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Causes of Owls Admission to the Wildlife Rescue Centre in Beijing (China) from 2006–2022

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ABSTRACT

Data from wildlife rescue centers are crucial for understanding the threats faced by wild animal populations. This study examines the causes of admission and outcomes for Strigiformes owls at the Beijing Wildlife Rescue Center (BWRC) using data collected from January 2006 to December 2022. A total of 1,109 records from nine raptor species were analyzed, with the eurasian scops owl (*Otus scops*; 27.5%), eurasian eagle-owl (*Bubo bubo*; 26%), and long-eared owl (*Asio otus*; 19.4%) being the most frequently admitted. Collisions were the primary cause of admissions, accounting for 55.1% of cases, followed by healthy orphaned chicks at 28.2%.Gunshot wounds resulted in the highest mortality rate (85.7%), The fatality rate from collisions is 10%,while orphaned birds had the lowest (0.4%). The analysis considered factors such as estimated age at admission, admission date, habitat of the location where the owl was found, primary cause of admission, and outcome. The majority of admissions were linked to human activities, particularly collision trauma and the collection of uninjured fledglings. Adults exhibited higher mortality rates, while most young birds survived and were released. Collisions and gunshot wounds had a significant impact on adult mortality. Urban areas were associated with higher instances of persecution, building collisions, and trauma of unknown origin, whereas rural areas had more vehicle-related collisions. The study recommends anatomopathological and toxicological examinations of deceased birds and post-release monitoring to improve the understanding of mortality causes and enhance rehabilitation strategies. Beijing's urbanization over the past two decades has led to increased adult bird mortality due to collisions, with urban areas experiencing higher rates of persecution and building collisions, while rural areas face threats like prey shortages.

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Authors' Contribution
GF and YS designed and planned this study. GF, YS, JL, MYL, ZJL, YFW, PZ, XYG and XYG performed wilderness rescue missions and data collection and analyzed the data. JP organization proposed amendments.

Key words
Strigiformes owls, Wildlife rescue center, Conservation, Environmental threats, Morbidity, Mortality

INTRODUCTION

The widespread decline in urban biodiversity due to urbanization has garnered significant global attention (McDonnell and Hahs, 2013; McKinney, 2008). Data from wildlife rescue centers are invaluable for assessing threats to wild animal populations and monitoring ecosystem health (Molina-López and Darwich, 2011). In Europe, although the overall population trend of certain owl species shows a slight decline, they are still classified as least concern. Contributing factors include competition with species like the tawny owl (*Strix aluco*), fluctuations in vole populations (Village, 1981; Tulis *et al*., 2015), pesticide use (Ruiz-Suárez *et al*., 2014), and road traffic collisions (Erritzøe, 1999). Research on owl morbidity and mortality remains limited, yet owls are recognized as sentinels of environmental change due to their position in the food chain (Sheffield, 1997). Rehabilitation of wild raptors offers several benefits: it supports population reinforcement after release, particularly for endangered species; aids in identifying the causes of morbidity and mortality; and helps evaluate the effects of regulatory changes that address human-induced admissions (Molina-López *et al*., 2013). Data from wildlife rehabilitation centers are crucial for recording causes of morbidity and mortality, assessing the health of wild populations (Wendell *et al*., 2002), and identifying trends in anthropogenic threats over time (Thompson *et al*., 2013). Rehabilitating and releasing individuals can help mitigate the adverse effects of human activities, especially for species sensitive to conservation concerns (Dessalvi *et al*., 2021; Hernandez *et al*., 2018; Montesdeoca *et al*., 2017). Urban environments present unique survival challenges for raptors, including collisions with man-made structures, poisoning, and electrocution (Lehman *et al*., 2007; Wendell *et al*., 2002).

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Wildlife threats are multifaceted, arising from both natural causes (e.g., interspecific interactions, starvation, diseases) (Crandall *et al*., 2019; Guthrie *et al*., 2016) and anthropogenic sources (e.g., collisions, electrocution, poisoning, trapping, shooting) (Millsap *et al*., 2022; Loss *et al*., 2015). Although rehabilitation aims for wild release post-treatment, severely injured animals with little chance of recovery should be humanely euthanized through a triage process to prevent further suffering. Barriers in the natural habitats of free-living raptors can cause injuries from both natural incidents and human-made objects or conditions. Power lines, vehicle collisions, gunshot injuries, intoxications, and heavy metal contamination are significant anthropogenic causes of morbidity, leading to admissions at rescue centers. Effective conservation measures require a detailed understanding of the spatial and temporal variations in mortality causes, which are crucial for demographic studies and conservation planning (Holz, 2002; Molina-López and Darwich, 2011; Rodríguez *et al*., 2009).

This study analyzed owl admission data from the Beijing Wildlife Rescue Center (BWRC) over a 17-years period (2006-2022) to examine raptor admissions, species prevalence, and primary reasons for admission. It also explored the relationship between urbanization levels and hospitalization rates, with the hypothesis that urbanization increases the risk of collisions with buildings or vehicles. Additionally, the study predicted that the causes of admission would vary based on the degree of urbasnization.

MATERIALS AND METHODS

Study area

Admission data for native raptors at the Beijing Wildlife Rescue Center (BWRC), located in a 16,440 km² region in Northern China, reveal a diverse intake of species (Fig. 1). The geographical landscape of Beijing is predominantly characterized by industrial and service sectors, with 62% of the urban area covered by mountains and 38% by plains. Beijing has a population of approximately 21.83 million (Source: https://www.beijing.gov.cn/renwen/bjgk/#bjgk).

The BWRC primarily provides assistance to terrestrial wildlife, including birds, mammals, amphibians, and reptiles, with most admissions being from class Aves (birds). Currently, the compilation of admission and outcome data into a unified national database is not yet in practice, although such a system could provide invaluable insights into the morbidity and mortality of various wildlife species. Strategically positioned at the confluence of the middle medieval and oriental zoogeographical realms, Beijing serves as a crucial transitional corridor between the Northeast sub-cold zone and the warm temperate zone of North China. This unique geographic positioning makes Beijing an essential migratory route for numerous bird species traveling between the north and south, thereby enhancing its avian biodiversity. The region's complex terrain further supports a rich biodiversity. Within the Beijing area, 10 owl species have been identified, categorized according to their residency and migratory patterns. Resident species include the eurasian eagle-owl, little owl, tawny owl, and ural owl. Winter migrants feature the long-eared owl (*Asio otus*) and short-eared owl (*Asio flammeus*), while summer breeders include the Eurasian scops owl, collared scops owl, and brown hawk owl. additionally, the Asian barred owlet is noted as a vagrant visitor.

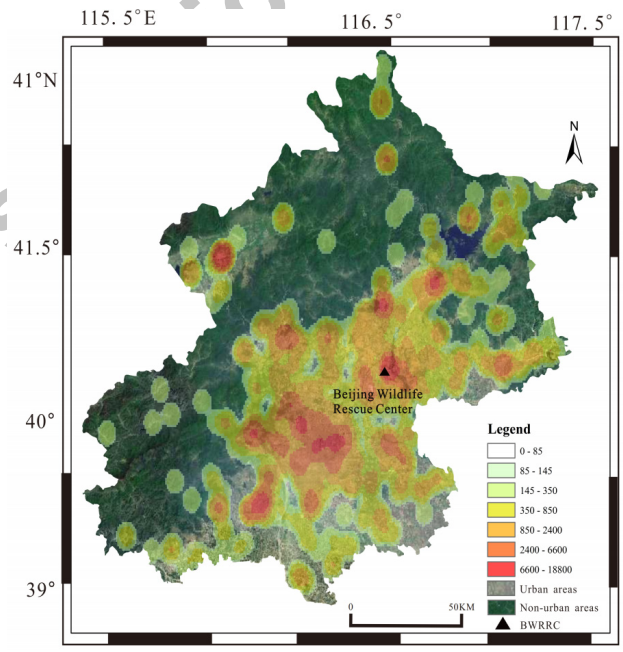

Fig. 1. Spatial distribution for 9 species of owls admitted to wildlife rescue centers between 2006 and 2022 in Beijing (China).

Data collection

The BWRC provided data for this study, covering records from January 2006 to December 2022. The study examined several parameters: estimated age at admission, date of admission, habitat at the location where the animal was found, primary cause of admission, and the eventual outcome. Animals were classified into age categories adult, juvenile, and pullus based on morphological characteristics and plumage development. Habitats were categorized into various types: Urban or rural buildings (both inhabited

and uninhabited), industrial zones, roadsides, forests, grasslands and pastures, agricultural lands, wetlands, and other or undetermined locations.

Admission causes were identified through case histories and veterinary examinations, including gunshot wounds, collision trauma, healthy orphaned chicks, starvation, illegal captivity, natural diseases, poisoning, predation, entanglement or contaminated feathers, and unknown causes. The natural diseases category encompassed conditions such as metabolic, nutritional, infectious, and parasitic diseases. Outcomes were classified into four categories: released, kept in captivity (for animals with disabilities that prevent release), under treatment, or deceased this last category included both natural deaths and euthanasia. Spanning a comprehensive 17-year period, from January 20, 2006, to December 14, 2022, this dataset provides an in-depth analysis of the wildlife rescue operations conducted by the center.

Classifying causes of morbidity and mortality

To ensure comparability with previous research, the categorization of admission causes followed established classifications in the literature (Molina-López and Darwich, 2011). Upon the birds arrival, trained wildlife care professionals conducted thorough examinations, using admission notes for each case to assign admissions into distinct categories based on types (i.e., anthropogenic, natural, and unknown) and more specific causes. A detailed listing of all admission types, causes, codes, and aggregated miscellaneous causes can be found in Table I. In cases where the cause of admission could not be determined, the admission type was classified as Unknown. This category included cases with undetermined causes, where the reason for admission was unclear and no obvious injury was present, and unknown trauma, where physical injuries were observed but the underlying cause remained unidentified.

Landscape and demographic variables

To assess the impact of urbanization on raptor admission types and causes, this study utilized geo-referenced admissions data (N= 1,119). Land cover information was extracted for these cases, and the proportion of urban habitat within a 2-km radius was calculated. Maps were generated using ArcGIS 10.2, with data sourced from http://xdc.at/map/wmts and integrated via the ArcGIS web map tile service (WMTS). The land cover data were reclassified using the reclass function in ArcGIS, resulting in a new binary raster layer that designated urban and suburban areas as 1, with all other land cover types assigned a value of 0. Kernel density analysis in ArcGIS employed the default base unit of per square unit count, calculating the density of points within each square relative to its area, expressed as points per square unit. Statistical analyses were conducted using SPSS version 15. Descriptive statistics, normality tests, and inferential analyses were all performed at a 95% confidence level or higher, with R software (R Development Core Team, 2015) also used for additional analyses.

Table I. The number of owls received by Wildlife Rescue Center from 2006 to 2022.

Species	Year																	
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Total**
Resident																		
Athene noctua	21	31	26	10	9	7	3	3	8	5	2	7	1	3	5	9	14	164
Bubo bubo	6	17	16	20	31	18	14	13	21	20	25	24	14	17	8	14	13	291
Strix aluco	1	3	5	3	2	1	0	2	1	3	4	4	4	4	12	5	9	63
Winter migratory species																		
Asio otus	17	20	17	15	21	14	9	13	6	7	8	10	11	8	18	15	8	217
Asio flammeus	3	7	3	2	1	2	4	0	1	11	0	0	0	1	6	0	0	41
Summer breeders																		
Otus scops	9	37	47	16	12	10	10	10	12	12	19	5	5	13	38	21	32	308
Otus semitorques	4	4	4	1	0	0	1	0	1	0	0	1	2	1	2	0	3	24
Ninox scutulata	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	6	9
Vagrant visitor																		
Glaucidium cuculoides	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Total	61	120	121	67	76	52	41	41	50	56	58	51	37	46	84	64	83	1119

Chi-square analysis was employed to compare proportions where appropriate. The study further examined variations in bird admissions across different years and months, as well as among various age groups and causes of mortality, using chi-square or fisher's exact tests to assess differences in frequency distributions.

Statistical analysis

Data obtained from medical records were systematically encoded numerically and organized into tables for statistical analysis using Pivot graphics and tables in Excel 2016 (Microsoft Corporation, Redmond, WA, USA). The variable related to the sex of the birds was excluded from the analysis due to indeterminate status in over half of the subjects. To investigate factors influencing the cause of admission, a multinomial logistic regression was performed. The dependent variable was the cause of admission (excluding the undetermined category due to its ambiguity), while independent variables included species family (Accipitridae, Falconidae, Tytonidae, Strigidae), maturity (fully feathered or not), season, and year of admission. Two additional multinomial logistic regression models were developed to explore temporal shifts in admission causes, both annually and within specific years. These models used year and season of admission as dependent variables, with species, family, and maturity as independent factors. In a final analysis to determine factors affecting rehabilitation outcomes, a logistic regression was conducted with the outcome (released vs. not released) as the dependent variable. Independent variables included species family, the interval between discovery and admission (GAP), maturity, body condition score (BCS), diagnosis (excluding ischemic necrosis syndrome, undetermined causes, and illegal captivity to avoid including birds without definitive medical diagnoses), season, and year of admission. Initially treated as categorical variables, GAP and BCS were later analyzed as ordinal variables after graphical verification of coefficient linearity. The relationships between BCS and both the cause of admission and GAP were examined using a Kruskal-Wallis test. Significant outcomes were further analyzed with pairwise comparisons using Dunn's procedure, adjusted with a Bonferroni correction for multiple comparisons. Variations in admission numbers across different years and seasons were assessed using a chi-square test. All statistical tests, models, and odds ratios were considered significant at an alpha level of 5%. Results were presented with p-values (P) and odds ratios (OR) along with their 95% confidence intervals. All analyses were performed using IBM SPSS Statistics software (IBM Corp., Released 2017, IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY, USA).

The BWRC receives reports of injured wildlife from the public, local authorities, and various organizations. All animals originating from Beijing are collected, identified, and examined by the center's staff. Depending on their condition, injured birds either undergo rehabilitation or are euthanized; rehabilitated birds are banded and reintroduced into the wild. Where feasible, each bird's locality, date, age class, and the date and location of release are meticulously documented. This study focuses on raptor admission data from 2006 to 2022, with reasons for admission categorized into nine groups: (1) shooting, (2) collision, (3) disease, (4) poisoning, (5) glue-trapping, (6) starvation, (7) poaching, (8) other, and (9) unknown. Categories were assigned based on (1) direct evidence from the location of discovery, (2) information provided by individuals who found the bird, and (3) diagnostic symptoms. For example, shootings were confirmed through the presence of gunshot wounds or via X-ray imaging. The collision category included birds injured by structures or vehicles, as well as those with fractures or limb injuries of unidentified origins. Birds with parasites or organ lesions, often emaciated, were categorized as diseased. Poisoning was identified by symptoms such as flight incapacity, fluid discharge, neck stiffness, dilated pupils, and gastrointestinal damage. Starving birds exhibited low weight, muscle wasting, and lack of body fat without signs of other conditions. Some raptors, such as long-eared owls, barn owls, and eurasian kestrels, were admitted with plumage damage or flight incapacity caused by entanglement in plant burrs (Rodríguez *et al*., 2009) and were classified under other. A small number of birds, deceased upon collection or before arrival at the BWRC, were also recorded as admissions and included in the study. It is hypothesized that all birds admitted would likely have perished if not reported to the BWRC, although this remains speculative and may not fully capture the reality.

RESULTS

Numbers and species of raptors admitted

Between 2006 and 2022, the BWRC documented the admission of 1,119 owls from 9 distinct species. Resident birds accounted for 46.3% (n=518) of these admissions, while migratory birds, including winter migrants, summer breeders, and vagrant visitors, made up 53.7% (n= 601). Prominently, the long-eared owl (*Asio otus*) accounted for 19.4% (n= 217) of admissions, followed by the eurasian eagle owl (*Bubo bubo*) at 26% (n= 291) and the eurasian

scops owl (*Otus scops*), which represented 27.5% (n= 308) (Table I, Fig. 2). The remaining species contributed to the residual percentage of admissions. Notably, the sex of the birds was indeterminate, so classification was based solely on age groups: juveniles (26.5%, n= 297), pulli (27.3%, n= 306), and adults (46.1%, n= 516) (Table II). A statistically significant difference was observed across age groups (χ^2 = 12.851, P < 0.001).

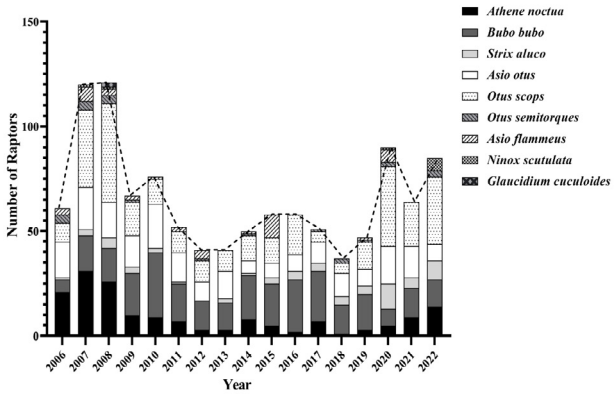

Fig. 2. The number of owl birds rescued by the Wildlife Rescue Center from 2006 to 2022.

Admission types and causes

The study encompassed a total of 1,119 birds, with the majority (96.0%, n= 1074) alive upon admission, with 37.4% (n=419) of the animals being successfully released (Table III). Analyzing mortality differences across age categories revealed that adult owls experienced a higher death rate (3.6%, n= 40), compared to only 0.4% of pulli (n=5) ($\chi 2 = 7$; P < 0.008), indicating a significant disparity in survival outcomes. Notably, a substantial portion of pulli (72.1%, n=313) were released. Detailed outcomes for various admission causes by adult and pulli age classes are documented in Table IV. The overall mortality rate was

Table II. Reasons for receiving owls and their age distribution in age classes in Wildlife Rescue Center (2006-2022).

	Adult		Juvenile		Pullus	
	n	%	n	%	n	%
Gunshot wound	7	1.3	0	0.0	0	0.0
Collision trauma	202	38.0	12	4.0	0	0.0
Healthy orphaned chicks	0	0.0	103	34.7	216	70.6
Starvation	265	50.3	123	41.4	83	27.1
Illegal captivity	8	4.0	13	4.4	0	0.0
Natural disease	3	0.6	0	0.0	0	0.0
Poisoning	3	0.6	9	3.0	0	0.0
Predation	10	1.9	30	10.1	5	1.6
Entanglement or dirty feathers	10	1.9	3	1.0	0	0.0
Unknown causes	8	1.4	4	1.4	2	0.7
Total	516	46.1	297	26.5	306	27.3

Table III. Owl species and injuries received by the Wildlife Rescue Center between 2006 and 2022.

Species	Gunshot wound	Collision trauma	Healthy orphaned chicks	Star-vation	Illegal captivity	Poi-soning	Natural disease	Preda-tion	Entangle-ment or dirty feathers	Released (%)
Resident										
Athene noctua	5	58	88	2	5	0	2	2	2	68.3
Bubo bubo	13	166	15	85	12	0	0	0	0	50.2
Strix aluco	4	35	17	4	1	0	0	1	1	61.9
Winter migratory species										
Asio otus	5	199	0	1	11	0	0	0	1	65.0
Asio flammeus	0	28	0	7	6	0	0	0	0	39.0
Summer breeders										
Otus scops	8	104	188	2	1	0	0	4	1	77.9
Summer breeders Otus semitorques	0	18	6	0	0	0	0	0	0	75.0
Ninox scutulata	0	7	2	0	0	0	0	0	0	66.7
Vagrant visitor										
Glaucidium cuculoides	0	2	0	0	0	0	0	0	0	50.0

Total	35	617	316	101	36	0	2	7	4	
%	3.1	55.1	28.2	9.0	3.2	0	0.1	0.6	0.3	37.4

Table IV. Outcomes for different causes of admission in adults and pulli of Owls in wildlife rescue centre (2006–2022).

Age class	Outcome	Gunshot wound		Collision trauma		Healthy orphaned chicks		Starvation		Illegal captivity		Natural disease		Poisoning		Predation		Entanglement or dirty feathers		Unknown causes	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Adults	Released	0	0.0	133	64.9	0	0.0	255	95.5	18	85.7	0	0.0	3	33.3	5	0.9	3	0.6	2	0.4
	Dead	6	85.7	10	4.9	0	0.0	12	4.5	3	14.3	3	100	6	66.7	0	0.0	0	0.0	0	0.0
	Kept in captivity	1	14.3	62	30.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Still being treated	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	1.9	10	1.9
	Total	7	100	202	100	0	0.0	265	100	8	100	3	100	3	100	10	100	10	100	8	100
Pulli	Released	0	0.0	0	0.0	213	98.6	83	100	0	0.0	0	0.0	0	0.0	3	60.0	0	0.0	2	100
	Dead	0	0.0	0	0.0	3	0.4	0	0.0	0	0.0	0	0.0	0	0.0	2	40.0	0	0.0	0	0
	Captivity still being treated	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Total	0	0.0	0	0.0	216	100	83	100	0	0.0	0	0.0	0	0.0	5	100	0	0.0	2	100

4%, with a χ^2 value of 312.347 and a significance level of $p < 0.001$, underscoring significant differences in causes of death across different years. Multiple comparison analyses showed no significant year-on-year variation for predation, gunshot wounds, dirty feathers, and poisoning ($p > 0.05$). However, there was a notable difference in illegal captivity between 2008 and 2016 ($p < 0.05$), and collision-related injuries in 2010 significantly differed from those in 2018 ($p < 0.05$). Significant disparities were also found between 2008 and subsequent years, including 2012, 2013, 2019, and 2021 ($p < 0.05$).Admission patterns for adult birds primarily occurred from late October to December (wintering period) and in April, while pulli admissions were concentrated during the breeding season from May to July. The center admitted its first injured owl on January 5. Long-eared Owls, in particular, frequently interacted with human activities, resulting in a notable number of admissions related to human encounters. During the breeding season, residents often find healthy juvenile owls that have either fallen from their nests or are fledging. These cases are typically reported to the BWRC. For young owls that have experienced nesting accidents or are in flight training, the public is advised to place them in an elevated location nearby to allow continued parental care. Injured juveniles, however, are rehabilitated and released back into the wild after treatment and feeding (Table IV). A minority of pulli admissions were due to trauma or illness: 83 pulli were admitted due to starvation (27.1% of admitted chicks), and five due to predation injuries (1.6%).

Annual and seasonal trends

Over the course of this 17-years study, the seasonal admission rates of birds of prey were as follows: 15.2% (380/2496) in spring, 50.3% (1256/2496) in summer, 19.0% (473/2496) in fall, and 15.5% (387/2496) in winter (Fig. 3). The cold winter and spring months in the Beijing area lead to reduced activity of rodents, birds, and mammals, which impacts the survival of owls due to diminished food availability. Conversely, summer and autumn represent the owl breeding season, during which juvenile birds often leave the nest or fall during their fledging phase, resulting in increased owl admissions. The reasons for admission largely followed the general annual case trend, with a few exceptions: nestlings were reported once in February, then reappeared from April to August; infectious/parasitic cases were absent in December and January; captive birds of prey were not reported in February; and no dead-on-arrival (DOA) cases were recorded in February, April, September, October, or November (Fig. 3).

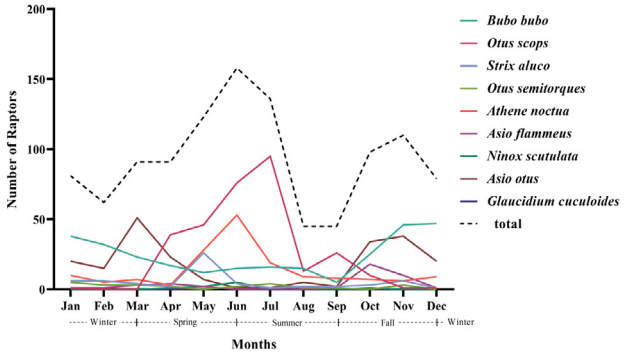

Fig. 3. Seasonal overall trend of birds of prey admitted during the study period of 2006–2022.

Adult birds were predominantly admitted between late October and December (wintering period) and in April, while peak admissions for chicks occurred during the breeding season from May to July. The first injured owl of the year was admitted on January 5. Long-eared owls, in particular, had frequent interactions with human activities, with a significant number found in human-influenced areas. Specifically, a substantial proportion of these owls were discovered in urban (38.6%, n= 83) and rural (27%, n= 58) buildings, or along roadsides (34.4%, n= 74), indicating a strong association with human environments (Fig. 1).

Chi-square analysis of admissions for different bird species across months revealed significant variation (χ^2 = 811.601, $p < 0.001$). Subsequent multiple comparison tests showed no significant monthly differences in admissions among eagle osprey, spotted dove, and northern collared horn osprey. However, specific disparities were observed: admissions of Diao Cheng birds in April, May, and September differed significantly from those in December, February, and January. October admissions for the short-eared duck were significantly different from those in January, April, May, June, and July. Additionally, December, February, January, March, and November showed significantly different admission rates compared to April, August, July, June, May, and September. July also exhibited significant differences in admissions compared to April, August, June, May, and October. Furthermore, April, December, July, June, March, November, and October displayed significant disparities in admissions compared to May. Admissions in June and July for changer species significantly diverged from those in April, August, and October. December, February, January, March, May, November, and October showed significant variation, with May and September admissions differing significantly from those in November and October. Notably, admissions for ducklings with longitudinal abdominal patterns in May and April were significantly distinct.

Causes of admission to the rescue center

The reasons for admission were consistent with the overall annual trend in cases, with collision trauma, healthy chick orphans, and starvation significantly more than other causes of injury and illness (Fig. 4). Collisions were the predominant cause of admissions at the BWRC, accounting for 55.1% of total admissions, followed by healthy orphaned chicks at 28.2% (Table III). Even when excluding rare species with fewer than ten individuals, collisions remained the leading cause of admission across many species. Specifically, healthy orphaned chicks, particularly *Otus scops* and *Athene noctua*, made up 28.2% of admissions, while hungry chicks, especially *Bubo bubo,* represented 9% (Table III). Secondary causes of mortality included gunshot wounds (3.1%) and illegal captivity (3.2%), with predation accounting for 0.6%, and *Athene noctua* entangled in dirty feathers making up 0.3%. Birds with gunshot wounds were often targeted with slingshots, as China implemented a gun ban in 1996. The use of slingshots on owls is rooted in traditional cultural beliefs that associate owls with misfortune, leading to their persecution as a means of protecting domestic animals and poultry raised by villagers. Eagle-owls in Beijing, in particular, face challenges preying on poultry during winter, an issue that requires attention. Villagers encroach on the eagle-owls' mountain habitats for poultry farming, degrading their natural environments. This encroachment reduces the eagle-owls' food sources, forcing them to hunt poultry, which often results in injuries from traps set by villagers, causing significant harm to the eagle-owl population.

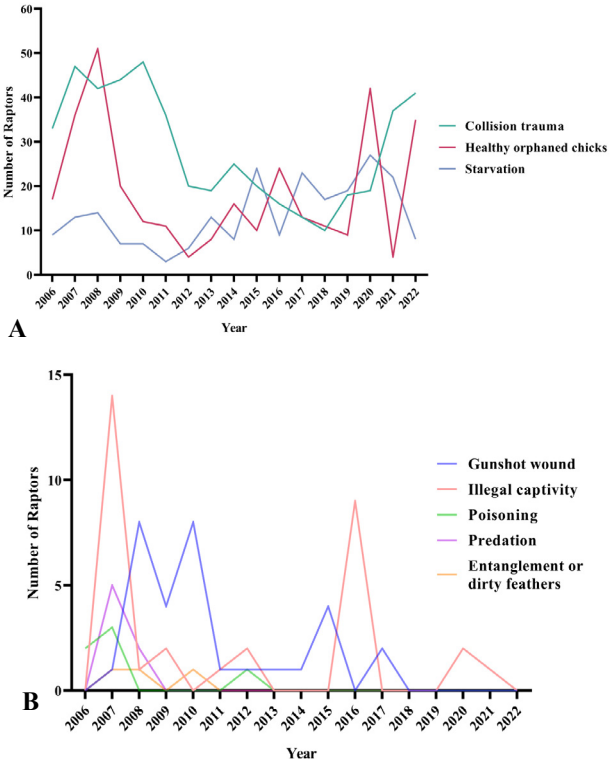

Fig. 4. Number of cases for the different causes of admissions during the period of 2006–2022.

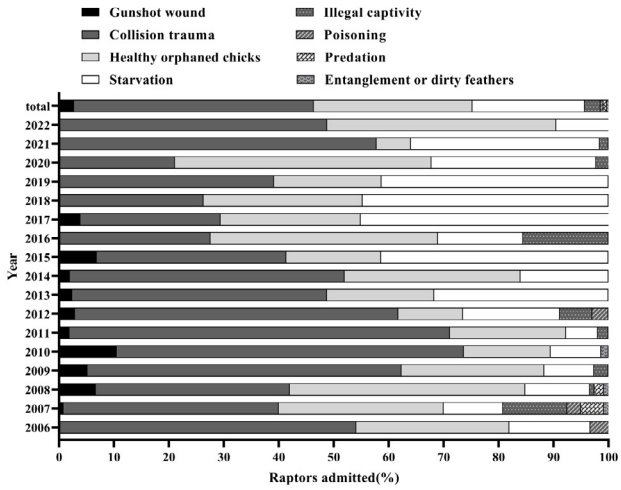

Fig. 5. Wildlife Rescue Center 2006-2022 rescue owl injury causes.

Recovery rate

The analysis revealed no significant statistical differences in the habitat of discovery across age classes. The predominant causes of admission were collision trauma, accounting for 19.2% (n = 214) of cases, and the collection of orphaned chicks, which contributed to 28.5% (n= 319) of admissions. A substantial portion of collision incidents involved adult animals, comprising 94.4% (n = 202) of such cases (Table II). In contrast, orphaned chicks were mainly from the pulli age class, making up 70.6% (n = 216) of their respective admissions category (Table IV). Certain injuries prevented owls from being released back into the wild, such as broken wings from collisions, blindness, or disabilities like leg injuries caused by traps during winter. These impairments rendered the birds unable to regain flight capabilities, necessitating long-term care or captivity due to their irreversible conditions. Upon admission to the BWRC, 45 individuals were recorded as deceased. Of the birds admitted alive, 720 (64.3% of live admissions) were successfully rehabilitated and released into the wild. The remaining cases, after diagnostic evaluation (Fig. 5), were deemed untreatable and were either euthanized or retained in captivity for educational, conservation, or scientific purposes.

Outcome and release rate

The multivariable multinomial logistic regression model was significant and interpretable (N = 1,117, χ^2 = 1,400.22, df = 72, $p < 0.001$). The model revealed that, compared to other times of the year, the risk of collision trauma was significantly higher in summer than in winter (p = 0.004, OR = 3.016 [1.429–6.366]), and also higher in spring than in winter (p = 0.003, OR = 2.735 [1.422–5.259]). Additionally, the risk for young birds was lower than for adults (p = 0.044, OR = 0.517 [0.272–0.981]). For healthy orphaned chicks, the risk in summer was significantly higher than in winter ($p < 0.001$, OR = 17.788 [4.306–73.477]), with spring (p = 0.001, OR = 24.74 [3.616–169.283]) and summer (p = 0.023, OR = 9.156 [1.362–61.536]) also presenting significantly higher risks than winter. In terms of starvation, spring (p = 0.002, OR = 0.258 [0.109–0.61]), summer ($p < 0.001$, OR = 0.022 [0.005–0.11]), and fall (p = 0.017, OR = 0.454 [0.238–0.866]) all had significantly lower risks than winter, and the likelihood of not being kept in captivity was significantly higher than being kept in captivity ($p < 0.001$, OR = 10.944 [4.936–24.265]).

The logistic regression model assessing release in relation to factors such as age, year, season, outcome, and captivity status was also significant and interpretable (N = 1,117, χ^2 = 874.999, df = 27, $p < 0.001$). The season was significantly correlated with the release rate, with a notably higher release rate in summer than in spring (p = 0.005, OR = 4.686 [1.601–13.716]). The relationship between injury type and release rate was also significant: collision trauma (p = 0.009, OR = 2.727 [1.288–5.771]), healthy orphaned chicks ($p < 0.001$, OR = 23.07 [4.877–

109.126]), and starvation ($p = 0.001$, OR = 5.685 [2.005–16.119]) all had higher release rates compared to other injuries. The likelihood of release for birds kept in captivity was significantly lower than for those not kept in captivity ($p < 0.001$, OR = 0.001 [0.00–0.002]). Among adult birds, significant differences in release and death rates were observed across causes, with starvation showing notably higher mortality rates compared to other causes ($\chi^2 = 320.451$, $p < 0.001$). While no significant differences were found between release and death rates for collision injuries (Fig. 5), significant variances were noted in captivity status, ongoing treatment, and release outcomes. Gunshot wounds and congenital diseases only showed significant differences between release and death rates. Unknown causes displayed a significantly higher treatment rate than other categories, and poisoning cases exhibited significant disparities between preservation, imprisonment, and death outcomes. For young birds, the analysis revealed that only predation significantly impacted release versus non-release outcomes ($\chi^2 = 14.855$, $p = 0.003$).

DISCUSSION

Numerous studies have identified trauma and injuries from various collisions, particularly with anthropogenic structures, as significant contributors to non-natural mortality among raptor species (Erritzøe *et al*., 2003; Harris and Sleeman, 2007; Keran, 1981; Kelly and Bland, 2006; Wendell *et al*., 2002). Our findings corroborate that collisions encompassing those with vehicles and high-voltage transmission towers, among others are prevalent. The heightened survival challenges faced by raptors in the urbanized environments of Beijing are primarily due to habitat urbanization, increased human activities, and the illegal trade and breeding of these birds. Adult long-eared owls are predominantly hospitalized due to collision traumas or gunshot injuries, while pulli are chiefly admitted as healthy, uninjured chicks. Young owls tend to vacate the nest prematurely, likely as a strategy to evade parasitism, nest predators, or human disturbances, or to seek more temperate roosting sites (Kristan *et al*., 1996). These juveniles continue to rely on parental provision for sustenance over the following months, often perceived as vulnerable by well-meaning bystanders who then intervene (Griffiths *et al*., 2010; Molina-López and Darwich, 2011). Additionally, fledglings found under roofs or within chimneys of urban and rural structures are often rescued by property owners and delivered to wildlife rescue centers. These healthy, uninjured owlets show a notably high release rate (85.7%, n = 84), in contrast to the adult birds frequently admitted with severe injuries or illnesses. Suspected collision injuries are raised for any case exhibiting symptoms of head trauma or fractures, potentially resulting from vehicular impacts or collisions with windows, fences, and other barriers. A significant proportion (38%, n= 202) of adult birds presenting with trauma symptoms were found along roads, indicating a possible prevalence of road traffic accidents as a causative factor. Nevertheless, the exact cause of many collisions often remains undetermined.

During the winter, eagle owls frequent rural enclosures, often hunting domestic chickens or sustaining wing injuries. Adult eagle owls constitute 22% (n = 66) of these cases.

Over the past decade, economic and industrial changes in Beijing's mountainous regions, coupled with increased vehicular access to rural roads, have spurred rural tourism activities, leading to habitat loss and fragmentation for wild animals. As a result, eagle owls in Beijing face challenges securing food during winter, sometimes attacking poultry, which leads to injuries from traps set by villagers. The nocturnal nature of raptors makes them particularly vulnerable to collision trauma and road traffic hazards. Contributing factors include the use of roadside structures for support, foraging along roadsides where small mammals are abundant, or temporary blindness caused by traffic lights (Erritzøe, 1999; Erritzøe *et al*., 2003; Massemin and Zorn, 1998; Molina-López and Darwich, 2011).

The high mortality rate observed in this study aligns with typical outcomes in wildlife rehabilitation centers, where release rates are often reported to be 50% or lower (Fix and Barrows, 1990; Holz, 2002; Ress and Guyer, 2004). Mortality is influenced by factors beyond the primary cause of admission, such as malnourishment or concurrent illnesses, complicating recovery. Neurological signs in Athene noctua and poor body condition in Strix aluco have been associated with poor outcomes (Molina-López *et al*., 2013). Ocular lesions from road traffic accidents (Seruca *et al*., 2012) also require comprehensive assessment, as they can hinder release prospects (Cousquer, 2005).

CONCLUSION

In fact, during the owl breeding season, citizens often find healthy young owls that accidentally fall into the nest or encounter young owls practicing flight after leaving the nest, and report them to the BWRC. If it is a case of accidental nesting and flight training, we will instruct the public to stay in place on a nearby high place, and the parent birds will continue to take care of the young birds. If it is an injured baby bird, it will be released into the wild after treatment and feeding. Because owls are defined as unlucky birds in Chinese traditional culture, they often bring bad luck to humans, so they are hated by humans. The owl's nocturnal behavior reduces the chance of being shot by mistake, but there is still a risk of poaching. Due to China's

strict gun control regulations, residents are not allowed to own guns, but there have been isolated cases of using slingshots or other tools to attack eagle owls. The mortality rate for both collision and gunshot wounds was high: 7.2% (n = 16) of adult owls with signs of collision trauma died, while 2.7% (n = 16) of those struck (Table II). The overall mortality rate was not high, but not surprising, because instead of attacking with a firearm, slingshot attacks caused disabilities caused by broken wings and could not be released into the wild. overall mortality rate was not high, but not surprising, because instead of attacking with a firearm, slingshot attacks caused disabilities caused by broken wings and could not be released into the wild.

The difficulty in achieving definitive diagnoses in wildlife rescue centers highlights the complexity of trauma-related morbidity and mortality (Wendell *et al*., 2002). The roles of food scarcity, sub-lethal infectious diseases, and poisoning remain under exploration. As secondary consumers, nocturnal raptors are prone to pesticide exposure, particularly from second-generation anticoagulant rodenticides (Sánchez-Barbudo *et al*., 2012). Chronic exposure to such toxicants may increase vulnerability (Albert *et al*., 2010). Performing necropsies on all deceased birds is crucial for understanding mortality causes. Monitoring contaminants, especially anticoagulant rodenticides, would provide insights into environmental challenges and sub-lethal poisoning effects. Anatomopathological investigations could also reveal whether prolonged hospitalization increases susceptibility to captivity-associated diseases, influencing rehabilitation success. Anthropogenic factors, including poisoning, collisions, commercial fishing, introduced species predation, and hunting, impact raptor population dynamics (Hernández and Margalida, 2008). Understanding spatial and temporal mortality variations is vital for effective conservation strategies (González *et al*., 2007). Analyzing injured or deceased birds offers indirect insights into population trends and landscape changes, while raising public awareness (Fajardo, 2001; Wendell *et al*., 2002). Studies on life expectancy and post-rehabilitation outcomes using radiotelemetry and band-recovery data are essential for improving rehabilitation efficacy (Fajardo *et al*., 2000; Kelly and Bland, 2006). Comprehensive clinical and contaminant analyses are critical for assessing raptor health, with complete necropsies helping reveal the impact of contaminants and poisoning (Battaglia *et al*., 2005; Gangoso *et al*., 2009; Lemus *et al*., 2008). Increased funding is necessary for wildlife rescue operations and to study raptor risk factors in the Beijing area. Monitoring the survival rates of released owls, potentially using satellite telemetry (Petty and Thirgood, 1989), is recommended to assess recovery success. Enhanced post-release monitoring involving wildlife rehabilitators could provide valuable data on survival, habitat use, foraging success, and dispersal, allowing comparisons between recovered and unrecovered owls.

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Ethics statement

All experimental procedures are carried out in accordance with the guidelines set out in the Regulation on the Administration of Experimental Animals (Ministry of Science and Technology of China, 2004) and approved by the Beijing Municipal Bureau of Landscaping.

Statement of conflict of interest

The authors have declared no conflict of interest.

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