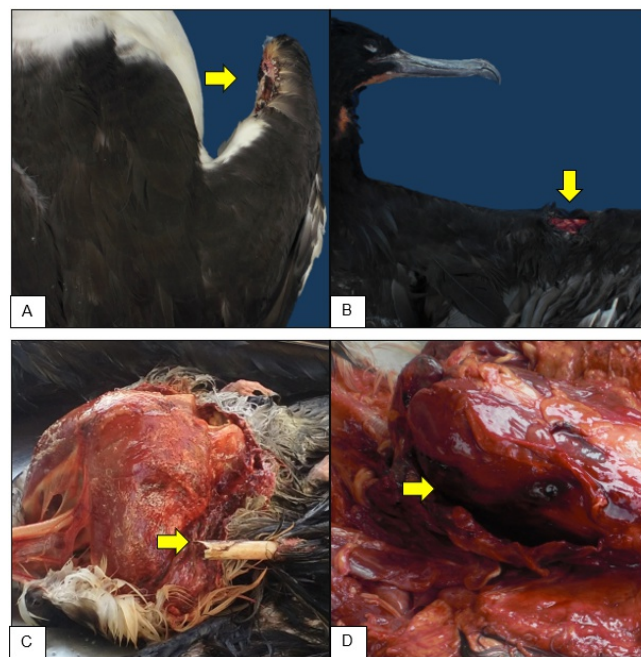
Source: Author's collection.

these groups were more vulnerable to stranding in the evaluated region and period. This difference can be attributed to sexual segregation in foraging patterns and habitat use, as males and females tend to forage in different areas or at different times, which can increase their exposure to human-caused risks (Reyes-González *et al.*, 2021; Giambalvo *et al.*, 2022; Militão *et al.*, 2023). In addition, studies such as that by Gianuca *et al.* (2017) point out that accidental capture of seabirds shows trends related to sex and age, reflecting behaviors and distributions that increase the vulnerability of certain groups. For example, more males and adults were caught in subpolar regions close to the colonies, while females and juveniles were caught more frequently in subtropical waters. These findings are in line with the differences according to sex detected in the present study and highlight the importance of considering

ecological and anthropogenic factors when assessing the mortality of these species.

Among the injuries observed, fractures were the most frequent, occurring in 32 (20.8%) birds (single trauma in 25 [78.1%] and polytrauma in 7 [21.9%]) (Figure 2). Injuries to the glenohumeral joint, ligaments, and tendons occurred in 26 (16.9%) birds (dislocation in 18 [69.2%] and laceration and rupture in 8 [30.8%]), and cachexia was observed in 15 (9.7%) birds. Pulmonary edema was observed in three birds (1.9%). Peritonitis, stomach occlusion, and diffuse congestion was seen in two birds each (1.3%), and pericarditis, immobility, rectal occlusion, hepatitis, pulmonary hemorrhage, external wounds, stomatitis, ectoparasites, and amputation were seen in one bird each (0.6%). In 62 (40.3%) birds, no macroscopic alterations were observed. More details are shown in Table 2. This differs from the study by Mariani *et al.* (2019), who reported that infectious processes were the most frequent cause of disease in seabirds, along with a lower percentage of traumatized birds.

Figure 2 – Traumatic injuries to seabirds: A – Region of laceration on the right wing of *L. dominicanus* (yellow arrow). B – Region of laceration on the right wing of *F. magnificens* (yellow arrow). C – Open fracture and right mass of *F. magnificens*. After peeling back the skin, a laceration was observed in the pectoral muscles (yellow arrow), associated with marked edema. D – Laceration of the pectoral muscles of *F. magnificens* (yellow arrow), associated with hemorrhage caused by polytrauma.



Source: Author's collection.

Garbage ingestion was detected in six birds (3.9%): three (50%) *P. puffinus*, one (16.7%) *Sula* sp., one (16.7%) *Fulmarus* sp., and one (16.7%) *Spheniscus magellanicus*. The type of waste included a variety of plastic fragments, nylon thread, and latex. For one bird, there was no record of the type of waste. This differs from the study by Mariani *et al.* (2019), who reported that ingestion of garbage was the most frequent (54%) bird injury caused by anthropogenic interaction. In this study, seabirds were seen following tourists on beaches and boats and eating the food (cookies, bread) that

Table 2 – Macroscopic lesions observed in seabirds stranded on beaches in the Região dos Lagos, RJ, Brazil.

Injury	Species/Genus													Total
	<i>A. stolidus</i>	<i>F. magnificens</i>	<i>Fregata</i> sp.	<i>F. glacialis</i>	<i>L. dominicanus</i>	<i>Larus</i> sp.	<i>P. puffinus</i>	<i>S. magellanicus</i>	<i>Sterna</i> sp.	<i>S. leucogaster</i>	<i>Sula</i> sp.	<i>T. chlororhynchus</i>	<i>Thalassarche</i> sp.	
Polytrauma	0	1	0	0	3	1	0	0	0	2	0	0	0	7
Peritonitis	0	0	0	0	0	0	1	0	0	0	0	0	1	2
Pericarditis	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Paralysis	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Rectal occl	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Stom. occl	0	0	0	0	0	0	1	1	0	0	0	0	0	2
Dislocation	0	2	0	0	2	1	0	0	0	11	1	0	1	18
Lac./Rupture	0	3	4	0	0	0	1	0	0	0	0	0	0	8
Hepatitis	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Pulm. hem.	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Gastritis	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Fracture	0	4	4	0	5	0	1	0	1	10	0	0	0	25
External wounds	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Stomatitis	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Pulm. edema	0	0	0	0	0	0	2	0	0	1	0	0	0	3
Ectoparasitism	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Congestion	0	0	0	0	0	0	1	0	0	0	0	0	1	2
Cachexia	0	0	0	1	5	0	5	1	2	1	0	0	0	15
Amputation	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Not determined	1	1	0	0	9	0	45	0	0	2	2	2	0	62

Legend: Rectal occl - rectal occlusion; Stom. occl - stomach occlusion; Lac. - laceration; Pulm. hem. - pulmonary hemorrhage; Pulm. ed. - pulmonary edema; *A. stolidus* - *Anous stolidus*; *F. magnificens* - *Fregata magnificens*; *F. glacialis* - *Fulmarus glacialis*; *L. dominicanus* - *Larus dominicanus*; *P. puffinus* - *Puffinus puffinus*; *S. magellanicus* - *Spheniscus magellanicus*; *S. leucogaster* - *Sula leucogaster*; *T. chlororhynchus* - *Thalassarche chlororhynchus*.

people were giving them. On two beaches, seabirds were seen rummaging through garbage and consuming what they found. Understanding what garbage they ingest is an important conservation factor because seabirds are important environmental sentinels, as they are top-of-the-chain predators (Matos *et al.*, 2023). The low frequency of garbage ingestion observed in our study (3.9%) confirms the findings of Serafini *et al.* (2024). The authors state that, despite finding plastic in 29% of stomachs, they did not identify a significant association between plastic ingestion and hepatic molecular biomarker responses, which indicates that dissolved or bioaccumulated chemical pollutants in the trophic chain may pose a more immediate threat to bird physiology than ingested plastic waste.

This study demonstrated the high prevalence of death among free-living seabirds, mainly related to trauma, as also shown in other studies (Rodríguez *et al.*, 2012; Stenkat; Krautwald-Junguanns; Schmidt, 2013). Similar findings have been reported in free-living terrestrial birds, whose main causes of hospitalization in rehabilitation centers are traumatic injuries and weakening, with more than 60% of these birds dying spontaneously (Garcês *et al.*, 2018). In addition to trauma, seabirds that spend most of their time at sea are constantly exposed to human actions, such as accidental capture, reduced food resources due to fishing competition, and marine contamination by oil, heavy metals, and plastics (Dias *et al.*, 2019; Saviolli *et al.*, 2020; Meissner, 2025). These factors exemplify the wide variety of challenges that these birds constantly face and help explain the high mortality rate, which is mainly related to trauma.

The 154 birds in this study belonged to four orders, the most common being Procellariiformes. Seabirds are the most threatened group of birds worldwide, with the Procellariiformes order being the most vulnerable (Croxall *et al.*, 2012). Procellariiformes are birds with high longevity, low reproductive rates, and late sexual maturity and spend most of their lives at sea (Saviolli *et al.*, 2020). Maree *et al.* (2014) reported the death of 7,200 albatrosses out of a total of 9,300 seabirds after interacting with a trawl net. Thus, as observed in this study, Procellariiformes are believed to have the highest number of deaths due to their behavioral patterns and the fact that they are large birds that tangle more easily in fishing nets (Maree *et al.*, 2014). Because of the large number of deaths of Procellariiformes, an international agreement was reached in 2004 to establish methods of preserving these birds (Saviolli *et al.*, 2020). This demonstrates the worldwide concern for these animals, as well as the importance of in-depth studies into the causes of death among these birds.

Most of the birds were found on the beaches of Armação de Búzios, one of the most popular tourist centers in the state of RJ (Bárcia, 2020; Costa; Ferreira, 2019). In this area, there are large crowds of people, tourist and fishing boats, and high levels of noise and light (Costa; Ferreira, 2019). The combination of these factors leaves birds confused and disoriented, attracting them to the light, which can lead to collisions and impair their ability to forage (Afán *et al.*, 2019; Rodríguez *et al.*, 2017). It is believed that the high frequency of dead birds in this region is related to the high population density and associated environmental changes. However, as highlighted by Ramos *et al.* (2024), it is important to recognize that the stranding site does not

always correspond to the place of death; moreover, combining necropsy findings with estimation of the post-mortem interval and back-trajectory modeling (Ramos *et al.*, 2024; Jones *et al.*, 2025) can reveal mortality hotspots in the high seas, enabling more effective implementation of mitigation efforts.

Trauma was the main cause of death, as shown in other studies (Rodríguez *et al.*, 2012; Stenkat; Krautwald-Junguanns; Schmidt, 2013). This finding is related to interactions with anthropogenic factors (Ibañez *et al.*, 2020), including boats, buildings, and electrical wires and poles (Rodríguez *et al.*, 2012). Collision with boats is one of the main causes of death (Afán *et al.*, 2019). Maree *et al.* (2014) reported that in 782 trawl net deployments, there were 996 interactions with seabirds, resulting in 41 bird deaths. Cherel, Weimerskirch and Duhamel (1996) observed 8,388 free-living seabirds, of which 323 were attracted by the longline. The birds approached the boats because they had easy access to discarded fish or were attracted by the sound and light, ultimately colliding with or becoming caught in the fishing nets (Afán *et al.*, 2019). Artificial light affects young and adult birds, regardless of body condition (Guilford *et al.*, 2019; Rodríguez *et al.*, 2017), and the highest incidence of impact occurs in birds close to the coast (Rodríguez *et al.*, 2015). Procellariiformes are believed to experience approximately 25 collisions per hour with boats, causing mild trauma (Branco *et al.*, 2014; Favero *et al.*, 2011). Land birds show a similar pattern, with 57% of deaths related to trauma, and collisions with vehicles and buildings being the main cause (Garcês *et al.*, 2019). These data confirm that flying birds, both marine and terrestrial, are negatively impacted by human intervention in the environment.

As well as being the main cause of death, trauma was the primary cause of weakness and stranding. When unable to fly, these birds can be easily predated, run over, or drown at sea (Rodríguez *et al.*, 2012). In addition, few fallen birds are sent to rehabilitation centers, and most end up dying spontaneously (ICMBio, 2018; Saviolli *et al.*, 2020). The intensity of the trauma alone can result in immediate death or prolonged periods of weakness requiring recovery. However, the longer they stay in rehabilitation centers, the less likely they are to recover (Rodríguez *et al.*, 2012).

Injury to the glenohumeral joint, ligaments, and tendons occurred in 16.9% of birds, with dislocation in 69.2% and laceration or rupture in 30.8% of these cases. One possibility is that this injury is related to the intense physical effort during migration. The flight distance between feeding and migration areas varies among species but can reach hundreds of kilometers (Afán *et al.*, 2019). Even birds that make short journeys spend hours flying and can become exhausted (Rodríguez *et al.*, 2012). During migration, these birds are exposed to intense wind gusts, storms, and temperature variations, placing high demands on the musculoskeletal system (Afán *et al.*, 2019; Christensen-Dalsgaard *et al.*, 2022). In addition, young birds tend to fly faster and take less rest than adults, which favors the development and progression of this injury (Afán *et al.*, 2019).

Cachexia occurred in 9.7% of the seabirds. The combination of the hundreds of kilometers traveled, intense physical effort, short rest periods, and the need to search for food (Afán *et al.*, 2019) are probable causes

of the birds' weight loss and weakness (Afán *et al.*, 2019; Croxall *et al.*, 2012). This is similar to free-living terrestrial birds, which have a low body condition due to long migratory journeys (Garcês *et al.*, 2018). In addition, weakened seabirds are unable to feed and hydrate properly, thus developing poor body condition (Rodríguez *et al.*, 2012). Sublethal effects of chemical pollution (Serafini *et al.*, 2024) also influence the body condition of *P. puffinus*, the most abundant species in this study, in response to cellular stress, which suggests that body weakness is a multifactorial symptom that includes exposure to xenobiotics comprising the animal's general health.

The pulmonary edema observed in some birds, in the absence of disease, suggests that drowning occurred, as shown in other studies (Christensen-Dalsgaard *et al.*, 2022; Rodríguez *et al.*, 2012). Drowning of seabirds is frequent and characterized by fluid-filled air sacs, swollen and congested lungs leaking fluid during handling, cranial and caudal venae cavae, and a distended heart with dark blood (Simpson; Fisher, 2017).

The cases of pulmonary hemorrhage may have occurred due to traumatic collisions. The lungs of seabirds are delicate structures attached to the back of the coelomic cavity (Simpson; Fisher, 2017), which makes them susceptible to injury from collisions. The trauma may have occurred due to collisions with boats or other objects, falls into the sea with exposure to wave action, or direct collisions with rocks or sandbanks (Christensen-Dalsgaard *et al.*, 2022). Simpson and Fisher (2017) necropsied 177 seabirds and reported a predominance of death by drowning and a high frequency of hematomas, located mainly around the neck, shoulders, sternum, lateral aspect of the thighs, and internal organs. These findings show that collisions do not just cause fractures but also result in various injuries of differing intensity.

The presence of waste in the gastrointestinal tract was infrequent. The amount of garbage dumped into the sea increases every year (Javanovic, 2017; Lebreton *et al.*, 2017), and several species of animals die from ingesting it (Avio *et al.*, 2020; Ibañez *et al.*, 2020; Lima *et al.*, 2018; Lusher *et al.*, 2015). These species include seabirds (Dias *et al.*, 2019; Petry; Benemann, 2017). Waste can cause direct and indirect damage to the animal organism and is sometimes offered as food to chicks (Saviolli *et al.*, 2020). The most frequently ingested types of waste are plastic and nylon thread (Petry; Benemann, 2017). Ingestion is believed to occur because these components float on the water surface, and birds mistake them for easy prey (Azzarello; Van Vleet, 1987). In fish, plastic particles can cause physical damage, cytotoxicity, and changes in lipid metabolism and behavior (Javanovic, 2017). In sea turtles, the formation of intussusception and fecaloma has been reported, as well as intestinal pleating and twisting (Lima *et al.*, 2022). It is noteworthy that the ingestion of toxic products adhered to waste particles can cause intoxication and weakness in these birds, although these lesions are not frequent (Montesdeoca *et al.*, 2017).

During the 17 months of this study, 154 seabirds were found dead and necropsied, although the actual number of deaths could be significantly higher. The carcasses of these birds often float in the water and can be swept out to sea or to beaches outside the study

area, eventually sinking or being eaten by predators (Christensen-Dalsgaard *et al.*, 2022). Thus, the number recorded probably represents only a fraction of the total deaths. However, these data reinforce the warning about the risks arising from interactions between seabirds and human activities and highlight the need for prevention and mitigation measures. Industrial pollution, habitat fragmentation and reduction, and marine contamination by toxic compounds are examples of negative impacts resulting from this interaction (Garcês *et al.*, 2021; Serafini *et al.*, 2024). These impacts are not only from environmental changes but also from episodes of cruelty to birds, such as deliberate tearing of the beak and laceration of the interdigital membranes in Procellariiformes, as described by Saviolli *et al.* (2020). The greater the interaction with humans, the higher the chances of mortality for these birds (Garcês *et al.*, 2019; Garcês *et al.*, 2021). Therefore, procedures that mitigate this interaction, such as reducing the lighting on vessels (Wienecke; Robertson, 2002), using signaling tape on hook cables to repel seabirds (Watkins; Petersen; Ryan, 2008; Wienecke; Robertson, 2002), changing the spectrum and colors of lights, rehabilitating injured individuals, controlling predators, grounding power lines, and creating reserve areas for nesting (IUCN, 2014), need to be intensified. In addition, the mortality of free-living seabirds has been shown to be consistent, and it is indicated that mortality will continue until the underlying causes are controlled. Burt *et al.* (2024) experimentally demonstrated that the partial reduction of coastal lighting reduces the number of stranding events of *Hydrobates leucorhous*, highlighting the importance of mitigation actions for the species preservation.

The extinction or decrease in seabird numbers can compromise entire ecosystems (Christensen-Dalsgaard *et al.*, 2022), and data on the aggressors and injuries are difficult to obtain and analyze (Maree *et al.*, 2014). Epidemiological monitoring and analysis provide information for actions to prevent aggression (Christensen-Dalsgaard *et al.*, 2022; Croxall *et al.*, 2012). The Brazilian government has identified 16 seabird species with some level of conservation threat and has created a national conservation plan (ICMBio, 2018). It warns, for example, that seabirds can change their behavioral patterns, spending more time in different environments than usual, which compromises nesting and feeding areas (Garcês *et al.*, 2019). This study therefore provides valuable information on the health of seabirds and highlights the precarious environmental quality to which these animals are exposed. Furthermore, the high incidence of traumatic injuries, such as glenohumeral fractures and dislocations, suggests that collisions with boats are an important anthropogenic threat to seabirds. Identifying where these events occurred requires the application of forensic ecology methods, such as carcass back-trajectory modeling, as proposed by Ramos *et al.* (2024). This approach can be used to determine fishing or tourism routes and activities associated with these impacts, according to Kapsar, Sullender and Kuletz (2025), who describe that the areas of greatest co-occurrence of seabirds and shipping routes coincide with regions of high traffic, confirming that the spatial concentration of maritime traffic is a determining factor in collision and stranding rates.

CONCLUSIONS

In conclusion, the death of free-living seabirds in the Região dos Lagos, Rio de Janeiro, is common, frequent, and constant throughout the year, with the beaches of Armação de Búzios showing the highest frequency of deaths. The Procellariiformes order is the most vulnerable and accounts for the highest number of deaths. The main injuries observed at necropsy were single or multiple fractures and joint injuries, such as dislocation, laceration, and rupture of tendons and ligaments. Cachexia, pulmonary edema, hemorrhage, and ingestion of garbage occur less frequently but continuously. The negative impact of man-made environmental changes is one of the main causes of death of free-living seabirds and represents a worldwide concern for the preservation and conservation of these animals.

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