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Does size matter? Aspects (survival and seasonality) that influence birds with cranioencephalic trauma admitted at a wildlife rehabilitation center in Rio Grande do Sul, Brazil

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Abstract: birds with cranioencephalic trauma suffer severe implications to their neurological function, and whereas the main treatment focuses on life support and analgesia, the recovery time is uncertain, often resulting in death within days. Collisions are the leading cause of brain injuries, with more than eight million birds being run over per year in Brazil and generalist synanthropic species being more affected by window impacts. We used the chi-square test to analyze the relation between body size, season, and outcomes of 265 birds of 60 species with CET received at the Wildlife Study Group of the University of Passo Fundo (GEAS-UPF), southern Brazil, between 2015-2023. Passeriformes and Strigiformes were the most frequent orders, and species such as the Red-breasted Toucan, the Tropical Screech Owl, the Rufous-bellied Thrush, and the Monk Parakeet were the most recurrent. Most individuals succumbed to death (72%) on average three days after admission (60.7%). Body size seems to influence prognosis, with smaller birds having higher mortality rates (45%) than larger ones (20%), possibly due to more extensive internal damage and a more challenging rehabilitation. The predator guild was the most affected (72.8%), probably because their hunting behavior makes them more susceptible to fatal impacts. Most cases occurred during the breeding season (70%), as birds are more prone to collisions due to increased territorial activity. Interactions between birds and human structures can lead to instantaneous death or the development of cranioencephalic trauma; thus, data on birds with such injuries collected from wildlife rehabilitation centers over years of operation can provide valuable insights into the actual impacts of collisions on avian populations, especially in Latin America and Brazil, where information is scarce, underscoring the necessity for further studies. As Brazil is one of the world's richest countries in bird diversity, studies such as this are important to assess the real range of cranioencephalic trauma on Neotropical birds.
Keywords: avian conservation; head trauma; ornithology; survival rate; traumatic brain injury.

1. Introduction

Cranioencephalic trauma (CET), also known as traumatic brain injury, involves damage to the cranial region and the brain with significant implications for neurological function and overall health (Veltri and Klem, 2005). The physiological impacts of CET are profound, as neurological damage can be immediate, involving contusions, lacerations, and hemorrhages, which can develop as a secondary injury with inflammation, increased intracranial pressure, and ischemia exacerbating the initial damage (Lee et al., 2024). Affected birds may show altered flight patterns, impaired coordination, difficulty in foraging, and changes in vocalization and social behavior due to limitation or absence of proprioception, leading to imbalance and incoordination, seizures, tremors, loss of consciousness, swelling, bleeding, opisthotonos, dysregulated body temperature, altered respiratory frequency, fractures to the beak, spine, and skull, and partial or total blindness due to swelling and intracranial hematomas (Fornazari et al., 2021; Ushine et al., 2021).

Diagnosis of CET in birds involves clinical examination evaluating proprioception and reduced or absent pupilar reflexes responses to light exposure, imaging techniques like radiography, CT scans, and MRI to assess the extension of the neurological impairment (Jenkins, 2016). Treatment focuses on life support to allow the natural resolution of the condition, maintaining the patient in a low-stimulus warm environment, oxygenation, hydration, and soft food for easy swallowing, also managing pain with anti-inflammatory and analgesic drugs, diuretics to manage intracranial pressure, and antibiotics to prevent infection (Jenkins, 2016; Stout, 2016). Long-term rehabilitation involves physical therapy, environmental enrichment, and gradual reintroduction to the wild when possible (Stout, 2016). The recovery time is indeterminate and often progresses to death within a few days, as the severity of the injury, speed of treatment, comorbidities, and level of stress are some of the determining factors of a positive or negative progression of the clinical condition (Klem, 1990; Jenkins, 2016).

Collisions are a leading cause of CET in birds, and whereas data for Latin America is still unknown, between 365 million and 988 million birds die annually in the United States (Kahle et al., 2016). Species with generalist synanthropic tendencies, such as Passeriformes and Columbiformes, and during the breeding season, due to increased mating activities, seem to be more affected in urban areas, frequently colliding with windows and glass buildings (Basilio et al., 2020; Fornazari et al., 2021, Lee et al., 2024). Birds also have the highest reported number of roadkill deaths, being estimated that more than eight million birds are run over on Brazilian roads every year (González-Suárez et al., 2018). The most vulnerable species to roadkill seem to be those with larger wingspans that fly slower and lower and/or feed on the sides of roads (Benítez-López et al., 2010; Hu et al., 2020). Also, other human activities, such as hunting and trapping, and attacks by domestic animals, such as outdoor cats and dogs, often lead to direct trauma to the skull and brain (Isaksson, 2018).

In general, data for bird collision and especially for CET are still incipient. Wildlife rehabilitation centers can provide rich material for studies on the real impacts of collisions and head traumas in birds, yet there remains a notable scarcity of knowledge regarding species prone to collisions and their recovery rates. Understanding the physiological impacts and effective management strategies is crucial for veterinary care and conservation efforts. The main objective of this study was to provide an overview of the birds admitted to a wildlife rehabilitation center located in the south of Brazil.

2. Materials e Methods

Data collection: The patient control records from the wildlife rehabilitation center GEAS-UPF (Wildlife Study Group of the University of Passo Fundo, Grupo de Estudos de Animais Silvestres da Universidade de Passo Fundo, northernmost Rio Grande do Sul State, Brazil) from 2015 to 2023 was inspected in search for cases of birds with characteristic traumatic brain injury. The records were selected based on their entry diagnosis, including all cases identified with the keywords “cranioencephalic trauma,” “traumatic brain injury,” “trauma,” “shock,” and “spinal cord injury.” From the available information in each record, it was selected the bird species along with dates of arrival/leaving the wildlife center and its clinical outcome (death or discharge, which could include release or destination). Some species identifications were undefined (i.e., patients identified with generic common names such as “dove”) and were assigned the closest taxonomic level (i.e., dove = Columbidae spp.). Unfortunately, the cause of the trauma (window collision, vehicular collision, or other, etc.) was not recorded on the spot, as most of the time, the birds were found injured and brought in with little to no knowledge of their clinical history; therefore, this data could not be evaluated.

Data analysis: The collected dataset was evaluated by tallying individuals for each taxon to determine species richness and abundance and the number of individuals per family and order. Clinical outcomes were categorized as follows: 1) death – any bird that died, whether due to natural causes or euthanasia; 2) release or liberation (freed) – discharge of native birds that survived and were returned to their natural habitat; and 3) destination – discharge of native or exotic birds that could not be returned to the wild. The survival rate of individuals who died ranged from the beginning of treatment until the date of death. The number of cases recorded for each month was evaluated in seasons (summer, autumn, winter, and spring) to determine any seasonality in cases.

The bird species were classified according to the official species nomenclature catalog of Brazilian birds (Pacheco et al., 2021). Their occurrence status and endemism to the state of Rio Grande do Sul were evaluated as 1) native – any migratory or resident species that spend all or part of their life in the State, or 2) exotic – any species originating from another region that has been introduced in the State (Pacheco et al., 2021). Their conservation status was based on the global lists from the International Union for Conservation of Nature (IUCN, 2024). Their physical size was classified as 1) small – any species weighing up to 100 g; 2) medium – any species weighing between 101-300 g; and 3) large – any species weighing above 301 g, based on the average weight of the species available in the literature (i.e., specialized ornithology websites such as eBird and WikiAves: www.ebird.org; www.wikiaves.com.br). The species were also categorized according to their feeding guild (Sick, 1997) to evaluate their roles in the environment and imply any environmental impacts related to the loss of specimens.

A chi-square test was conducted to assess the association between the season in which the cases occurred and the number of cases. This test aimed to determine if the distribution of cases differed significantly among seasons. A chi-square test was conducted to examine the relationship between body size and survival outcomes. This test aimed to determine if the distribution of survival outcomes differed significantly among birds of different sizes. The chi-square test is a statistical method specifically designed to assess whether there is a statistically significant association between two variables by comparing the observed frequencies in each category with the expected frequencies under the assumption of independence. The analysis was conducted using the R programming language with the 'nnet' package.

3. Results

Between 2015-2023, 265 birds with head trauma were admitted at GEAS-UPF. They belong to 60 species, out of which 58 were native, including four migratory species and two exotics, composing 25 families and 15 orders (Table 1). The species with the highest abundance (N) were the Red-breasted Toucan (*Ramphastos dicolorus*) (N=33, 12.5%), the Tropical Screech Owl (*Megascops choliba*) (N=27, 10.2%), the Rufous-bellied Thrush (*Turdus rufiventris*) (N=20, 7.5%), and the Monk Parakeet (*Myiopsitta monachus*) (N=15, 5.7%) (Table 1). The most representative orders in species richness (S) and abundance were Passeriformes (S=17, 28.3%; N=70, 26.4%) and Strigiformes (S=7, 11.7%; N=61, 23%) (Table 2). As for conservation status, no species were classified as globally or nationally threatened of extinction (Table 1), but at a State level, one species, the Chestnut-eared Aracari (*Pteroglossus castanotis*), is classified as near threatened (SEMA, 2014).

There was 100% of mortality among patients of the following species: Rufous-bellied Thrush (N=20), Eared Dove (*Zenaida auriculata*) (N=8), Southern Lapwing (*Vanellus chilensis*) and Campo Flicker (*Colaptes campestris*) (both N=6), Blue-and-white Swallow (*Pygochelidon cyanoleuca*) (N=5), Sayaca Tanager (*Thraupis sayaca*) and Fork-tailed Flycatcher (*Tyrannus savana*) (both N=4), Surucua Trogon (*Trogon surrucura*) and Creamy-bellied Thrush (*Turdus amaurochalinus*) (both N=2). (Table 1). Among the species with the highest abundance, the Rufous Hornero (*Furnarius rufus*) had the highest mortality rate (88.9%), followed by the Burrowing Owl (61.5%), the Red-breasted Toucan (60.6%), the Monk Parakeet (60%), and the Tropical Screech Owl (51.9%) (Table 1). As for successful cases, both Aplomado Falcons (*Falco femoralis*) and both Collared Forest-falcon (*Micrastur semitorquatus*) were rehabilitated and reintroduced, as well as the majority of Southern Caracaras (*Caracara plancus*) (66.7%) and Saffron Finches

(*Sicalis flaveola*) (60%) (Table 1). Among the species with the highest abundance, the Tropical Screech Owl had the highest recovery rate (48.1%), followed by the American Barn Owl (45.5%) and the Monk Parakeet (40%) (Table 1).

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Taxa	Common name	Guild	Occurrence status	Body size	Conservation status	N	AF%	Discharge	DiF%	Death	DeF%
Columbiformes											
Columbidae											
Columba livia	Rock Pigeon	Gran.	Exotic	Medium	LC	6	2.3	3	50.0	3	50.0
Leptotila verreauxi	White-tipped Dove	Gran.	Native	Medium	LC	1	0.4	0	0.0	1	100.0
Zenaida auriculata	Eared Dove	Gran.	Native	Medium	LC	8	3.0	0	0.0	8	100.0
Columbina talpacoti	Ruddy Ground-Dove	Gran.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Columbidae spp.	Dove	Gran.	Native	Small	-	6	2.3	1	16.7	5	83.3
Nyctibiiformes											
Nyctibiidae											
Nyctibius griseus	Common Potoo	Ins.	Native	Medium	LC	1	0.4	0	0.0	1	100.0
Caprimulgiformes											
Caprimulgidae											
Nyctidromus albicollis	Common Pauraque	Ins.	Native	Small	LC	1	0.4	1	100.0	0	0.0
Apodiformes											
Apodidae											
Chaetura meridionalis	Sick's Swift	Ins.	Native*	Small	LC	1	0.4	0	0.0	1	100.0
Trochilidae											
Anthracothorax nigricollis	Black-throated Mango	Ins.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Chlorostilbon lucidus	Glittering-bellied Emerald	Ins.	Native	Small	LC	1	0.4	1	100.0	0	0.0
Leucochloris albicollis	White-throated Hummingbird	Ins.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Hylocharis chrysura	Gilded Hummingbird	Ins.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Trochilidae spp.	Hummingbird	Ins.	Native	Small	-	5	1.9	1	20.0	4	80.0
Charadriiformes											
Charadriidae											
Vanellus chilensis	Southern Lapwing	Omniv.	Native	Medium	LC	6	2.3	0	0.0	6	100.0
Pelecaniformes											
Thresrkiornithidae											
Theristicus caudatus	Buff-necked Ibis	Carn.	Native	Large	LC	4	1.5	1	25.0	3	75.0
Accipitriformes											
Accipitridae											
Elanoides forficatus	Swallow-tailed Kite	Carn.	Native*	Large	LC	1	0.4	1	100.0	0	0.0
Heterospizias meridionalis	Savanna Hawk	Carn.	Native	Large	LC	1	0.4	0	0.0	1	100.0
Rupornis magnirostris	Roadside Hawk	Carn.	Native	Medium	LC	2	0.8	1	50.0	1	50.0
Strigiformes											
Tytonidae											
Tyto furcata	American Barn Owl	Carn.	Native	Large	LC	11	4.2	5	45.5	6	54.5
Strigidae											
Megascops choliba	Tropical Screech-Owl	Ins.	Native	Medium	LC	27	10.2	13	48.1	14	51.9
Megascops sanctaecatarinae	Long-tufted Screech-Owl	Ins.	Native	Medium	LC	3	1.1	1	33.3	2	66.7
Athene cunicularia	Burrowing Owl	Carn.	Native	Medium	LC	13	4.9	5	38.5	8	61.5
Asio clamator	Striped Owl	Carn.	Native	Large	LC	1	0.4	0	0.0	1	100.0
Asio stygius	Stygian Owl	Carn.	Native	Large	LC	5	1.9	1	20.0	4	80.0
Strigidae sp.	Owl	Carn.	Native	Large	-	1	0.4	0	0.0	1	100.0
Trogoniformes											
Trogonidae											
Trogon surrucura	Surucua Trogon	Frug.	Native	Small	LC	2	0.8	0	0.0	2	100.0
Coraciiformes											
Alcedinidae											
Chloroceryle americana	Green Kingfisher	Pisc.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Piciformes											
Ramphastidae											
Ramphastos dicolorus	Red-breasted Toucan	Omniv.	Native	Large	LC	33	12.5	13	39.4	20	60.6
Pteroglossus castanotis	Chestnut-eared Aracari	Omniv.	Native	Medium	LC	1	0.4	1	100.0	0	0.0
Picidae											
Melanerpes candidus	White Woodpecker	Ins.	Native	Medium	LC	1	0.4	0	0.0	1	100.0
Colaptes melanochloros	Green-barred Woodpecker	Ins.	Native	Medium	LC	1	0.4	0	0.0	1	100.0
Colaptes campestris	Campo Flicker	Ins.	Native	Medium	LC	6	2.3	0	0.0	6	100.0
Picidae spp.	Woodpecker	Ins.	Native	Medium	-	1	0.4	0	0.0	1	100.0
Cariamiformes											
Cariamidae											
Cariama cristata	Red-legged Seriema	Omniv.	Native	Large	LC	1	0.4	0	0.0	1	100.0
Falconiformes											
Falconidae											
Micrastur ruficollis	Barred Forest-Falcon	Carn.	Native	Large	LC	1	0.4	1	100.0	0	0.0
Micrastur semitorquatus	Collared Forest-Falcon	Carn.	Native	Large	LC	2	0.8	2	100.0	0	0.0
Caracara plancus	Crested Caracara	Detr.	Native	Large	LC	3	1.1	2	66.7	1	33.3
Falco sparverius	American Kestrel	Carn.	Native	Medium	LC	5	1.9	1	20.0	4	80.0
Falco femoralis	Aplomado Falcon	Carn.	Native	Medium	LC	2	0.8	2	100.0	0	0.0
Falco peregrinus	Peregrine Falcon	Carn.	Native*	Medium	LC	1	0.4	0	0.0	1	100.0
Psittaciformes											
Psittacidae											
Myiopsitta monachus	Monk Parakeet	Frug.	Native	Medium	LC	15	5.7	6	40.0	9	60.0
Pionus maximiliani	Scaly-headed Parrot	Frug.	Native	Medium	LC	2	0.8	1	50.0	1	50.0
Pyrrhura frontalis	Maroon-bellied Parakeet	Frug.	Native	Small	LC	8	3.0	4	50.0	4	50.0
Passeriformes											
Passeriformes spp.	Bird	-	Native	Small	-	1	0.4	0	0.0	1	100.0
Furnariidae											
Furnarius rufus	Rufous Hornero	Ins.	Native	Small	LC	9	3.4	1	11.1	8	88.9
Tyrannidae											
Pitangus sulphuratus	Great Kiskadee	Omniv.	Native	Small	LC	7	2.6	1	14.3	6	85.7
Tyrannus melancholicus	Tropical Kingbird	Ins.	Native*	Small	LC	1	0.4	0	0.0	1	100.0
Tyrannus savana	Southern Fork-tailed Flycatcher	Ins.	Native*	Small	LC	4	1.5	0	0.0	4	100.0
Hirundinidae											
Pygochelidon cyanoleuca	Blue-and-white Swallow	Ins.	Native*	Small	LC	5	1.9	0	0.0	5	100.0
Hirundinidae spp.	Swallow	Ins.	Native	Small	-	1	0.4	0	0.0	1	100.0
Turdidae											
Turdus leucomelas	Pale-breasted Thrush	Omniv.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Turdus rufiventris	Rufous-bellied Thrush	Omniv.	Native	Small	LC	20	7.5	0	0.0	20	100.0
Turdus amaurochalinus	Creamy-bellied Thrush	Omniv.	Native	Small	LC	2	0.8	0	0.0	2	100.0
Turdus spp.	Thrush	Omniv.	Native	Small	-	1	0.4	0	0.0	1	100.0
Passeridae											
Passer domesticus	House Sparrow	Omniv.	Exotic	Small	LC	6	2.3	1	16.7	5	83.3
Fringilidae											
Cyanophonia cyanocephala	Golden-rumped Euphonia	Frug.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Passerellidae											
Zonotrichia capensis	Rufous-collared Sparrow	Gran.	Native	Small	LC	1	0.4	0	0.0	1	100.0
Thraupidae											
Sicalis flaveola	Saffron Finch	Gran.	Native	Small	LC	5	1.9	3	60.0	2	40.0
Thraupis sayaca	Sayaca Tanager	Frug.	Native	Small	LC	4	1.5	0	0.0	4	100.0
Thraupidae spp.	Tanager	Frug.	Native	Small	-	1	0.4	0	0.0	1	100.0
Total	60					265		74		191	

Table 1. Bird species with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023.
Obs.: Guild: Carn. – carnivorous; Detr. – detritivorous; Frug. – frugivorous; Gran. – granivorous; Ins. – insectivorous; Omniv. – omnivorous. Occurrence status: * – migratory species for Rio Grande do Sul state. Conservation status: LC – Least concern. N – number (abundance) of birds; AF% – abundance frequency; DiF% – discharge frequency; DeF% – death frequency.

Regarding clinical outcomes, 191 individuals perished, and 74 were recovered (Figure 1, Figure 2). Most of the survivors were reintroduced to nature, with only six being placed under the care of zoos and wildlife sanctuaries either due to being exotic species or because they were not in their full physical and/or behavioral capacity for reintroduction (Figure 2). The average survival time of the individuals whose condition progressed to death during hospitalization was three days (Figure 3). Regarding physical size, most species were categorized as small-sized, which also encompassed the highest number of fatalities (Table 1, Figure 1). The chi-square test for the association between body size and survival outcome yielded an X-squared value of 16.415 and a p-value of 0.0002725. These results indicate a statistically significant association between body size and survival status, and the high chi-square value suggests that the observed distribution of survival and death across different body size categories deviates significantly from what would be expected under the assumption of independence. Therefore, body size is likely to be an important factor influencing survival outcomes in this population, as large-sized species had the highest discharge rate and the lowest mortality rate (Table 1, Figure 1).

Taxa	S	SF%	N	AF%	Discharge	DisF%	Death	DeF%	Body size		
									Large	Medium	Small
Columbiformes	5	8.3	22	8.3	4	18.2	18	81.8	0	3	2
Columbidae	5	8.3	22	8.3	4	18.2	18	81.8	0	3	2
Nyctibiiformes	1	1.7	1	0.4	0	0.0	1	100.0	0	1	0
Nyctibiidae	1	1.7	1	0.4	0	0.0	1	100.0	0	1	0
Caprimulgiformes	1	1.7	1	0.4	1	100.0	0	0.0	0	0	1
Caprimulgidae	1	1.7	1	0.4	1	100.0	0	0.0	0	0	1
Apodiformes	6	10.0	10	3.8	2	20.0	8	80.0	0	0	6
Apodidae	1	1.7	1	0.4	0	0.0	1	100.0	0	0	1
Trochilidae	5	8.3	9	3.4	2	22.2	7	77.8	0	0	5
Charadriiformes	1	1.7	6	2.3	0	0.0	6	100.0	0	1	0
Charadriidae	1	1.7	6	2.3	0	0.0	6	100.0	0	1	0
Pelecaniformes	1	1.7	4	1.5	1	25.0	3	75.0	1	0	0
Threskiornithidae	1	1.7	4	1.5	1	25.0	3	75.0	1	0	0
Accipitriformes	3	5.0	4	1.5	2	50.0	2	50.0	2	1	0
Accipitridae	3	5.0	4	1.5	2	50.0	2	50.0	2	1	0
Strigiformes	7	11.7	61	23.0	25	41.0	36	59.0	4	3	0
Tytonidae	1	1.7	11	4.2	5	45.5	6	54.5	1	0	0
Strigidae	6	10.0	50	18.9	20	40.0	30	60.0	3	3	0
Trogoniformes	1	1.7	2	0.8	0	0.0	2	100.0	0	0	1
Trogonidae	1	1.7	2	0.8	0	0.0	2	100.0	0	0	1
Coraciiformes	1	1.7	1	0.4	0	0.0	1	100.0	0	0	1
Alcedinidae	1	1.7	1	0.4	0	0.0	1	100.0	0	0	1
Piciformes	6	10.0	43	16.2	14	32.6	29	67.4	1	5	0
Ramphastidae	2	3.3	34	12.8	14	41.2	20	58.8	1	1	0
Picidae	4	6.7	9	3.4	0	0.0	9	100.0	0	4	0
Cariamiformes	1	1.7	1	0.4	0	0.0	1	100.0	1	0	0
Cariamidae	1	1.7	1	0.4	0	0.0	1	100.0	1	0	0
Falconiformes	6	10.0	14	5.3	9	64.3	5	35.7	3	3	0
Falconidae	6	10.0	14	5.3	9	64.3	5	35.7	3	3	0
Psittaciformes	3	5.0	25	9.4	11	44.0	14	56.0	0	2	1
Psittacidae	3	5.0	25	9.4	11	44.0	14	56.0	0	2	1
Passeriformes	17	28.3	70	26.4	6	8.6	64	91.4	0	0	17
Furnariidae	1	1.7	9	3.4	1	11.1	8	88.9	0	0	1
Tyrannidae	3	5.0	12	4.5	1	8.3	11	91.7	0	0	3
Hirundinidae	2	3.3	6	2.3	0	0.0	6	100.0	0	0	2
Turdidae	4	6.7	24	9.1	0	0.0	24	100.0	0	0	4
Passeridae	1	1.7	6	2.3	1	16.7	5	83.3	0	0	1
Fringilidae	1	1.7	1	0.4	0	0.0	1	100.0	0	0	1
Passerellidae	1	1.7	1	0.4	0	0.0	1	100.0	0	0	1
Thraupidae	3	5.0	10	3.8	3	30.0	7	70.0	0	0	3
Unidentified	1	1.7	1	0.4	0	0.0	1	100.0	0	0	1
Total	60		265		74		191		12	19	29

Table 2. Orders e families of birds with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023.
S – species richness; SF% – species richness frequency; N – number (abundance) of birds; AF% – abundance frequency; DiF% – discharge frequency; DeF% – death frequency.

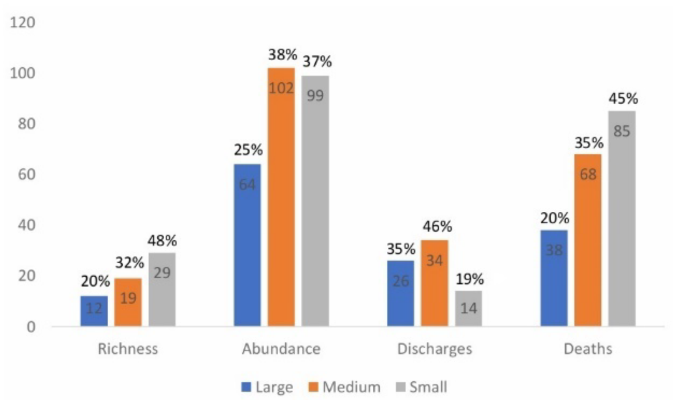

Figure 1. Species richness, number of individuals (abundance), numbers/frequencies of discharges, and deaths for each body size type of the birds with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023.

http://dx.doi.org/10.5380/avs.v29i4.95996

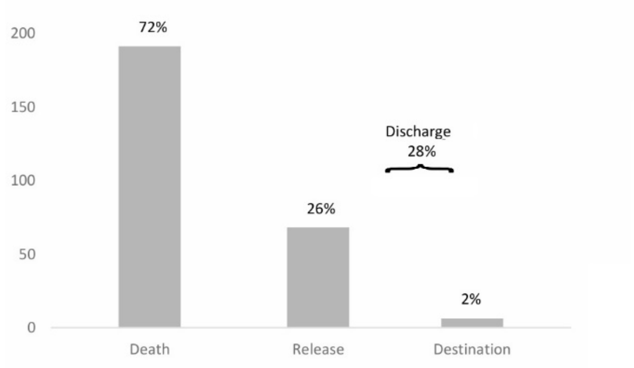

Figure 2. Outcomes of the birds with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023.

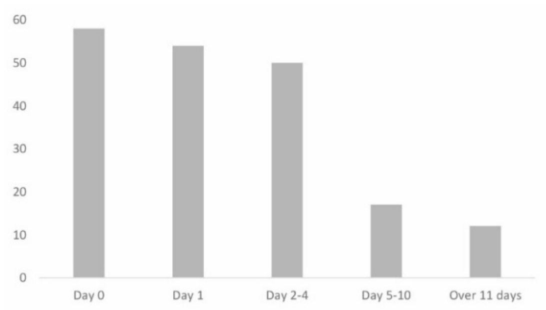

Figure 3. Survival time of the birds with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023 whose condition progressed to death.

Regarding seasonality, 185 records occurred during spring-summer (September to March in South America), which encompasses the breeding season for most bird species (Figure 4). The chi-square test for the association between the number of cases and season yielded an X-squared value of 28.562 and a p-value of 9.073e-08. This suggests that cases are not evenly distributed between these periods, and there is a strong association between the breeding season and the occurrence of cases. Seven feeding guilds were identified, of which 44 species are classified as predators (Figure 5). One unidentified species from the order Passeriformes could not be assigned to a guild.

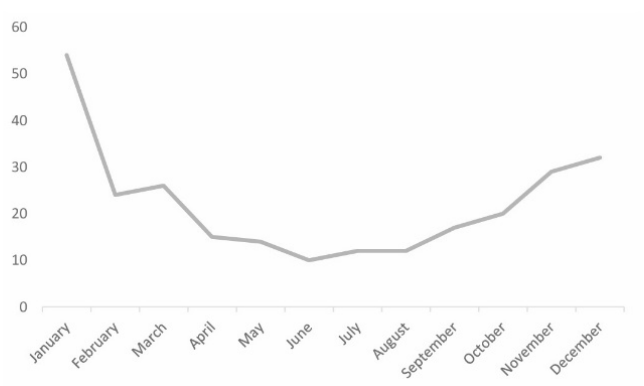

Figure 4. Seasonality of cases of birds with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023.

http://dx.doi.org/10.5380/avs.v29i4.95996

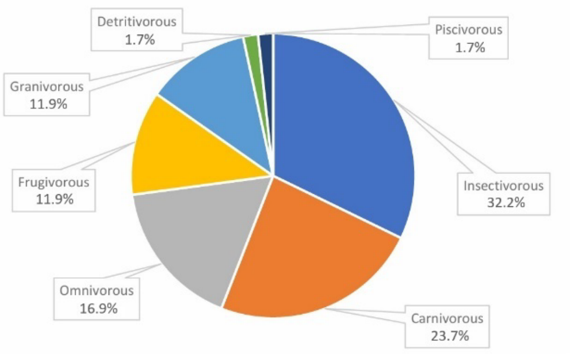

Figure 5. Feeding guild of the birds with cranioencephalic trauma received at the wildlife rehabilitation center GEAS-UPF between 2015 and 2023.

4. Discussion

The highest frequency of admissions to the wildlife department, GEAS-UPF, accounted for small and medium-sized species (75%), while large-sized birds recorded the lowest (25%). This may be biased due to the majority of birds present in urban environments being small-sized, particularly those belonging to the order Passeriformes, which is known to be the most affected by collisions with glass windows, often resulting in immediate death (Wittig et al., 2017; Fornazari et al., 2021). This finding was also reported by Lee et al. (2024), who found the Ruddy Ground-Dove (*Columbina talpacoti*) and the Pale-breasted Thrush (*Turdus leucomelas*) to be the most common species to be affected by the collision. Also, Fornazari et al. (2021) found the Rufous-bellied Thrush, the Eared Dove, and the Ruddy Ground-Dove to be the most commonly affected species.

The majority of the cases of birds with CET in this study progressed to death (72%), with survival appearing to decrease over time, as 161 deaths (60.7%) occurred within the first three days of treatment. This data is supported by evidence found by Klem (1990), where out of the evaluated birds, 300 individuals died immediately after the collision or a few days after the impact, and 31 survived, either recovering shortly after the collision due to less severe impact or requiring a variable period of treatment. Similarly, Ushine et al. (2021) found that collision and trauma cases resulting in death had an average survival time of one to two days. Smaller-sized animals present greater challenges in clinical management, patient stabilization, and life support, as manipulation induces an elevation in cortisol levels, disrupts hydroelectrolytic balance, and commonly leads to capture myopathy due to elevated creatine kinase (CK) levels, thereby increasing their risk of death (Stout, 2016).

In this study, small-sized species such as thrushes and doves, as well as families and orders predominantly consisting of small-sized species, had the lowest discharge rate (19%) and the highest mortality rate (45%). Small-sized animals are more prone to injuries, increasing the chances of bone fractures, organ ruptures, internal hemorrhaging, and permanent neurological injuries following physical impacts, leading to immediate or delayed death (Stout, 2016). Fornazari et al. (2021) found that post-mortem alterations included skull hemorrhages (77.3%), encephalic contusions (64.4%), and coelomic hemorrhages (40.7%). Lee et al. (2024) report fractures in several bones, as well as bruises and cranial hemorrhages. Ushine et al. (2021) found that kidney discoloration and anterior lobe extension were a common post-mortem alteration, with rupture of renal blood vessels caused by the impact. Klem (1990) found that broken bills were the most frequent external injuries, while intracranial hemorrhage was common to birds that did not perish immediately after colliding despite appearing physically stable and alert, suggesting that the number of birds progressing to death after the impact may be higher. Veltri and Klem (2005) found that subadults had more severe subdermal injuries than adults, such as intracranial blood pooling, and fracture cases affected mostly the mandible-anterior skull junction, which is the first body part to make contact during collisions. Unfortunately, as no necropsy was performed on the birds with CET admitted to GEAS-UPF, it was not possible to verify which additional injuries were linked to these patients.

In this study, large-sized species, families, and orders, with a majority of large-sized bird species, had the highest discharge rate (35%) and the lowest mortality rate (20%). However, the Red-breasted Toucan, a large-sized bird, was one of the most frequently admitted species and one of the highest in terms of mortality rate, possibly due to the susceptibility of the Piciformes group to develop rhabdomyolysis and capture myopathy when kept in captivity, hindering their recovery (Ruder et al., 2012). All individuals of Southern Lapwing, a medium-sized territorial species associated with open areas (Marcon and Vieira, 2017), died during treatment. This species is easily observed near roads, making it prone to vehicle collisions while moving within its territory. Owls (order Strigiformes) were also a group with a high number of species and individuals treated by GEAS-UPF, confirming previous observations that they are greatly impacted by collisions, especially on highways (Novelli et al., 1988; Massemin et al., 1998; Bencke and Bencke, 1999). It is estimated that collisions with vehicles, glass windows, and other structures are responsible for the deaths of billions of birds annually, with a projection of eight million birds being run over in Brazil annually (González-Suárez et al., 2018). Additionally, bird collisions with aircraft also contribute to the mortality of these animals, with over 19,000 bird-aircraft collision records reported between 2011 and 2020 in Brazil (CENIPA, 2020).

The majority of the species of birds with CET in this study belong to predator guilds (72.8% as insectivorous, carnivorous, and omnivorous). Predators have naturally lower population densities compared to prey animals due to various ecological factors, such as different hunting strategies, smaller number of offspring, and large individual territory areas (Muneret et al., 2022). Therefore, the loss of individuals belonging to these guilds directly impacts the ecological balance. The reduction in the number of predators increases the population sizes of prey species, causing alterations in the trophic cascade and directly and indirectly affecting human activities, such as an increase in insect pests in crops and the proliferation of animals considered pests and disease vectors in residential areas (Muneret et al., 2022). Birds of prey, such as owls, hawks, and falcons, which are considered mesopredators, comprise a significant portion of the number of birds affected by collisions, especially through roadkill on highways (Pedroso et al., 2022). Most collisions occur during hunting when the bird is in free flight to capture prey and ends up colliding with structures like windows and moving vehicles that intersect its flight path (Pedroso et al., 2022). Wittig et al. (2017) found that foliage gleaning presented an increased risk of collision, while ground foraging had a lower risk.

The dataset from GEAS-UPF indicates a correlation between the season of the year and bird collision, showing that most cases occurred during the breeding season (70%). Fornazari et al., 2021 also demonstrated a seasonal pattern of collisions, with the majority of events occurring during spring (32.8%). Wittig et al. (2017) also found that breeding birds were more vulnerable to collisions, corroborating the findings of the GEAS-UPF hospitalization dataset. Furthermore, Fornazari et al. (2021) showed that 91% of collisions primarily involved actively breeding males (50% of them with active gonads), which could be related to mating activities such as competition for territories and mates. Veltri and Klem (2005) found subadult individuals were more affected by tower collisions (69.8%) than windows, on which adults were the most prone to collide (55.5%). Unfortunately, age and sex were not defined for most of the birds with CET admitted to GEAS-UPF, so it was not possible to verify if the data corroborated those findings. The types of collisions (with windows, walls, or vehicles) were also not reported in the patient records of GEAS-UPF due to the birds being found already injured by civilians without witnessing the collision itself, making it impossible to evaluate the importance of each type of impact on the regional bird population. However, data from the citizen science website Urubu System (Sistema Urubu, 2022) demonstrates that from 2014 to 2022, over 13,000 bird roadkill records have been registered on Brazilian highways, affecting 410 species. Statistics for window collisions in Brazil are not available, but it is believed that the mortality rate is as high as in other countries, such as the United States, where bird mortality is estimated at 100 million to one billion annually (Loss et al., 2014).

5. Conclusion

CET affects bird species of all physical sizes and dietary guilds. Due to being more common in urban environments and more sensitive to injuries and veterinary management, small-sized birds appear to be the main victims with a higher mortality rate. Unfortunately, the chances of survival after brain trauma are small, usually resulting in immediate death or an average survival of only three days after the injury. Predator species seem to be the most affected, possibly due to their hunting habits, which increase the likelihood of being struck by vehicles or colliding with windows. Additionally, admittances occurred mainly during the breeding season, the period of highest bird activity, making them more prone to collisions. Wildlife rehabilitation centers collect years of crucial data on epidemiological casuistry and species occurrences; however, such data is still underutilized. These datasets should be further explored, particularly in Brazil, where information on the impact of bird collisions is scarce or almost nonexistent.

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