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Providing evidence-based education and resources on wildlife rehabilitation to move the □eld of wildlife rehabilitation forward; to promote wildlife conservation and welfare; and to mitigate human-wildlife con□icts worldwide, through better understanding of wild animal ecology, behavior, and welfare.

ABOVE:
Northern gannet *(Morus bassanus),* IUCN red list category–least concern.
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ON THE COVER:
White-bellied tree pangolin twins *(Phataginus tricuspis)* in care.
USED WITH PERMISSION.

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EDITORIAL

Strengthening our voices through collaboration

I write this editorial at the close of IWRC's 50th year. Re ecting on what we as an organization and community have done, and what we can do more of, better, differently. I write it with some hope for the future, thinking of the legacy of individuals like Dr Jane Goodall in our every intention, because it is "we", it is "us", it is "our" that will shape what is next.

I recently read Robin Wall Kimmerer's essay about learning Potawatomi. I was struck by a language that incorporated living beings and entire systems in such a sensible way, well sensible once I could get my English language trained mind around the preponderance of verbs and assigning grammatical agency to mountains and bays. As a teacher told her "grammar charts relationships in language"[1]. I took away from the essay the knowledge that I am not alone in speaking to non-humans as fellow beings inhabiting the same landscape, but also that I should also be thinking bigger, to the animacy of systems.

When we consider information through multiple lenses we obtain a broader understanding. Languages, arts, sciences, cultures, community, each of these is a lens, and sometimes an entire epistemology. Last year I led an art project at a scienti c conference that asked people to use color to categorize a particular picture of a cat as friendly, nuisance, wild, dangerous, cute. I chose the particular image because, for most people, the image didn't contain declarative clues as to context and species. People not only used color to show their perceptions, they used color and shape to create a story of their perceptions. From the British national who immediately IDed the cat as the very endangered Scottish wild cat (*Felis silvestris silvestris*), the Australian to whom the picture represented an invasive menace, and the person who was reminded of their pet cat, everyone - all of them working in elds of wildlife research, policy, and care - reacted to the image through art via a combination of past experiences and general knowledge. Sharing the images in a gallery created a rich tapestry of conversation and visual intake throughout the day, providing a glimpse as to how we can expand our thinking with di erent manners of communication.

Dr Helina Jolly spoke to an IWRC audience in September of her work studying ways of knowing and coexisting in a local environment, illuminating knowledge erased by colonial homogenization. In speaking about human-wildlife interactions she stated that "coexistence is an active choice". It is study and communication, not prescriptive solutions but understanding the "how, why, and where coexistence works"[2].

Two eyed seeing means looking at the world from more than one way of knowing, a term coined by Mi'kmaw elders Albert Marshall and Dr Murdena Marshall alongside Dr Cheryl Bartlet in approaching learning from both Indigenous lenses and Western thinking. Not just understanding but experiencing the world in multiple ways leads towards coexistence. Dr Jolly notes that understanding local ways of relating to animals, such as considering animals as "co-inhabitants with shared and entangled histories" and "seeing and engaging with animals as sentient beings", i.e. individuals, invites coexistence[2].

By moving deeper into relational thinking, considering our world through relationships between creatures, people, landscapes, and concepts rather than separating knowledge into siloed buckets, I think we can improve our work. To my surprise in listening to Dr Jolly I realized that wildlife rehabilitation already practices multispecies ethnography when we engage in dialogue with the public over the bat in the attic, the bird that hit a window, the turtle crossing the road. Dr

–Continued on page 33

WILDLIFE REHABILITATION AND HUSBANDRY

Case study: Successful delivery and rehabilitation support of twin white-bellied tree pangolin *(Phataginus tricuspis)*

Jessica Harvey-Carroll,[1,2,3] **Daire Carroll,**[1,2,3] **Ellen Connelly,**[1] **Mark Donaldson,**[1] **Julie Vanassche,**[1] **Marine Montblanc,**[1] **Lisa Hywood**[1]

White-bellied tree twin panolins in care

Introduction

All species of pangolin are currently in decline and vulnerable to extinction (IUCN, 2023). Overharvesting by humans is a main driver of this decline.[1–3] To counteract overharvesting, a primary conservation method is banning the collection or sale of pangolins.[4–6] Enforcing such bans results in the seizure of both live and dead pangolins. In some cases, live pangolins are then transported to rehabilitation centres. Considerable knowledge of rare and understudied species can be gained by studying individuals recovered from tra cking during rehabilitation.[7–9]A good understanding of reproductive biology is vital for e ective wildlife conservation and management, particularly in cases where overharvesting is occurring.[10–12] Due to their behavioural ecology and

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ABSTRACT
We present the rst documented case of the delivery of living twins in any pangolin species. The white-bellied tree pangolin (*Phataginus tricuspis*) twins were born during October 2024 to an individual recovered from Nkolndongo bushmeat market (the primary selling point for fresh and live wild animals in Yaoundé, Cameroon). We document their growth, maternal care, and behaviour during the rst 149 days of their life until the mother was released into the wild. The case highlights unknowns regarding pangolin ecology and life history, and the value of monitoring individuals in a rehabilitation setting. We argue for increased communication and sharing of data and observations during rehabilitation to improve our understanding of understudied species.

KEYWORDS: Pangolin, rehabilitation, twins, wildlife trade

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the inaccessibility of their habitats, studying the life history and ecology of pangolins is challenging.[9] is is particularly true for arboreal species, such as the white-bellied pangolin (*Phataginus tricuspis*), as dense vegetation limits the use of VHF and satellite tags for monitoring. is poses a signi cant challenge for conservation e orts, with reproductive biology in particular being poorly understood.[13] e true wild gestation and weaning period for many pangolin species remains unknown within the literature, alongside the possibility of delayed implantation.[10,12] Female pangolins generally give birth to and rear a single o spring (referred to as a pup) at a time. eir capacity to give birth to multiple viable o spring has previously been unknown.

Twins are suspected in ground *(Smutsia temminckii)*, Sunda (*Manis javanica*), Indian (*Manis crassicaudata*), and Chinese *(Manis pentadactyla)* pangolins. Most previous reports of live pangolin twins are unveri ed and based on anecdotal accounts of a pangolin seen with two smaller individuals.[14–19] In Supplemental Information 1, we report a suspected case of ground pangolin twins birthed during tra cking reported by law enforcement. Previous reports have assumed multiple pups in the presence of an adult are of the same litter; however, orphaned pups are known to follow other pangolins.[20] ere is sparse de nite evidence of multiple simultaneous pregnancies in pangolins. A wild Sunda pangolin birthed twins during a captive breeding program; however, one twin died during birth.[21] To our knowledge, the only other occurrence of twins comes from a necropsy on a Sunda pangolin recovered from illegal wildlife trade. e individual was reported to have two embryos, each occupying their own uterine horn, the left and right respectively.[20]

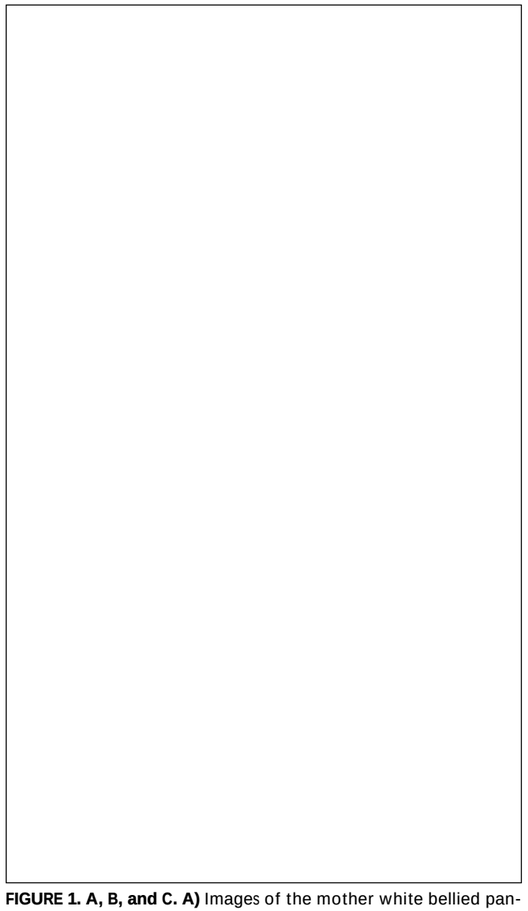


FIGURE 1. A, B, and C. A) Images of the mother white bellied pangolin and twins at Postnatal day 1. **B)** Pups demonstrated the ability to hold onto the mother's tail from Postnatal day 0. **C)**. Both pups were documented holding the mother's tail simultaneously from postnatal day 0 (Image taken on Postnatal day 16).

Methods

We report the rst published case of a pangolin birthing living twins. During an organised mission to con scate pangolins from illegal bushmeat markets, a female white-bellied pangolin (individual THFC-105-24) was recovered from Nkolndongo market, Yaoundé, Cameroon on the 10th of September 2024. She was turned over to Tikki Hywood Foundation, Cameroon; a wildlife rehabilitation organisation. During a clinical investigation, THFC-105-24 was found to be pregnant through external examination and abdominal palpation. No health issues were noted. She was found to weigh 2.19 kg. e gestational age of the foetus was unknown as there are no standardised developmental references for white-bellied pangolins. e decision to maintain THFC-105-24 in care was made after full consideration of her welfare and logistical challenges associated with release. It was noted that THFC-105-24 had reduced mobility and climbing ability due to her abdominal size. In previous cases with other pangolin species, the authors have observed that it is unlikely for heavily pregnant pangolins to survive on release. Furthermore, there is a high risk of pup abandonment following release even if the mother survives [Authors' Observations]. THFC-105-24 was fed an arti cial diet alongside daily foraging walks during which she was free to select prey and toilet naturally under supervision of a trained pangolin minder (Harvey-Carroll et al., 2024).

At 06:30 on the 6th October 2024, the pangolin was found to have birthed twins; an 87 g female and an 85 g male (Fig. 1A). e pups weighed less than other newborn white-bellied pangolins previously born at the centre (male mean 126.5 g, n = 2. Female mean 119.67 g, n = 3). However, out of ve pups born previously, four died, likely due to complications associated with premature birth. e lower mass documented for the twins may be an adaptation to limited uterine capacity, reducing the likelihood of dystocia.[22,23] Following the birth of the twins, THFC-105-24 was found to have delivered two placentas, suggesting a dichorionic twin gestation.

Both twins had their eyes open and were able to climb onto the mother and nd the nipple. Both pups exhibited the ability to climb on the mother's tail from postnatal day 0 (Fig. 1B and C). roughout the early postnatal period, the twins were observed feeding individually and simultaneously from the mother (Fig. 2). If not suckling from the mother, pups were o ered milk replacer (Royal Canin babycat milk) every 4 hours for postnatal day 0, as maternal lactation was uncon rmed. Without su cient feeding, pangolin neonates can become hypothermic and die within 24 hours. No digestive issues were observed, and pups were checked for hypoglycemia symptoms during monitoring.

e mother exhibited no signs of stress upon handling of the pups. Lactation was con rmed at postnatal day 1, therefore, supplemental feeding was reduced to once/twice daily to support the mother. At postnatal day 4 the male pup appeared less active (and less willing to nd the nipple) and weighed less than the female, so arti cial feeding was increased to four times per day (unless he was observed suckling on the mother during routine checks). Following this, the number of feeds each day was determined based on daily weight for the male. Supplemental feeding ended at postnatal day 23 for the female and 24 for the male as pup growth was deemed to be su cient. No indications of rejection of the twins by the mother were noted.

At postnatal day 44, both pups were deemed t enough to join the mother on daily foraging walks. Typically, both pups attempted to cling to the mother's tail while she walked. Anecdotally, the pup clinging to the distal part of the tail often fell o . e mother did not return to a pup or look for it if it had fallen o her tail. Nor did the mother wait for the pup to climb back on her tail if it had fallen o while she was stationary before moving on; however, this has been observed in other white-bellied pangolins at THF [Authors' Observations]. It is unclear whether these events would have led to loss and abandonment of the pup in the wild, or if she would have retrieved them later. From the rst walk, both pups were documented ingesting ants with increasing vigour. After foraging walks, pups were observed feeding on ants from each other's and their mother's scales.

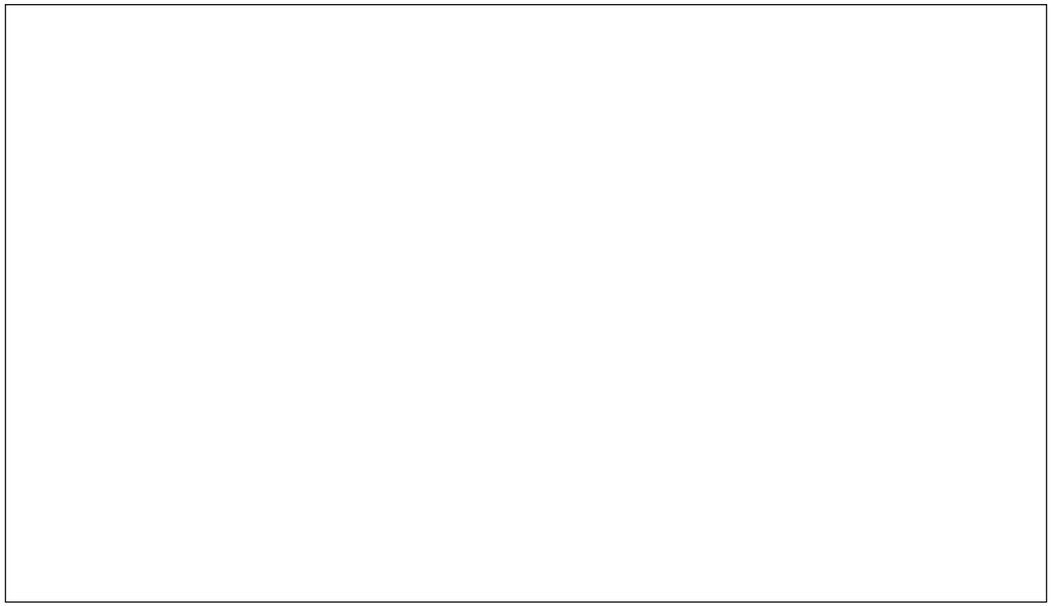


FIGURE 2 A and B. A) Pups were observed suckling simultaneously (top pup female, bottom pup male). **B)** Pups individually suckling (female shown suckling). Photographs taken on postnatal day 1.

Over the following months, the pups gradually increased in independence. eir diet became more reliant on ants and termites than on milk, although they continued to nurse until separated from the mother. e decision to separate them from THFC-105-24 was made on post-natal day 165 due to observations of aggressive behaviour by the male towards the mother. At this point, THFC-105-24 was released into the wild. Both pups remain in care at Tikki Hywood, Cameroon, and will be released into the wild once they are deemed to have reached a su cient level of maturity to survive independently.

Pups were weighed during routine care at a range of times throughout the day. Between birth and postnatal day 149, the male and female pups increased in mass by 653 g and 693 g re-

TABLE 1. Linear Regression Results for the Effect of Sex and Day on Mass.
Adjusted R-Squared = 0.995

	ESTIMATE	SE	T VALUE	P
Intercept Female	85.2	2.12	40.12	<0.0001
Intercept Male	90.9	3.01	1.89	0.06
Slope Female	4.18 g/day	0.03 g/day	169.12	<0.001
Slope Male	4.05 g/day	0.04 g/day	−3.7	<0.001



FIGURE 3. Scatterplot depicting the mass increase of both pups across their first 149 days of life. The estimated mass increase per day was 5.72 g for the female and 5.59 g for the male pup.

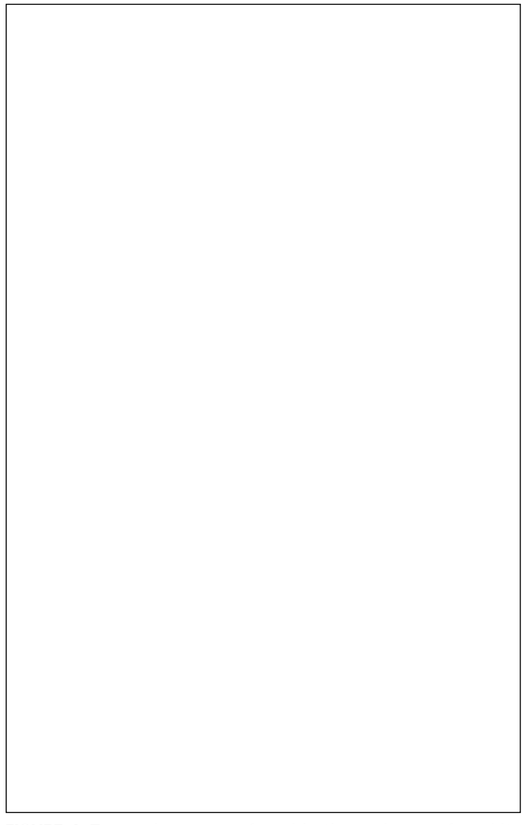


FIGURE 4. Two embryos were found in the enclosure of a white bellied tree pangolin recovered from trade. Embryos weighed 3 g (left embryo in all images) and 6 g (right embryo in all images). The state of the 3 g embryo suggested intrauterine death.

spectively. A linear regression was conducted with mass as the dependant variable, individual and postnatal day as independent variables, and an interaction effect of individual and mass. Growth rate was found to significantly differ between the pups.

The estimated mass increase per day was 4.18 g for the female and 4.05 g for the male pup (Table 1, Fig. 3). To our knowledge, the growth or mass increase of white-bellied tree pangolin neonates has not previously been published, preventing comparison of growth between the twins and with an average individual.

Discussion

Prior to the successful delivery of twins described here, aborted twins were also recorded in white-bellied pangolins. A female weighing 1830 g, with a previously amputated left hand in addition to a snare wound, was recovered from Mantoum, Cameroon, during an organised mission. Two embryos were found in her enclosure, weighing 3 and 6 g, 10 days after admission to THF. The total lengths measured were 9.8 cm and 9.6 cm for the 3 and 6 g foetus respectively. No placenta was found. The 3 g foetus displayed signs of intrauterine death (Fig. 4).

Relevance of observations to rehabilitation

It is clear that white-bellied tree pangolins are capable of giving birth to two living offspring, and this may be the case for other pangolin species. Through a combination of maternal care and appropriate rehabilitation support for white-bellied tree pangolins, both pups can be successfully reared to at least 149 days postnatally. Previous anecdotal observations of wild female pangolins accompanied by multiple smaller individuals may in truth have been twins. The situation in which we observed the twins was highly controlled, and there was a large amount of human intervention. It is unclear whether both would have survived without this intervention. Given that the female did not specifically reject either pup and was observed feeding both, it is possible that she may have successfully reared both to independence in the wild. In the future, the implementation of an ultrasound scan, alongside characterization of white-bellied pangolin embryo development, may help rehabilitators assess the need for intervention for pregnant, white-bellied pangolins. Nonetheless, all decisions in the present case were made based on informed discussions between a qualified vet and wildlife experts with more than thirty years of experience in pangolin rehabilitation. The measures taken ensured the survival of both the mother and offspring.

There is a considerable lack of information on the biology of wild pangolins. Recording and sharing of observations of pangolins in rehabilitation care has already improved our fundamental understanding of pangolin behaviour.[24] It is imperative both for the successful rehabilitation of individual pangolins and conservation of pangolin species in the wild that observations from rehabilitation be shared.

Ethical statement

All handling and decisions regarding the care of pangolins were made by THF staff. THF has been rehabilitating pangolins since 1994 and works in close cooperation with government officials and law enforcement. Procedures, housing, and monitoring of pangolins were conducted under a memorandum of understanding between the government of the republic of Cameroon and the Tikki Hywood foundation relating to the support, conservation and protection of pangolin species in Cameroon (0022).

Zimbabwe Parks and Wildlife Management Authority (ZPWMA), permits: 106(1) (d) & (2) 06/2023, 46 (1) (b) 05/2023, 46 (1) (b) 02/2023, 46 (1) (b) 03/2023, 46 (1) (b) 04/2023.

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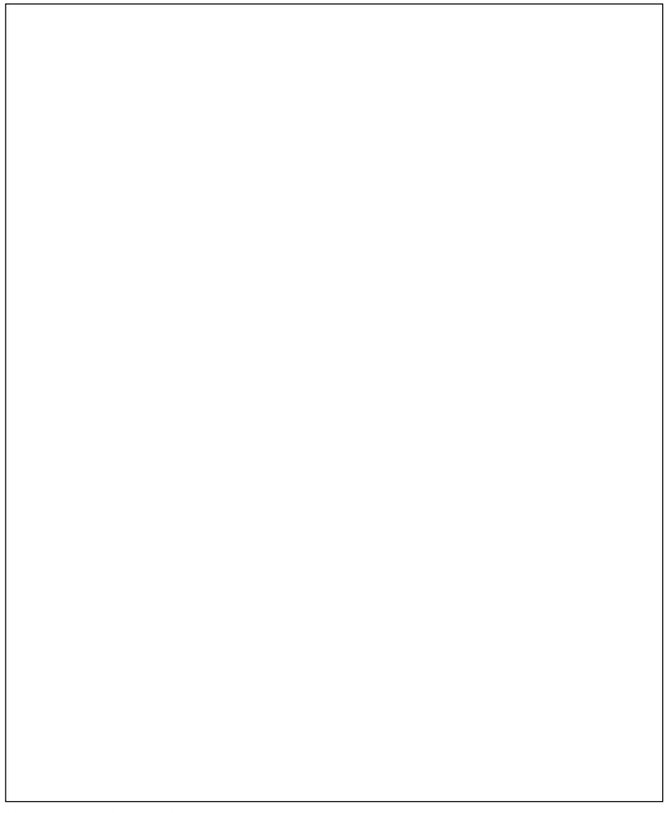
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Prey selection in Harris's hawk in captivity
Selección de presas en Aguililla Rojinegra en cautiverio

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PHOTO © MIKAEL MALES DREAMSTIME.COM



Harris hawk (Parabuteo unicinctus)

Introduction

The diet of raptors has been widely studied, allowing for the identi cation of their main prey targets.[1,2] However, the availability of prey in the diet of wild raptors is determined by environmental conditions, regardless of individual selection.[3,4] Studying birds in captivity can minimize the number of environmental stressors and allow for the identi cation of behavioural characteristics of each individual.[5,6]

Most birds in the wild feed on whole prey, and the size of the prey is delimited by the dimensions of the beak. In the case of raptors (Accipitriformes, Strigiformes, and Falconiformes), the hunting method is de ned by their talons. e beak in raptors is a specialized tool for tearing and ingesting prey in small pieces, allowing them to hunt much larger prey than other birds.[6] e ingestion of small prey fragments indicates long feeding periods for raptors.[6]

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ABSTRACT
Prey selection studies in captive birds of prey can help to discover and verify basic information that has been obtained through pellet analysis and diet studies in the wild, as well as improve the strategies and results of rehabilitation programs. In this study, the diet selection of ve captive Harris's hawks (*Parabuteo unicinctus*) was analyzed; three females and two males. Ten trials were conducted for each individual, offering simultaneously a rat, mouse, guinea pig, and chicken as potential food.
The results obtained indicate that the Harris's hawks used for this study have a marked preference for mice (50%), which is consistent with other diet studies conducted on Harris's hawks in the wild.

KEYWORDS: Birds of prey, diet selection, Harris's hawks

RESUMEN
Los estudios de selección de presas en aves rapaces en cautiverio pueden ayudar a conocer y comprobar la información básica que se ha obtenido a través de análisis de egagrópilas y estudios de dieta en vida silvestre, así como a mejorar las estrategias y resultados de rehabilitación en cautiverio. En este estudio analizamos la selección de dieta de cinco individuos de Aguilillas Rojinegras (*Parabuteo unicinctus*), tres hembras y dos machos, realizamos 10 muestreos por cada individuo, en cada uno ofrecimos ratón, rata, cobayo y pollo como alimentos potenciales.
Los resultados obtenidos nos indican que las Aguilillas Rojinegras que utilizamos para este estudio, tienen una marcada preferencia por ratones (50%), lo cual concuerda con otros estudios realizados en aguililla rojinegras en vida silvestre.

PALABRAS CLAVE: Aguililla Rojinegra, aves rapaces, selección de dieta

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Information on the speci c characteristics of food ingestion in raptors is limited, but it covers aspects such as the weight of ingested food, dietary preferences, and the temporality of feeding.[7] It has been observed that birds primarily feeding on mammals tend to spend less time feeding compared to those feeding on birds, due to di erences in their digestive systems.[6] Some studies mention di erences between species or morphologically similar groups; however, there is no research to corroborate this.[8, 9]

Researching the feeding preference behavior of raptors is crucial to increase the e ciency of rehabilitation processes, optimizing e ciency and resources.[4] When a raptor is admitted to a rehabilitation center, feeding can be initiated more e ciently by providing preferred prey, then gradually introducing the changes required for nutritional rehabilitation. is also improves the likelihood of independent feeding in newly admitted birds that, due to stress or other causes, may not eat other types of prey.

Birds in captivity

Many studies have analyzed the diet of raptors in the wild; however, there are numerous factors in eldwork that directly and indirectly in uence the possible results of such studies. rough the results obtained in these studies, approximations have been made as to the characteristics of nutritional programs for raptors in captivity.[5]

e diet of raptors in the wild is in uenced by both direct and indirect factors. Working with raptors in captivity can reduce environmental stressors by acting from an understanding of behavioral characteristics at a general, individual, or species level.[6]

Wildlife conservation and rehabilitation centers excel in generating information on management and rehabilitation strategies for wildlife; however, there are few studies on prey selection in raptors. ere is a study on eastern screech owls (Megascops asio)[10] and an article studying prey selection of red-shouldered hawks (Buteo lineatus) specimens.[4] In this study, four prey items were o ered: white mouse, brown mouse, white rat, and brown rat. ey concluded that the red-shouldered hawks selected mice (91%) over rats (0%); however, they did not determine a relationship between the prey and its color.

According to a 2014 study by Forbes,[11] rats, mice, and day-old chicks are the foods that provide the most nutrients to raptors. ese are easier prey to obtain for feeding, presenting a lower health risk compared to quail, guinea pigs, pheasants, and some wild prey. However, the relationship between nutritional contribution and prey selection has not been studied. It is relevant to know prey selection preferences and integrate them into nutritional rehabilitation programs by o ering prey with a higher probability of being selected by the bird. is strategy can accelerate feeding independently in birds that may not feed themselves due to the stress generated when entering a rehabilitation center.

Wildlife conservation and rehabilitation centers

Wildlife conservation and rehabilitation centers play a fundamental role in the e ective management of ecosystems, providing wild individuals injured or seized by government institutions, veterinary services, or biological services with treatment and support that allow their reintroduction into the environment.[4,12] Despite the existence of a large number of these centers, the number of individuals and the variety of species they receive are greater than the available information for each species and individual.

erefore, it is necessary to establish research projects focused on the characteristics of wildlife species from di erent parts of the world to facilitate rescue and rehabilitation processes.[13]

Harris's hawk

e Harris's hawk (*Parabuteo unicinctus*) is a bird of prey that exhibits sexual dimorphism (females: 789–1203 g, males: 536–829 g).[14] It has been extensively studied, covering aspects such as geographical distribution, habitat, social behavior, and cooperative hunting.[1] However, research on its diet is scarce. In Chile, research has been conducted on its feeding habits by analyzing pellets and prey remains at di erent times of the year, concluding that this group mainly feeds on small rodents.[1,15,16]

Methods

is study was conducted at the "Konkon" Wildlife Conservation Centre, located in Puebla, Mexico. is center is registered as an Environmental Management Unit for Wildlife Conservation (UMA) with the Secretariat of Environment and Natural Resources (SEMARNAT) and specializes in the conservation of raptors through the rehabilitation and reintroduction of individuals. All birds are received from the Federal Attorney for Environmental Protection (PROFEPA). e birds included in this study were received at Konkon with incapacitating injuries resulting from illegal tra cking, mishandling in captivity, and accidents in the wild, among others; therefore, these birds cannot be released.

We worked with ve specimens of Harris's Hawks, two males and three females (Fig. 1). e study animals had been housed for at least a year at Konkon's facilities, so they were accustomed to captivity, well-fed, and in good physical condition. We could ensure they did not present any nutritional or behavioral disorders, and were not fearful, malnourished, or starving, factors which might a ect food selection. All the birds are housed outdoors and fed once a day; the quantity of food assigned daily to each bird depends on its weight and activity. e prey o ered every day varies between rat, mouse, guinea pig, and 1-to-5-day-old chicken. All the birds are fed at the same hours every day, between 12 and 1 pm.

For the development of this research, we used a square wooden board measuring 1.20 × 1.20 m on which we placed the bird on a perch in the center and o ered four di erent prey items: mouse, rat, guinea pig, and day-old chick (Fig. 2). No attempt was made to control the color or pattern of the o ered prey. All the trials were made between 12 and 1 pm, which is the time when the birds are usually fed.

e location of each prey was changed in each evaluation—rotating clockwise, to ensure that the selection was not determined by the prey's location—maintaining the scale, from smaller to bigger: day-old-chick, mouse, guinea pig, rat. All the prey were weighted to ensure the size and weight according to Table 1; we did not o er prey over 150 g.

We recorded the selection based on the rst prey consumed by the bird, as in some cases, the bird would grab prey but not tear it apart, or ingest it and then move on to consume another prey.

TABLE 1. Weight Range Of The Different Offered Prey Animals

PREY	WEIGHT RANGE
1-Day-Old Chicken	40–42 g
Mouse	55–60 g
Guinea pig	80–100 g
Rat	120–150 g

We established a period of acclimatization to the board and the location where the study was conducted, starting one week before the investigation, to reduce any undesired behavioral responses resulting from entering a new place or the presence of unfamiliar materials such as the wooden board. Additionally, we assigned a single person for handling throughout the process, reducing factors or stimuli that could change behaviors or stress the birds, thus a ecting prey selection.

Sampling

Once the acclimatization process was completed, we began data collection. We conducted two samplings per week for ve weeks, completing 10 samplings per individual. In these samplings, we placed a di erent prey item in each corner of the board (Fig. 2).

Once the bird was placed on the bench perch, we conducted constant observation for a maximum period of 2 hours until it consumed prey. After this time, if the bird did not choose any prey, we recorded it as NE (not chosen). At the end of each sampling, we returned each bird to its enclosure, provided the missing food to complete the assigned food weight in its nutritional program, cleaned the board of any prey remnants, and proceeded to place another bird for the next sampling.

Results and Discussion

e results we obtained indicate that the Harris's hawks showed a marked preference for mice (50%), followed by rats (24%), guinea pigs (20%), and chickens (4%), with two percent of the trials showing no prey selection (Fig. 3).

Both sexes showed a higher preference for mice (50%). In the case of males, the next selected prey were rats (30%), with chicks and guinea pigs both at 10%. For females, after mice, the preferred prey selection was guinea pigs (26.6%) and rats (20%), and in only 3.3% of the trials, females did not select any prey (Fig. 4).

A standard deviation analysis (Table 2) was performed to evaluate the signi cance of the individual variable in relation to food selection by raptors. e results show a signi cant deviation in the individual variable concerning food selection when considering a con dence level of 99%.

Similarly, the goodness-of- t of the model was evaluated using the logarithmic probability and R^2 of the model, which yielded 0.80102, indicating a good t of the model explaining

FIGURE 1. Female Harris Hawk included in the project

FIGURE 2. Arrangement of perch and prey animals

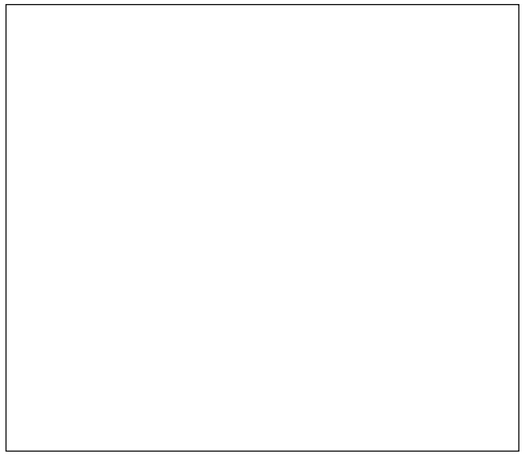


FIGURE 3. Prey selection of Harris's hawk (both sexes)

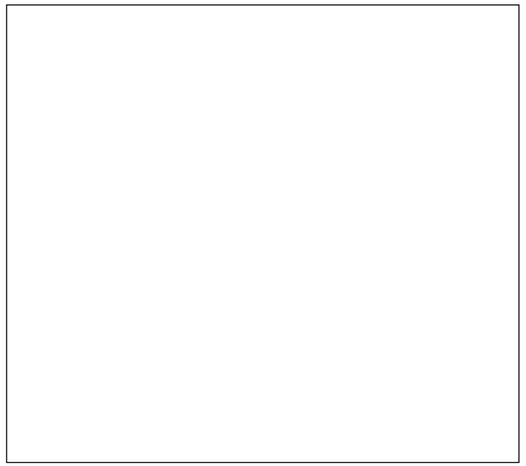


FIGURE 4. Prey selection separated by sex

TABLE 2. Analysis of Deviance

TERM OMITTED	DF	DEVIANCE	INCREASE FROM MODEL DEVIANCE	PROB LEVEL
ALL	12	123.60868	32.58751	0.00112
INDIVIDUAL	12	123.60868	32.58751	0.00112
NONE (MODEL)	12	91.02118		

The prob level is for testing the signi□cance of the term after considering all other terms.

TABLE 3. Log Likelihood & R^2

TERM(S) OMITTED	DF	LOG LIKELIHOOD	R^2 OF REMAINING TERM(S)	REDUCTION FROM MODEL R^2	REDUCTION FROM SATURATED R^2
ALL	3	−61.80434	0		
INDIVIDUAL	12	−61.80434	0	0.80102	1
NONE (MODEL)	12	−45.51059	0.80102	0	0.19898
NONE (SATURATED)	60	−41.46312	1	0	

80.1% (Table 3) of the variance in food selection by the studied raptors. Additionally, a logistic regression analysis was conducted to investigate food selection by the raptors, providing a more comprehensive understanding of their choices. For example, individual 4 (Fig. 5) showed a preference for rats with ve recorded observations, while individual 2 primarily selected mice.

e methodology employed for prey selection provided an adequate response in 98% of the trials, with only 2% of trials resulting in no prey selection. Most selections occurred within the rst 10 minutes of waiting. Despite rotating prey items on the board for each trial, the birds consistently chose mice, indicating that selection was not de ned by location. In some cases, the bird traversed the board, picked up a prey item, and left it, ultimately consuming the mice.

In comparison with the results of studies on the diet of Harris's hawks (*Parabuteo unicinctus*) in the wild,[16] the Harris's hawks in this study exhibited a similar diet selection to that concluded through the review of pellets and prey remains. ese captive hawks showed a preference for small mammals, despite most variables that could a ect prey selection in the wild being controlled in captivity, with the long-tailed pygmy rice rat (*Oligoryzomys longicaudatus*) being the most frequently chosen prey in the wild, with an average weight between 24 and 41 g.

Despite the di erence in size and weight between the red-shouldered hawk (*Buteo lineatus*) studied by Coon et al.[4] and the Harris's hawk (*Parabuteo unicinctus*), with the Harris's hawk being larger and heavier, diet selection was very similar. Both species showed a marked tendency to select mice over other prey.

Conclusions

We can conclude that captive Harris's hawks (*Parabuteo unicinctus*) have a marked preference for mice over other prey such as rats, chickens, or guinea pigs. is information, along with the nutritional contributions of prey published by Forbes,[11] allows us to establish the allocation of mice as a good strategy to initiate the rehabilitation work of individuals of the species, ensuring that this diet will maintain adequate nutrition and a high supply of vitamin A. Special attention should be paid to the age of the mice, as older mice provide more fat and less protein. e second prey most often chosen by the Harris's Hawks was rats, which are prey with good nutritional value.[11]

It is important to emphasize that a preference for a prey type does not mean that a captive bird should be fed exclusively with that type of food. e diet should be varied and enriched according to the nutritional needs of the species. Feeding mice exclusively can lead to nutritional de ciencies, as well as excessive beak growth. Larger prey should be provided so that the beak can be sharpened naturally during the process of removing meat from the bones.

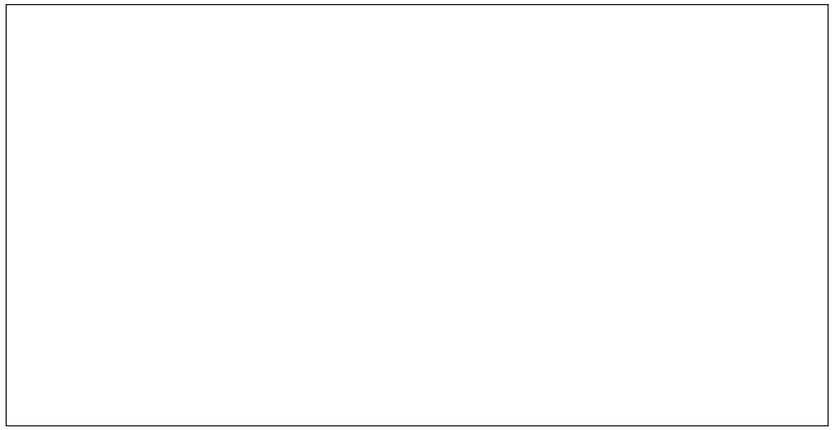


FIGURE 5. Logistic aggression analysis of individual's prey preference

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Rehabilitation outcomes of bird-building collision victims in the Northeastern United States

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ABSTRACT

Building collisions are a leading threat to wild birds; however, only those that are found dead or fatally wounded are included in current mortality estimates, with injured or stunned birds largely assumed to survive long-term. We examined the wildlife rehabilitation records of over 3,100 building collisions with 152 different avian species collected across multiple seasons to identify patterns of survival and release among patients. The most common reported injury was head trauma and concussion. Our logistic and Poisson models found that mass had a strong positive effect on release probability, and the season of summer had a strong negative effect on release probability. Mass and winter had a strong positive effect on treatment time, and age and the seasons of fall and winter had a strong negative effect on treatment time in these models. Ultimately, about 60% of patients died in care, either by succumbing to their injuries or by euthanasia. Patients that were released remained in care for longer than patients that died. Increased communication and collaboration between wildlife rehabilitators and conservation researchers is recommended to better understand building collisions and how to respond to this leading threat to wild birds. These findings, along with our estimate of delayed mortality, suggest that overall collision mortality estimates based on carcass collection far exceed one billion birds in the U.S. each year.

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Introduction

Even common avian species in North America are declining,[1] so identifying and addressing threats to bird populations is critical for the conservation of not only individual species, but the ecosystems they belong to.[2] Collisions with buildings are a leading anthropogenic cause of death for birds in the United States,[3] with major collision events garnering national attention[4] and, as of 2024, 25 U.S. cities or states have passed legislation that requires new buildings to be bird-friendly.[5] Affecting over 50 avian families and hundreds of species;[6] building collisions kill between 365 million and 1 billion birds a year in the United States alone[7] and pose a significant threat to birds in other countries as well.[8–10]

Deadly collisions occur at both multi-story buildings and individual homes and in both urban and rural areas.[7,11] In North America collisions during fall migration typically surpass the other seasons;[12–15] however, frequent collisions are documented in the spring, summer, and winter months as well.[13,16–19] A number of factors endanger birds attempting to navigate in areas with buildings, many of these stemming from the difference in perception between humans and birds. Glass is transparent and largely invisible, so whereas humans are taught the concept of glass early in development and identify visual cues to identify it (but will still occasionally collide with it), birds do not understand glass and do not know or learn these visual cues.[20] Presumably, birds perceive the image reflected off of glass or seen through glass as potential habitat or open space, especially open sky, or vegetation.[21] Greenspace near reflective windows can be problematic as a result, and studies of bird-building collisions regularly consider the presence, height, and distance of vegetation from glass as risk factors.[6,22–26] Architectural factors like glass area,[23,24,27,28] building size[29] and individual building facade characteristics[30] have been shown to influence collision numbers. For homes, bird feeders have also been associated with increased collisions.[31–33]

Artificial light at night (ALAN) further exacerbates the risk of avian collisions with buildings, particularly for migratory species.[34] At broad scales, ALAN attracts nocturnal migrants, causing them to concentrate in urban areas[35,36] where they are in proximity to a high density of potentially deadly glass buildings. At the finer scale, ALAN emitted from individual buildings is associated with increased collisions at those locations.[37–39] Weather conditions can also play a role in risk of collisions for nocturnal migrants by affecting the density of migrants that stopover in a given location, the behavior of these migrants, or by amplifying the effects of ALAN.[14,15]

Most studies examining building collisions are conducted on recovered carcasses of collision victims that die on impact.[6,7,15,40] However, though over 80% of collisions with buildings were once estimated to be immediately fatal to birds,[23] more recent studies have not supported this pattern and suggest that far fewer than 80% of collision victims die on site. For instance, in Korner et al.'s 2022 study,[39] only 7.2% of casualties were found dead. Therefore, estimates based on bodies found at the scene of collisions might provide a drastic underestimate of the true toll of building strikes on bird populations.

Some birds survive the immediate collision and move away from the scene.[41] Possibly, the survivors may recover from their sustained injuries, but they may be more vulnerable to predation or succumb to these injuries with time[42–45] or suffer reduced fitness and reproductive disadvantages.[46] Though post-collision prognosis for a disoriented or injured bird may be bleak, building collision survivors that are brought to wildlife rehabilitators are thought to have the best chance of recovery and subsequent survival. To fully understand the crisis of building collisions, these delayed deaths, or potentially disadvantaged survivors, matter, especially if these survivors are less of an exception to the rule than previously thought.

Knowing how many birds hit buildings, survive, and fly away without intervention is impossible, let alone what becomes of them later. The closest cases we have available to observe what happens to birds that do not die upon impact are those taken to wildlife rehabilitators. The International Wildlife Rehabilitation Council (IWRC) defines wildlife rehabilitation as "the treatment and temporary care of injured, diseased, and displaced indigenous animals, and the subsequent release of healthy animals to appropriate habitats in the wild."[47,48] Wildlife rehabilitators, licensed by their state, can either practice as private individuals or as part of an organization, usually non-profit.[49,50] Due to the nature of their work, wildlife rehabilitators often find themselves mediating human–wildlife conflict or mitigating the effects of anthropogenic threats to wildlife.[48,51–53] Wildlife rehabilitators, owing to their unique vantage point, may have knowledge that is evident among themselves, but may be less apparent or known to others working in other conservation fields, as databases of wildlife rehabilitation and rescue information, despite having great potential to inform the understanding of many conservation issues in the face of anthropogenic threats, remain underutilized by researchers.[49,54] While wildlife rehabilitation data has been used to track pathogens and poisonings,[53,55–57] or identify potential threats of concern toward wildlife and particularly vulnerable species,[11,58–60] these studies represent only a small fraction of how rehabilitation data can inform conservation research and policy.[51,53]

This study aims to provide an example of wildlife rehabilitation data as applied to a pressing conservation issue. Wildlife rehabilitators have long been educators of the public about wildlife and mediators in human–wildlife conflict, providing a unique front-line vantage point for many crises that face wildlife. This study is an effort to merge the knowledge and perspective of rehabilitation outcomes with collision research and advocacy.

The first goal is to examine patterns of survival, identifying which factors, such as age, mass, season of admission, and organizational funding, affect a patient's time in treatment and ultimately, the outcome of their case (whether they are released, presumably recovered, or deceased, by euthanasia or dying on their own, usually referred to as the patient's disposition). The factors that affect a patient's outcome may be different from the factors that affect a patient's initial survival of the collision. Examining these factors may provide insight into how these collisions are happening and how collisions may be affecting different bird species.

The second goal is to investigate avian–building collisions from a new perspective, and to highlight that carcass surveys almost certainly provide an underestimate of collision casualties. Birds, even if they survive the initial impact with the glass, may not truly survive the ordeal but rather die later from their injuries. This is delayed death may remain even when removed to a safe environment and medically treated, which theoretically improves

their chance at survival. Examining delayed deaths even under the most ideal of conditions can greatly inform our understanding of avian collisions with building structures and windows.

Methods

Acquiring Rehabilitation Patient Data

We submitted Freedom of Information Act/Law requests (or the state equivalent) to eight states in the northeast and mid-Atlantic (Connecticut (CT), Delaware (DE), Massachusetts (MA), Maryland (MD), New Jersey (NJ), New York (NY), Pennsylvania (PA), and Rhode Island (RI)) requesting records regarding avian building collision cases (cases) between 2016 and 2021. We requested information including species, dates received, disposition (outcome), disposition date, and location.

Most license-issuing states require the submission of annual records of rehabilitation activity, but how much and what kind of information collected in annual records varies by state (Table 1). Some states request very minimal information, often only requiring tally forms, such as in New Jersey, Connecticut, and Massachusetts.

TABLE 1. INFORMATION REQUIRED BY STATE LAW IN WILDLIFE REHABILITATOR ANNUAL REPORTS BY US STATES.

Information/State	NY	PA	RI	DE	DC	MA	NJ	CT
Species	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes (2)
Disposition (outcome)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Date of Admission	Yes	Yes	Yes	No	Yes	No	Yes	No
Date of Disposition	Yes	Yes	No	No	Yes	No	Yes	No
Cause of Admission	Yes (1)	Yes	Yes (3)	No	Yes	No	No	Yes (2)
Injury information	No	Yes	Yes (3)	No	Yes	No	No	No
Age of Patient	Yes	Yes	Yes	Yes	No	No	No	No

Information required by state law in wildlife rehabilitator annual reports in seven United States and one federal district of the United States. These requirements hold for all wildlife rehabilitation patients, not just birds. (1) New York has an extensive system of standardized codes to differentiate and organize causes of admission that rehabilitators are required to use in their reports. (2) Connecticut forms contain highly limited choices regarding species and causes of admission; songbirds are all lumped together into one row on the tally sheet, and causes of admission are limited to "Hit by Car," "Attacked by Dogs," or "Attacked by Cats." (3) Cause of Admission and Injury information are often found lumped together, guaranteeing the presence of information for neither; for instance, Cause of Admission may contain simply "broken wing," which only provides injury information, or "hit by car," which gives no information on sustained injuries.

Furthermore, the format of rehabilitation data varied widely in level of detail and completion where speci c forms were not mandatory for collecting information, such as in Pennsylvania. ere was further heterogeneity in the level of detail contained even with standardized forms, as elds can be left blank and circumstances of admission or injuries left vague, and rehabilitators varied in what kind of information records contain even with databases shared with other rehabilitators.[49]

Cases were only included if the patient was a bird (Class: Aves), admitted due to a collision with a building (including window, glass storefront, door) or strong suspicion thereof (e.g., "suspected window strike," "probably hit window"), that was admitted between 2016 and 2021. Cases were omitted if the cause of admission was perhaps not a building or window strike, such as "found on ground" or "maybe hit by car." Cases also were omitted if the disposition was listed as "transferred" or "pending," as their nal disposition was not known. ere was only one case with the disposition "kept for education." Additionally, injury data from Tri-State Bird Rescue and Research was omitted due to the complex nature of reporting and coding incompatibility.

Due to variation in language used to describe injuries, injuries were categorized into more general categories (for instance, humerus and ulnar fractures were all classed as "wing fracture," dull mentation and depressed a ect was classed as "lethargy"), except for injuries whose language was extremely consistent ("Concussion," "Head trauma," "Unconscious," "Unable to y," "Skull Fracture"). Raw data and categorization rules are included in the Supplementary Materials accessible through the links in the Data and Code Availability Statement.

Cases were classi ed as major city (population density 5,000 people per square mile or more), urban (between 4,999 and 1,000 people per square mile), suburban (between 999 and 100 people per square mile), and rural (less than 99 people per square mile), based on county of location. Population density information for counties was provided by USA.com's[61] population density rankings and the 2010 US Census. To examine the e ect of organizational funding we obtained the average annual income listed for each organization from ProPublica's version of IRS form-990 lings, averaged across the years for which that organization contributed to the dataset.

Species mass data and family information were taken from Cornell Lab of Ornithology All About Birds website, averaged high and low values. De nitions of seasons were based on migration dates.[7] March, April, and May, when migrant species are traveling northward to their summer ranges, was de ned as spring; June and July, when most birds are breeding and rearing young, was de ned as summer; August, September, October, and November, when migrant species are traveling south to their winter ranges, was de ned as fall; and December, January, and February, when migrant birds are residing in their southern ranges and resident birds are primarily focused on foraging, was de ned as winter.

Missing Data Imputation

ere were several variables for which we have incomplete data: sex (90%), age (43%), organization type (14%), funding (17%), and treatment time (17%). Sex was missing far too much of the data and was excluded from analysis. For everything else, we handled missing data using the multiple imputation approach recommended by Bürkner,[62] a method that has been shown to produce more accurate estimates than both single imputation (e.g., replacing NA with averages)[63] and complete case analysis (e.g., dropping incomplete rows from the data).[64,65] First, we used multiple imputation with random forest machine learning to generate 10 di erent imputed versions of our data using the mice package in R.[66] All predictors and outcome variables included in the statistical modeling (treatment time, release, death, mass, funding, season, and age; see below) were also included during multiple imputation. en, we t our models to each imputed dataset separately and pooled the results across all of the models by simply combining the posterior distributions for each parameter.[62]

Statistical Modeling

All models were Bayesian and were run in STAN using the brms package in R,[62] t with 20,000 iterations across four MCMC chains. Categorical variables were converted to factors and continuous variables were scaled and centered for e cient model convergence. All analysis code, prior speci cations, and model diagnostics can be found in the Supplementary Materials accessible through the Data and Code Availability Statement.

Major drivers of rehabilitation were identi ed using two methods: (1) logistic and Poisson models of release and treatment time, and (2) using a right-censored survival model of treatment time where the censored cases are those where birds died and could not be released. e logistic and Poisson families were used because release and treatment time are binary and count variables, respectively. Logistic models are simply binomial models with a logit link-function. A right-censored survival model is a survival model where the survival times are missing for some individuals, due to death or other factors. We only included mass, funding, season, and age as xed e ects in the modeling. Causal analysis with a directed acyclic graph suggested that family, species, state, and type of organization were unnecessary for estimating e ects (see Supplementary Materials accessible through the Data and Code Availability Statement). e nal speci cation of the rst two models was as follows, with all predictors as xed e ects:

release ~ mass + age + funding + season

treatment e mass + age + funding + season

For the survival analysis, we used the parametric approach described by Kurz[67] and inspired by McElreath[68] using the brms package in R.[62] We modeled survival as a Weibull distribution, as a simple Weibull model outcompeted the other two common parametric forms: exponential and Gamma (see Supplementary Materials accessible through the Data and Code Availability Statement). Our survival analysis was right-censored, meaning that treatment time was the outcome variable, and the censored cases were those where birds died and could not be released. e speci cation for the survival model was as follows:

treatment | censored (death) ~ mass + age + funding + season

It is important to note that our data violated the assumption of non-informative censoring, or the assumption that the censored variable (death) is independent of the event variable (release).[69] ere are imputation methods that replace the event times of censored cases to account for bias introduced by non-informative censoring, but they are designed for cases where full data are available, or where missing data imputation is not also in use.[70] In this study we did not use specialized imputation for informative censoring, so the overall release curves will be systematically biased towards shorter times. We did not have a reason to expect this to bias predictor estimates, but the results of the logistic and Poisson models should be given greater attention than the survival model.

Descriptive statistics, Pearson Chi-Square Test, Fisher's Exact Test, Wilcoxon and Kruskal-Wallis rank sum tests, and Kolmogorov-Smirnov tests were calculated in R (version 4.2.2) and its built-in functionality.

Results

Sources of Case Data

We received responses from six states (NJ, CT, MA, NY, PA, and RI), two never responded (MD and DE), though, the Tri-State Bird Rescue and Research rehabilitation organization, based in DE, provided their building-collision cases independently from their digital database (Wildlife Rehabilitation Medical Database, also known as WRMD). ree of the states that responded could not provide any records matching our requests (NJ, CT, and MA). One state (NY) was only able to provide records from 2020–2021, from selected counties (we selected Kings, Queens, New York, Nassau, Su olk, Bronx, Westchester, Erie, Monroe, and Albany counties based on proximity to major cities and human population). Two states (PA and RI) produced all relevant records between 2016 and 2021, and one of these (RI) had fully digitized the data and provided a searchable spreadsheet; the other (PA) had simply sent all rehabilitation records from all species for all admission reasons for the time frame requested as non-indexed portable document format (.pdf) les (as did NY), and relevant cases were manually identi ed and transcribed into the dataset.

e dataset included a total of 3,159 included rehabilitation cases, with 1,644 cases from PA, 564 from DE, 418 from NY, 408 from RI, and 35 cases from other states brought to a rehabilitation center in the states examined (27 from NJ, 2 from CT, and 6 from Washington, D.C.). Of 3,159 cases, 74 could not be traced to the county level, 140 cases were from rural counties, 1,461 cases were from suburban counties, 1,387 were from urban counties, and 97 were from counties de ned by major cities, with

62 cases from Philadelphia County PA, 13 cases from New York County NY, 6 cases each from Washington D.C. and Queens County NY, 5 cases from Kings County NY, 3 cases from Bronx County NY, and 2 cases from Baltimore County MD. New York County was vastly underrepresented in our dataset because data from the largest wild bird rehabilitator in New York City could not be obtained for analysis.

Our dataset contained 152 di erent avian species and 42 different avian families. Mourning doves (*Zenaida macroura*) (n = 258), American robins (*Turdus migratorius*) (n = 188), northern cardinals (*Cardinalis cardinalis*) (n = 187), Cooper's hawks (*Accipiter cooperii*) (n = 174), and gray catbirds (*Dumetella carolinensis*) (n = 171) were the most common species patients. Picidae, Columbidae, Turdidae, Accipitridae, and Cardinalidae were the most common families in the patient dataset. Figure 1 plots the average mass of species in each family and relative abundance of cases in each family, and Table 2 reports all families with more than 20 cases and their release statistics.

Case Outcomes and Treatment Times

Of these 3,159 cases, 126 were dead on arrival. From the remaining 3,033 cases, 39.5% resulted in release (n = 1197), 32.1% resulted in unassisted death during treatment (n = 974), 28.4% resulted in euthanasia (n = 861), and 1 case resulted in the patient being kept as an educational animal (<0.1%).

Of the 3,159 cases, 127 could not be used for further analysis because birds were dead on arrival or 3,032 cases that omit dead-on-arrival cases and the kept-for-education, resulting in 3,032 cases available for further study. Patients that were released averaged 12.89 days in treatment (median: 7 days), with 27.15% of releasable patients released within the rst 2 days of treatment, and 51.21% of releasable patients released within the rst 10 days of treatment. Patients that died or were euthanized averaged only 2.64 days in treatment (median: 1 day), with 33.79% dying on the same day as intake, and 57.44% dying within the rst 2 days of treatment. Di erence in treatment time between released and deceased patients was signi cant ($p < 2.2e\text{-}16$, Wilcoxon and Kruskal-Wallis rank sum test; W = 344901 and Kruskal-Wallis chi-squared = 546.11, df = 1; $p < 2.2e\text{-}16$, Kolmogorov-Smirnov test, D = 0.4684).

Admission of building-collision patients varied by season; 579 cases were admitted in the spring (March through May, 21.6%), 626 cases admitted in the summer (June through July, 23.3%), 1,063 cases were admitted in the fall (August through November, 39.6%), and 417 cases were admitted in the winter (December through February, 23.3%). In years with more than 100 cases (2016–2021, but not 2014 or 2015), fall always had the most cases and winter always had the least, but summer cases outnumbered spring in 2017, 2019, and 2020.

e proportion of patients that were released after intake also varied by season, with summer having the lowest release proportion (0.29), and winter having the highest release proportion (0.46), leaving spring and fall with comparable proportions (0.39 and 0.40, respectively). Unlike admissions, in years with more than 100 cases (2016–2021), no season consistently had the highest or lowest release rate, and no season's release rate was always higher or lower than another. We found a signi cant e ect of season on nal disposition ($p = 1.08e\text{-}8 < 0.001$ for Pearson Chi-Square Test, and Fisher's Exact Test, for Pearson's Chi Square, $X^2 = 39.973$, df = 3; $p = 7.64e\text{-}9$ for Fisher's Exact Test.).

A total of 1,267 cases were missing age information (42%), 1366 cases were adult birds (45.1%), and 399 cases were juvenile birds (13.2%). e proportion of adults that were released was larger than that of juveniles (605 adult releases, 44.3%; 154 juvenile releases, 38.6%). e e ect of age on nal disposition was signi cant ($p = 0.0496 < 0.05$ for Pearson Chi-Square Test, $X^2 = 3.855$, df = 1; $p = 0.0444$ for Fisher's Exact Test).

Injury Statistics

e dataset we analyzed contained 1,217 cases with information regarding injuries patients were suffering from. e most common injuries reported were head trauma (534 cases, 34.8% released), concussion (257 cases, 66.9% released), balance issues (172 cases, 24.1% released), wing fractures (110 cases, 18.2% released), and inability to y (106 cases, 49.1% released). Injuries with the highest release rates were concussions (66.9%, 172 releases of 257 cases), shock or stunned (61.4%, 35 released of 57 cases), hypothermia (50.0%, 1 released out of 2 cases), inability to y (49.1%, 52 released out of 106 cases), and bruising or swelling (43.7%, 38 released out of 87 cases). No other injury type had more than a 35% release rate. No cases reporting paralysis (15 cases), unconscious patient (4 cases), or skull fractures (3 cases), resulted in release. Injuries with the lowest release rates were lethargic or weak patients (7.4%, 2 released out of 27 cases); leg fractures (11.1%, 3 released out of 27 cases); back, spine, or neck injuries (13.2%, 9 released out of 69 cases); nerve damage (13.6%, 3 released out of 22 cases); and internal bleeding (15.4%, 2 released out of 13 cases).

e vast majority of patients appeared otherwise healthy apart from injuries sustained from collision. Of the 1,217 cases with reported injury data, only 33 patients were emaciated or dehydrated (2.7%), and 29 had infections, parasites, or were otherwise sickened (2.4%). e dataset also included 6 cases with animal attacks in connection with the collision (usually after collision had occurred but before the patient reached rehabilitation); only one such patient was released of the 6.

Modeling Release and Treatment Time Probabilities

e results for both the logistic model of release and Poisson model of treatment time are shown in Table 3 and Figure 2. e logistic model showed only mass and the season of summer to have a strong e ect on release probability, with mass having a positive e ect on release probability (95% CI: 0.05, 0.24), and summer having a negative e ect on release probability (95% CI: −0.70, −0.23). is suggests that species with greater mass had better odds of release, and patients admitted in the summer had poorer odds of release than those admitted in the spring. No other season (fall or winter, relative to spring), nor organizational funding, had a signi cant e ect on release probability. e e ect of age trends is strongly positive, although the wide credible interval still overlaps with zero (see Table 3). e Poisson model

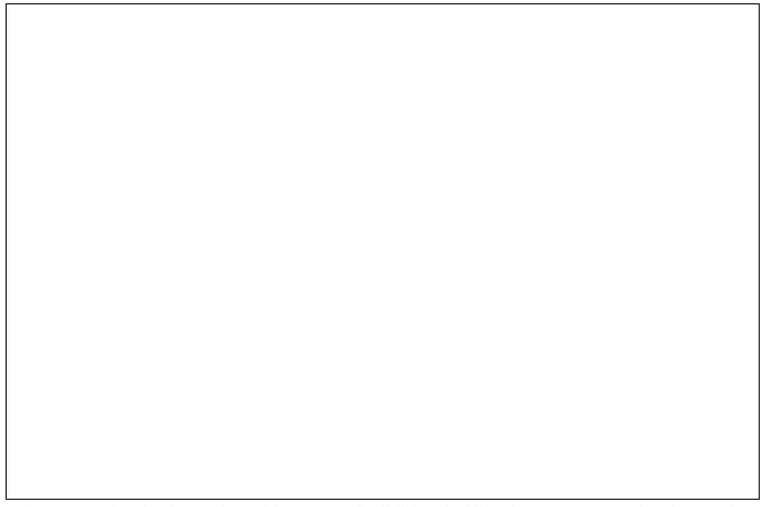


FIGURE 1. Avian families, plotted by mass, of wildlife rehabilitation cases stemming from avian–building collisions with known outcomes. Families were plotted based on the average mass of the species of that family represented in the building collision rehabilitation cases, and their number of cases in which they appeared in the rehabilitation records relating to building collisions.
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TABLE 2. RELEASE AND TOTAL WILDLIFE REHABILITATION CASES STEMMING FROM AVIAN–BUILDING COLLISIONS FOR FAMILIES CONTAINING MORE THAN 21 PATIENTS, WITH RELEASE DATES.

FAMILY	RELEASED	TOTAL	RELEASE RATE
Strigidae	19	30	0.6333
Falconidae	13	21	0.619
Parulidae	92	181	0.5083
Vireonidae	14	28	0.5
Accipitridae	131	270	0.4852
Bombycillidae	19	41	0.4634
Passerellidae	80	174	0.4598
Turdidae	129	286	0.451
Columbidae	132	295	0.4474
Fringillidae	59	137	0.4307
Sittidae	14	33	0.4242
Picidae	157	395	0.3975
Paridae	17	43	0.3953
Cardinalidae	81	214	0.3785
Mimidae	63	192	0.3281
Regulidae	12	38	0.3158
Trochilidae	18	58	0.3103
Passeridae*	38	139	0.2734
Troglodytidae	9	33	0.2727
Cuculidae	6	24	0.25
Corvidae	22	90	0.2444
Icteridae	25	103	0.2427
Scolopacidae	10	42	0.2381
Tyrannidae	5	24	0.2083
Sturnidae*	5	36	0.1389

Families are in the order of percentage released. Number of cases per family ranged from 395 to 1. Note that the smaller the number of cases, the more subject to chance release rate is, and considered with more caution.

* Families containing only invasive species.

TABLE 3. RESULTS OF PROBABILISTIC MODELS ON RELEASE AND TREATMENT TIME OF AVIAN PATIENTS IN WILDLIFE REHABILITATION CARE AFTER BUILDING COLLISIONS.

RELEASE MODEL (LOGISTIC)					TREATMENT TIME MODEL (POISSON)				
Variables	Est.	2.5%	97.5%	Sig Eff.	Variables	Est.	2.5%	97.5%	Sig. Eff.
Mass	0.14	0.05	0.24	*	Mass	0.09	0.08	0.10	*
Age	0.13	−0.07	0.34		Age	−0.20	−0.31	−0.09	*
Funding	−0.04	−0.12	0.04		Funding	−0.01	−0.04	0.03	
S: Summer	−0.47	−0.70	−0.23	*	S: Summer	−0.30	−0.42	−0.19	*
S: Fall	0.02	−0.18	0.22		S: Fall	−0.12	−0.18	−0.05	*
S: Winter	0.24	−0.01	0.48		S: Winter	0.30	0.24	0.38	*

2.5% and 97.5% mark the lower and upper bounds of the 95% credible intervals. Season conditions, with spring as the reference condition, are marked with a preceding "S:" The asterisks denote signi□cant effects: 95% credible intervals that do not overlap zero.



FIGURE 2. Visualized results of release and treatment time models for rehabilitated avian building collision victims. Results of the logistic model of release and the Poisson model of treatment for avian patients in wildlife rehabilitation care after building collisions. Panel A shows the effects of mass, age, and funding, whereas panel B shows the marginal effects of season. In panel A, the lines correspond to 95% credible intervals. Intervals that do not overlap zero denote signi□cant effects. https://doi.org/10.1371/journal.pone.0306362.g002

showed strong positive e ects of mass (95% CI: 0.08, 0.10) and the season of winter (95% CI: 0.24, 0.38) on longer treatment time, and strong negative e ects of age (95% CI: −0.31, −0.09) and the seasons summer (95% CI: −0.42, −0.19) and fall (95% CI: −0.18, −0.05) on treatment time. ere was still no e ect of funding on treatment time (95% CI: −0.04, 0.03).

Survival Modeling and Analyses

e Weibull survival model found that mass had a strong positive e ect on treatment time (95% CI: 0.06, 0.21), and adult age had a strong negative e ect on treatment time (i.e., decreases treatment time, 95% CI: −0.44, −0.05, Table 4). ese results agree with the Poisson model of treatment time, that treatment time increases with mass and decreases with age. However, there was no e ect of season or organizational funding on treatment time (95% Cis overlapped 0), although fall trends negative relative to spring. Posterior predictions from the Weibull model can be found in the Supplementary Materials accessible through the Data and Code Availability Statement.

TABLE 4. RESULTS FROM SURVIVAL MODEL ANALYSIS OF TREATMENT TIME FOR REHABILITATED AVIAN BUILDING COLLISION VICTIMS.

	Estimate	Est. Error	2.5% CI	97.5% CI	Sig. Eff.
Intercept	3.21	0.11	2.99	3.42	
Mass	0.13	0.04	0.06	0.21	*
Age (Adult)	−0.24	0.10	−0.44	−0.05	*
Funding	−0.0	0.03	−0.06	0.06	
Season: Summer	0.05	0.11	−0.16	0.27	
Season: Fall	−0.13	0.08	−0.28	0.03	−0.12
Season: Winter	0.13	0.10	−0.06	0.32	0.30

Results of the Weibull survival model for avian patients in wildlife rehabilitation care after building collisions. 2.5% and 97.5% mark the lower and upper bounds of the 95% credible intervals. The asterisks denote signi□cant effects: 95% credible intervals that do not overlap zero.

Discussion

Building Collision Survival Rates

Our ndings demonstrate that the number of deaths attributed to collisions is signi cantly underestimated and that well over 1 billion birds are dying each year in the United States. We found that even with active treatment and care from rehabilitators, 60% of building-collision patients die of their injuries or are euthanized. Our ndings are especially concerning when considering that death rates in the wild may be even higher than 60% if collision victims are not found and treated by rehabilitators. Loss et al. included only de nitive mortalities to estimate the number of dead birds killed in the U.S. each year, but injured birds with unknown outcomes equaled 14.9 percent of the number of dead birds found during the collision monitoring the study used.[7] If 60% of those birds die from their injuries, the upper boundary of the total estimate is likely at least 10% too low, and could be increased to 1.092 billion birds every year; however, recent monitoring e orts using 24-hour collision patrols and video monitoring suggest that estimates based on carcass surveys far underestimate the number of birds that collide with buildings,[39,41] and hence the number of birds that die but leave no evidence behind. A case study on a building's light pollution in Germany found most birds attracted to and colliding with the building were found alive but disoriented enough to be caught by hand before being released; only 7% were found already dead on site.[39] Another recent study using video monitoring found that nearly 80% of birds moved o -site directly following a collision and only 7% of birds died immediately following impact.[41] ese ndings, along with our estimate of delayed mortality, suggest that overall collision mortality estimates based on carcass collection far exceed one billion birds in the U.S. each year. Delayed mortality contributes to underestimation of collision deaths and should be considered alongside carcass removal and predation when adjusting for underestimation.[64] While collisions that do not stun birds may be less impactful to well-being and kill fewer birds (i.e., ricocheting birds caught on lm in Samuels et al.[41]), birds that are stunned enough to be captured by observers are unlikely to survive. Many released patients seem to require multiple days to recover to releasable condition, a luxury that is not o ered to most birds outside of rehabilitation.

Factors A ecting Survival

When collision victims are brought to rehabilitators, cases resulting in release had longer treatment times than cases resulting in death. While this di erence may partially stem from the practice of euthanasia, standard wildlife rehabilitation guidelines and practices call for euthanasia once a patient is determined to be unreleasable, rather than prolong an unviable or captive life.[47,71] However, case information reveals that many collision victims take at least a day in treatment before death, highlighting the sometimes-gradual lethality of collision incidents even when victims do not die at the scene. On the other hand, patients that survived and were released often presented a greater time investment for wildlife rehabilitators, particularly with juvenile patients who may have needed extra care during this stage of their development. Treatment time may also vary based on the severity or type of injuries incurred (e.g., fractures) or the protocols and practices of individual rehabilitators or facilities (e.g., not releasing in poor weather conditions).

e seasonal abundance of building collision cases follows the previously described pattern of being highest in fall,[7,12] but departs from this pattern by having more cases overall in the summer than spring (although see Hager et al., 2013).[27] In the northeast there are signi cant changes between seasons that a ect bird presence and behavior. Winter, the coldest months, generally occur from mid-November through mid-March. March through May coincides with spring migration, when birds are moving northward to breeding grounds. e breeding season, when most birds nest and breed, is June through mid-August. From mid-August through mid-November is fall migration, when most birds are moving southbound for the winter.[7] However, this di erence may be due to changes in human behavior between the seasons that would allow for more observation of collisions or injured birds in the summer, when more people in the northeast United States tend to be outside, than during spring migration, and thus more birds brought to rehabilitators. However, upon admission, summer had the highest rate of patients dying during care and had a negative impact on release probability (although fall had the most deaths overall). is decreased release rate may be due to the increased proportion of juvenile patients,[72] whose release rates are poorer than adult patients. is e ect could also be due to di erences in avian behavior during the summer, as for most species breeding occurs during that time[72] and breeding territorial behavior may contribute to collisions as they react to perceived territorial threats apparent in window re ections. Potentially, a di erence in species composition with an increased prevalence of species with poorer release rates may explain this variation at least partially, though no particular family or species with migratory behavior was found to explain this variation; despite the abundance of gray catbirds (Dumetella carolinensis) in the dataset, and this species' vulnerability to building-collision deaths,[7] their removal did not change this e ect. Additionally, though not statistically signi cant, winter had the highest release rate of the seasons. A decreased prevalence of species with low release rates, decreased patient tra c ("baby season" in the spring and summer tend to be the busiest times for wildlife rehabilitation centers),[73] or changes in species behavior during winter foraging[18,74] may account for this di erence.

Species mass was positively associated with release probability, suggesting that larger species, once admitted, are more likely to survive building collisions and recover to a releasable state. is result is contrary to the ndings of a study of carcasses surveyed by Veltri and Klem,[75] nding that larger birds sustained more severe injuries. However, these ndings are consistent with other rehabilitation studies.[76] Mass was also positively associated with treatment time. e longer treatment time may re ect increased survival, as cases ending in release had longer treatment times, presumably because they did not die or were euthanized midway through treatment. e increased probability of survival with larger mass may stem from di ering collision physics linked to ight speed or other behavioral di erences. Biological di erences may also account for this e ect; owls (Strigidae) in particular can survive certain ocular injuries that would necessitate euthanasia in other species (Anne Lewis, personal communication). Analysis of injury type prevalence and relationship to size or taxonomic family would provide further insight into the mechanism of this e ect, perhaps similar to the work conducted on a Toronto-based data set by Hudecki and Finegan.[43]

Although the logistic model of release found that age was not a strong predictor of release, the e ect of age trends strongly positive in the logistic model and the Fisher's Exact Test and Pearson Chi-Square Test found such an e ect to be signi cant, suggesting that adults had more releases than juveniles. Nevertheless, adult collision victims outnumber juvenile cases for every season, including summer and fall when juvenile cases were most numerous. is was unexpected, given juvenile casualties often outnumber adult casualties in studies.[7,72,77,78, though see 79]

e prevalence of adults in rehabilitation cases may be due to a di erence in ability to survive the initial collision, and juvenile birds may be more likely to die upon impact.[77] Alternatively, juvenile plumage may render younger victims harder for concerned humans to detect and bring to a rehabilitator. Nevertheless, birds do not escape the risk of collision by remaining in good health, as only slightly more than 5% of patients were su ering from infection, sickness, parasites, dehydration, or emaciation. Building collisions are therefore killing o members of the population in a non-selective manner, worsening the populations it a ects by removing otherwise t individuals.[80]

Neither probability of release, nor treatment time, were found to be a ected by organizational funding of rehabilitation centers or facilities. While well-funded organizations can treat more collision victims, increasing funding does not seem to a ect release rate. While release and treatment time were not a ected by funding, funding may still be important for bird well-being. Rehabilitation centers are dependent on funding for operations, purchasing new supplies, and supporting hard working sta . e 40% of birds that do survive rehabilitation undoubtedly bene t from care, and funding to support the well-being of these birds remains necessary.

Conclusions

Communication between the elds of scienti c research and wildlife rehabilitation is critical for increased understanding of the building collision crisis, and subsequently how to mitigate its impact on bird populations. However, signi cant barriers complicate e orts to incorporate the highly important knowledge and perspectives of wildlife rehabilitators. Both rehabilitators themselves and their licensing state can and should take measures to address these issues. ough most states require case logs and/or tallies from rehabilitators, the relevant agencies do not appear to have developed ways to examine, organize, or keep track of the data these records contain, a missed opportunity to monitor possible wildlife issues in their states. e quality and thoroughness of the records themselves are also quite heterogeneous. Descriptions of injuries varied from thorough to extremely vague (simply "bruising" or "injured"), if they were included at all, with great variability in the phrasing of injuries and reason for intake (i.e., "hit window," " ew into window," "building collision," "hit glass door"). Ideally, a standardized interstate database of all building collision victims would be ideal, but in lieu of that, licensing states can modify required forms and how they are processed, and individual rehabilitators or rehabilitation organizations can collaborate with researchers and each other to establish a database or modify existing databases (such as WRMD and WILD-ONe) to facilitate data-sharing and analysis.[60,81–83] However, wildlife rehabilitation sta and volunteers are often overworked and underfunded, making accurate and detailed record keeping di cult. Increased funding and guidance from state agencies or assistance from conservation researchers could help rehabilitators improve and maintain records that more e ectively aid in conservation research and care for patients. To the detriment of birds, wildlife rehabilitators are not typically included in ornithological conferences, and their studies are often restricted to rehabilitation-speci c journals not often reviewed by academic conservationists, resulting in limited dissemination of information across disciplines. More cooperation between scientists and rehabilitators may increase the dialogue between the two perspectives, to the bene t of both.[84]

While examining rehabilitation patients is perhaps the closest glimpse into what happens to birds after collisions, this model does not o er a perfect view. Bias likely a ects which birds are brought to rehabilitators.[49,60] Easily seen birds are preferentially brought in as smaller or more camou aged species may go unnoticed. Release rate does not represent the chances of surviving a building strike, but rather of recovery if one has already survived and was taken for treatment. Nevertheless, review of rehabilitation records provides a more complete view of factors a ecting collisions and subsequent survival. Including more states and regions in this kind of dataset and a more detailed and nuanced treatment of urbanization within counties would further bolster understanding of rehabilitation record patterns.[83] Additionally, more robust analyses of injury data, species ight styles and behavior, and taxonomic relationships of patients could be highly informative in gaining insight into the e ects of collisions and factors a ecting survival.[81–83,85] Furthermore, examining rehabilitation records over the course of time would provide further insight into the trajectory of the collision crisis and how collisions may be a ecting di erent populations, and human communities, locally, nationally, and potentially globally.[11,58,60,85]

e injuries from collisions, once sustained, have only around 40% combined probability of recovery, even with the highest standards of care. Additionally, information is missing about long-term e ects of collision post-rehabilitation, such as behavioral changes or other factors that could a ect survival and reproduction in the wild. For these reasons, though 60% chance of death is no doubt better than certain death, prevention of building collisions by making glass visible to birds and reducing arti cial light at night should remain the top priority, reducing the impact of collisions, and wildlife rehabilitators should continue to educate the public and advocate for implementation of safety measures. Buildings can be made safer for birds by using bird-friendly glass or by retro tting existing glass with applied bird-friendly lms. ese products reduce collisions using markings that are spaced no more than 2 by 4 inches apart, ideally 2 by 2 inches, and are visible to birds.[86]

A realistic understanding of outcomes after collisions is important to exploring and properly investing in second lines of defense. Wildlife rehabilitators, conservation researchers, policy advocates, and citizens are all crucial in the struggle to understand and respond to the calamities wild birds, and wildlife overall, face. e most e ective strategy to confront these realities are through cooperation between the four groups, by sharing knowledge, tools, and perspectives to formulate an informed, balanced response to mitigate a leading anthropogenic cause of death in avian wildlife in the United States.

Supporting Information

S1 Dataset. Wildlife rehabilitation cases of avian patients admitted due to building collisions. e complete dataset of all rehabilitation cases included in the analysis are listed in this dataset. "Source Organization" refers to the agency or organization that provided the data, and "Filename/Section" refers to the name of the le and the section of that le each case was found. "Patient Number" was listed with most rehabilitation cases obtained, and was preserved for ease of double-checking transcription. e species codes included are consistent with those used by the Institute of Bird Populations. "RhbFund" reports the average annual income listed for each organization from ProPublica's version of IRS form-990 lings, averaged across the years for which that organization contributed to the dataset. (XLSX)

S1 Table. Wildlife rehabilitation building collision injury classi cations and descriptions. Table listing the injury classi cations that were used, and notes on injury descriptions and classi cation rules aiding in binning cases by injury similarity despite highly varied language or word choice. (PNG)

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SELECTED ABSTRACTS

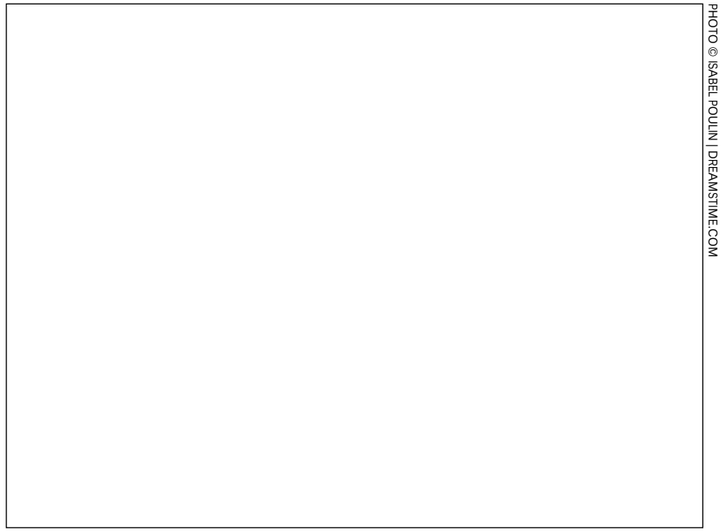


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Raccoon *(Procyon lotor)*

Mycoplasma-associated polyarthritis in raccoons (*Procyon lotor*) from the southeastern United States

Berdecia-Martinez V, Green K, Yabsley MJ, Garrett KB, O'Reilly A et al. One health (Amsterdam, Netherlands). 2025;21(101243):101243. https://doi.org/10.1016/j.onehlt.2025.101243

Arthritis in humans and animals can be caused by various infectious agents some of which are zoonotic so studying them in a One Health context is critical. is report describes four cases of *Mycoplasma*-associated arthritis in raccoons (*Procyon lotor*) from the southeastern United States. e cases were submitted between March 2023 and March 2024 from two states (Louisiana and Georgia). Raccoons had lesions of variable severity but included joints with purulent material, pockets of purulent material overlying joints and extending into adjacent subcutis, and abscesses through the subcutis.

ree of the four raccoons had co-morbidities that may have contributed to their risk of development of *Mycoplasma*-associated disease including canine distemper infection, amyloidosis, dental disease, and schistosomiasis, although amyloidosis may have developed secondarily to mycoplasmal disease. Two unique *Mycoplasma* sequences were detected. Phylogenetically, the two *Mycoplasma* sequences were most similar to *M. phocimorsus* which has been associated with human disease after exposure to seals and brown bears and abscesses in domestic cats. However, it is unknown if the two raccoon *Mycoplasma* represent strains of *M. phocimorsus*, are *M. phocimorsus* and a novel species, or are two novel species. *Mycoplasma*-associated polyarthritis was previously reported in juvenile raccoons in Canada undergoing rehabilitation, but the *Mycoplasma* sp. was not determined. Collectively, these data suggest *Mycoplasma*-associated arthritis occurs across a broad range and in both juvenile and adult raccoons. Further work is needed to determine if underlying conditions or coinfections are associated with the development of *Mycoplasma*-associated disease in raccoons and if the raccoon-infecting *Mycoplasma* are zoonotic.

Environmental DNA as a tool for detecting illegal wildlife trade

LeClair GD, Chat eld MWH, Kinnison MT. Forensic Sci Int. 2025;370(112446):112446. https://doi.org/10.1016/j.forsciint.2025.112446

e illegal wildlife trade presents signi cant challenges to wildlife conservation due to its large impact on population and species persistence. Forensic technology plays an important role in detecting and prosecuting such trade but has lagged human forensics where trace genetic evidence is important in conviction or exoneration. At present, most genetic applications in wildlife forensics focus on identi cation of taxa or populations via tissue samples or visible trace material (e.g., blood, hair or feathers). However, enforcement o cials may encounter common household objects that are suspected to be used in capture, transport, or holding of wildlife, but without visible evidence of wildlife presence. Here, we demonstrate that environmental DNA (eDNA) techniques can be used to detect trace DNA from turtles on both plastic and fabric objects with high con dence for at least six months following only an hour of exposure. Sampling location and subsequent swabbing did not impact detection probability. While we observed very di erent DNA concentrations in the two substrate types, detection outcomes were relatively similar.

e lack of substantial DNA decay during this experiment suggests a long window (potentially years) in which DNA may remain detectable to law enforcement o cials under common gear storage conditions.

Exposure to selected pathogens in wild mammals from a rescue and rehabilitation center in southern Italy

Minichino A, L. Ciuca, L. Dipineto, L. Rinaldi, S. Montagnaro et al. Exposure to selected pathogens in wild mammals from a rescue and rehabilitation center in southern Italy. One health (Amsterdam, Netherlands). 2025;20(101049):101049. https://doi.org/10.1016/j.onehlt.2025.101049

Wildlife is at the same time a reservoir and sentinel of numerous infections for humans and domestic animals. For this reason, wildlife rehabilitation centers

represent an opportunity to carry out surveillance against the most varied infections. In this work, wild animals (canids, mustelids, erinaceids, and cervids) hospitalized at a rst aid center in southern Italy were sampled and tested with multispecies ELISAs and rapid tests against a panel of pathogens, including viruses, bacteria, and parasites. Foxes and wolves were exposed to *Brucella canis*, *Coxiella burnetii*, canine coronavirus, and Pseudorabies virus. Furthermore, one and two foxes tested positive for *Anaplasma phagocytophilum* and *Diro laria immitis*. Although not con rmed by molecular assay, hedgehogs and porcupines tested positive for *Diro laria immitis* antigens. No animals were exposed to *Leishmania infantum*, *Borrelia burgdorferi*, *Mycobacterium avium*, or Schmallenberg viruses. A fox and a roe deer had antibodies against the hepatitis E virus. e overall prevalence of *Angiostrongylus vasorum* antigen was 25 % (all the positive samples were collected from red foxes). Parasitological analyses showed the positivity of wild animals to *Crenosoma* spp., *Strongyloides* spp., *Capillaria* spp., and *Cystoisospora* spp. Wild canids also tested positive for *Toxocara* spp. and *Trichuris vulpis*. e results of this study have demonstrated not only the circulation of numerous pathogens in the wildlife of southern Italy but also underlined the risk to which the operators of rst aid centers are subjected, considering that some of these animals stand periods of rehabilitation even of several months.

Factors determining the survival or mortality of *Nyctereutes procyonoides* (Canidae) rescued by a wildlife rescue centre: Is urbanisation a threat to wildlife?

Kim BK, Eo SH. Biodivers Data J. 2025;13(e163708):e163708. https://doi.org/10.3897/BDJ.13.e163708

E ective wildlife conservation requires an understanding of species' ecological characteristics and identifying survival-threatening factors. Speci cally, mitigating anthropogenic threats is imperative for wildlife facing human-wildlife con icts, such as raccoon dogs (*Nyctereutes procyonoides*). is study analysed data collected over 11 years on raccoon dogs rescued in South Korea, categorising 1,123 rescue cases, based on seven variables. Furthermore, it examined the impact of these variables on incident frequency and subsequent outcomes, including release and mortality. In raccoon dogs, rescue frequency was higher in autumn, in males and in juveniles, with incidents frequently occurring near buildings or involving parasitic infections. Causes of distress and triage were identi ed as key indicators when evaluating the release potential of rescued raccoon dogs. Additionally, the release potential was found to signi cantly decrease when they were rescued near roads or buildings or had experienced collisions with vehicles, highlighting urbanisation as a major threat to wildlife. is study provides guidance for the protection and management of raccoon dogs and supports the evaluation and improvement of wildlife rescue, treatment and rehabilitation e orts.

Rehabilitating wild animal welfare: A focus on veterinary rescue and rehabilitation interventions

Beaulieu M. Res Vet Sci. 2025;186(105582):105582. https://doi.org/10.1016/j.rvsc.2025.105582

Rescuing injured, sick, malnourished or orphaned animals before releasing them back into the wild belongs to the most frequent interventions that veterinary practitioners may perform when dealing with wildlife (Marc, 2023). Such rescue and rehabilitation interventions are often presented under a conservation banner. Whether these activities generally contribute to wildlife conservation is, however, debateable. For instance, the vast majority of animals admitted in wildlife rescue and rehabilitation centres do not belong to species of conservation concern (e.g., Miller et al., 2023; Mullineaux and Pawson, 2023). Even for species of conservation concern, the conservation consequences of such interventions are often uncertain (Paterson et al., 2021). Moreover, some veterinary interventions supporting the rescue and rehabilitation of wild animals, such as parasite control, often appear to be driven by "taxonomic chauvinism" rather than by objectively weighting the conservation status of vertebrate hosts against that of their invertebrate parasites (Pizzi, 2009). is chauvinistic pattern is likely due to the fact that veterinary activities are primarily governed by welfare considerations applicable to animals recognized as being sentient (i.e., having emotions), such as most vertebrates. Accordingly, most veterinary rescue and rehabilitation interventions (e.g., medicating, deparasiting, supplementing) directly bene t wild animals in terms of welfare by enhancing their health and/or nutritional status (following the ve-domain model of animal welfare, in which the emotional state of animals depends on their health and nutritional status, together with their behaviour and the environment they experience; Mellor et al., 2020). Implicit welfare considerations, therefore, appear to generally motivate veterinary rescue and rehabilitation interventions, rather than the conservation motivations that are frequently put forward.

Pathogens and planetary change

Carlson CJ, Brookson CB, Becker DJ, Cummings CA, Gibb R et al. Nat Rev Biodivers. 2025;1(1):32–49. https://doi.org/10.1038/s44358-024-00005-w

Emerging infectious diseases, biodiversity loss, and anthropogenic environmental change are interconnected crises with massive social and ecological costs. In this Review, we discuss how pathogens and parasites are responding to global change, and the implications for pandemic prevention and biodiversity conservation. Ecological and evolutionary principles help to explain why both pandemics and wildlife die-o s are becoming more common; why land-use change and biodiversity loss are often followed by an increase in zoonotic and vector-borne diseases; and why some species, such as bats, host so many emerging pathogens. To prevent the next pandemic, scientists should focus on monitoring and limiting the spread of a handful of high-risk viruses, especially at key interfaces such as farms and live-animal markets. But to address the much broader set of infectious disease risks associated with the Anthropocene, decision-makers will need to develop comprehensive strategies that include pathogen surveillance across species and ecosystems; conservation-based interventions to reduce human–animal contact and protect wildlife health; health system strengthening; and global improvements in epidemic preparedness and response. Scientists can contribute to these e orts by lling global gaps in disease data, and by expanding the evidence base for disease–driver relationships and ecological interventions.



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Harbor seals *(Halichoerus grypus)*

Leptospira interrogans serovar Copenhageni infection and exudative glomerulonephritis in rehabilitated gray seals (*Halichoerus grypus*) and harbor seals (*Phoca vitulina*) in Ireland

Imlau M, Russel T, Browne JA, O'Connell RA, Gray H et al. Vet Microbiol. 2025;311(110764):110764. https://doi.org/10.1016/j.vetmic.2025.110764

Leptospirosis in pinnipeds is nearly exclusively reported in California sea lions (*Zalophus californianus*), in which the disease is believed to be endemic. ere, the Pomona serovar is the predominant cause and severe lymphoplasmacytic interstitial nephritis is the characteristic pathological nding. e present study reports on nine cases of leptospirosis in gray seals (*Halichoerus grypus*) and harbor seals (*Phoca vitulina*) diagnosed over a period of 13 months at the Seal Rescue Centre, County Wexford, Ireland. e seals presented with jaundice, additional clinical signs included labored breathing and coughing, hemoptysis, epistaxis and anorexia. e seals were either found dead or had a clinical course of 6 days maximum. During post mortem examination the main gross lesions were jaundice and varying degrees of visceral hemorrhages. Common histological ndings were acute renal tubular necrosis, exudative glomerulonephritis (GN), hepatocyte dissociation and pulmonary hemorrhage. Exudative GN was characterized by markedly expanded urinary spaces lled with extravasated erythrocytes and brin in the absence of immune complexes. is unique lesion has only recently been associated with leptospirosis in dogs. Immunohistochemistry and/or PCR detected Leptospira sp. in the a ected seals. Subsequent multilocus sequence typing using six di erent primer pairs targeting *secY*, *adk*, *icdA*, *LipL41*, *rrs2*, and *LipL32* obtained sequences that closely matched *L. interrogans* isolates belonging to the Copenhageni serovar. e infection occurred in the center and terrestrial reservoirs such as rats are a likely source. is report details for the rst time the presentation and diagnosis of an important zoonosis in seals in rehabilitation.

Wildlife □eas and ticks in Wisconsin, USA: unrecognized vectors of bacterial pathogens

Moore CO, Andrews CV, Lemley EM, Gonçalves Funnicelli MI, André MR et al. Int J Parasitol. 2025 Aug 20. https://doi.org/10.1016/j.ijpara.2025.08.004

Small wildlife species host ea and tick species that can also infest or transmit pathogens to domestic animals and humans, including *Anaplasma*, *Babesia*, *Bartonella*, *Borrelia*, *Ehrlichia*, and *Rickettsia* species. Despite their zoonotic potential, little is known regarding the prevalence, diversity, and epidemiology of these pathogens. erefore, we aimed to survey the ectoparasites found on Eastern Cottontail Rabbits (rabbits), Eastern Grey Squirrels (squirrels), and Virginia Opossums (opossums) in south-central Wisconsin, and describe the prevalence of select pathogens. Ectoparasites were opportunistically collected from small mammals, then identi ed to the species level, pooled, washed, and DNA extracted for quantitative PCR (qPCR) to detect Anaplasmataceae, Apicomplexa, *Bartonella*, hemotropic *Mycoplasma*, and *Rickettsia*. To analyze the genomic diversity of uncharacterized *Bartonella*, three ea pools were subject to metagenomic sequencing. *Cediopsylla simplex* and *Haemaphysalis leporispalustris* were the most common ectoparasites on rabbits, while *Orchopeas howardi* was most common on squirrels and opossums. *Bartonella* species were detected in *C. simplex* pools (n = 52), most commonly two distinct *Bartonella alsatica*-like bacteria (38 %; 20/52). *Bartonella durdenii*, de nitively identi ed by metagenomic sequencing, was detected in 42 % (13/31) of *O. howardi* pools from squirrels. From metagenomic sequencing, *B. alsatica*-like species displayed a 4.8 % dissimilarity rate while *B. durdenii* displayed a 0.4 % dissimilarity rate. Sequencing of one *B. alsatica*-like ea pool also identi ed phage-associated genes not found in the *B. alsatica* genome. *Rickettsia felis* (n = 1) and opossum-associated hemotropic

Mycoplasma sp. (n = 2) were detected in *O. howardi* from opossums. *Rickettsia bellii* and *Anaplasma* sp. were detected in *Haemaphysalis leporispalustris* from rabbits. ese ndings reinforce the value of metagenomic sequencing, facilitating the correct identi cation of *B. durdenii* and identifying genes not found in the type strain, speci cally phage related genes. Due to the known zoonotic potential of *B. alsatica*, further examination of *B. alsatica*-like and *B. durdenii* pathogenicity is warranted.

Environmental DNA as a tool for detecting illegal wildlife trade

LeClair GD, Chat eld MWH, Kinnison MT. Forensic Sci Int. 2025;370(112446):112446. https://doi.org/10.1016/j.forsci-int.2025.112446

e illegal wildlife trade presents signi - cant challenges to wildlife conservation due to its large impact on population and species persistence. Forensic technology plays an important role in detecting and prosecuting such trade but has lagged human forensics where trace genetic evidence is important in conviction or exoneration. At present, most genetic applications in wildlife forensics focus on identi cation of taxa or populations via tissue samples or visible trace material (e.g., blood, hair or feathers). However, enforcement o cials may encounter common household objects that are suspected to be used in capture, transport, or holding of wildlife, but without visible evidence of wildlife presence. Here, we demonstrate that environmental DNA (eDNA) techniques can be used to detect trace DNA from turtles on both plastic and fabric objects with high con dence for at least six months following only an hour of exposure. Sampling location and subsequent swabbing did not impact detection probability. While we observed very di erent DNA concentrations in the two substrate types, detection outcomes were relatively similar. e lack of substantial DNA decay during this experiment suggests a long window (potentially years) in which DNA may remain detectable to law enforcement o cials under common gear storage conditions.

Refuge abandonment in a formerly harvested waterbird and the consequent formation of multi-species bird colonies

Ron-Arroyo N, Mouriño J, Rodríguez-Silvar J, Bermejo Díaz de Rábago A, Martínez-Abraín A. J Avian Biol. 2025;2025(5):e03451. https://doi.org/10.1002/jav.03451

e intense human persecution of wildlife in the past forced many animal populations to look for refuge in human-inaccessible habitats. With the decline of direct persecution, and the changes in the attitude of modern urban societies towards wildlife during the last few decades, an ecological process of abandonment of refuge habitats has become pervasive, and many species make habitat choices deemed surprising presently, such as colonizing sites that are more accessible to humans. We tested this process in the yellow-legged gull *Larus michahellis* by analysing long-term time series (1976–2022) of breeding pairs in seven colonies in southern Europe. Overall, yellow-legged gull numbers showed a strong pattern of decrease during the study period, due to the recent closure of open-air garbage dumps. However, while the number of pairs in colonies located in human-inaccessible sites (islets with cli s) declined rapidly, new colonization together with a monotonic linear population growth was detected in human-accessible sites, coinciding in time with the departure from refuges. Moreover, we found that the new small yellow-legged gull colonies acted as cores for the formation of multispecies waterbird colonies likely by heterospeci c attraction, that provides an added unexpected conservation value to yellow-legged gulls traditionally considered a pest species.

Use of mental models to identify one health priorities for wildlife health management in California

Shapiro HG, Lubell M, Cli ord DL, Heeren A, Gilardi K et al. One health (Amsterdam, Netherlands). 2025;(101258):101258. https://doi.org/10.1016/j.onehlt.2025.101258

Operationalizing a One Health framework for wildlife health requires interdisciplinary collaboration and developing a common vision of the system to prioritize management actions and policies. Mental models are simpli ed knowledge structures that provide a way to generate common understandings of complex social-ecological systems. We conducted a mental model exercise with wildlife and zoonotic disease experts at a workshop to graphically map the relationships of key factors that in uence the emergence and occurrence of disease in California wildlife. We found that experts had similar visions about what determinants of health should be included in the models, but low agreement on how these determinants connect, signaling the need for more system-level research and communication among scientists and decision makers. Participants also identi ed human expectations components of the system (e.g., policy, collaboration, agency capacity) as important determinants of wildlife health, though these components were not as well connected to the system as ecological components. Our research design and analysis demonstrate how mental models can be used to chart a course from common understanding to policy impact in complex One Health systems where cooperation is the key to e ective management and governance.

Activity budgets of hedgehogs *(Erinaceus europaeus)* in rehabilitation centers: A pilot study

Schüpbach R, Clauss M. J Vet behavior. 2025;79:68–74. https://doi.org/10.1016/j.jveb.2025.04.011

Erinaceus europaeus, the European hedgehog, was formerly very common but has recently su ered a decline across several European countries. ere is a long-standing tradition of hedgehog rehabilitation centers across Europe with reported high rewilding success. Surprisingly, however, few data exist on the behavior of the animals while in these centers. To gain a better understanding of hedgehog behavior under husbandry conditions of rehabilitation, we documented the behavioral repertoires of four hedgehogs over a 48-hour period, including behavioral observations and quanti cation of food consumed and

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Polar bear *(Ursus maritimus)*

distances covered per day. Most of the hedgehogs' time was spent resting, comprising about 20 h in a 24-hour period.

e majority of activity occurred at night and was spent feeding, followed by locomotion. Daily food consumption (of a dry cat kibble) ranged from 31 to 71 g of dry matter in 16–41 feeding bouts (1.1–2.6 g/bout, 2.4–3.8 min/bout). e hedgehogs covered a mean distance of 34–335 m per day, with a mean speed ranging from 0.12 to 0.25 km/h. Compared to data from free-ranging specimens, the hedgehogs spent less time active and covered less distance per day. No stereotypical behavior was observed. ese ndings suggest that for the aim of rehabilitation, husbandry conditions are adequate; for long-term husbandry, modi cations that facilitate more locomotion and more foraging behavior would be required.

Predators and scavengers: Polar bears as marine carrion providers

Gamblin HE, Derocher AE, Richardson ES, McGeachy D, Roth JD et al. Oikos (Copenhagen, Denmark). 2025;(e11628):e11628. https://doi.org/10.1002/oik.11628

Scavenging is a foraging strategy widely used across the animal kingdom and apex predators provide a large amount of energy in a food web by provisioning carrion. In the harsh environmental conditions of the Arctic, apex predators such as polar bears *Ursus maritimus* can provide scavenging opportunities for many species. Carrion can act as a bu er when food resources are low, and some terrestrial species use the marine environment for cross-ecosystem resource subsidies. We present an overview of scavenging as a foraging strategy in the Arctic marine environment and examine the contribution of prey provided by polar bears to the Arctic scavenging assemblage. As obligate predators of seals, polar bears contribute a substantial amount of carrion to the marine ecosystem, particularly to the sea ice surface where it is accessible for seasonal scavenging opportunities. We estimated that an average polar bear kills approximately 1001 kg of marine mammal biomass annually and given preferential feeding of blubber and abandonment of carcasses, we estimate that 30% of the biomass is left as available carrion. Consequently, polar bears provision approximately 7.6 × 106 kg year–1 of carrion biomass for scavengers across their range, equivalent to 3.93 × 107 MJ of energy. Eleven vertebrate species are known to scavenge polar bear kills, and an additional eight are possible scavengers. While foraging associations with polar bear kills for some species are better understood, others are scarce or undocumented. We provide an overview of what is known about the role of polar bears as carrion providers, the network of scavenging species on the sea ice, and the possible consequences of trophic downgrading in this ecosystem and recipient ecosystems. u

EDITORIAL continued...

Jolly explains multispecies ethnography as "rather than seeing animals in one place where they are 'supposed to be', and humans in another, we can see how humans and other animals coexist"[2]. Tell me that is not exactly what we are doing in our communications with the public. We are reengaging our communities in their local landscape, in some cases reintroducing entire communities to their local reality and not a homogenized "nature".

I believe when wildlife rehabilitators are doing their best work they are part of the community they serve. Wildlife rehabilitators must engage in two-eyed seeing - understanding the same event through multiple ways of knowing which allows us to bring our communities with us in seeing their interactions with wildlife through a broader ecological systems lens as well as human emotional and economic lenses. Successful wildlife rehabilitation is not a practice of fortress conservation, it is the active work of coexistence which starts with listening.

—Kai Williams
IWRC Board President

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TAIL ENDS

Hurry up and take the picture! I'm hungry!
HOLIDAY 2025. ROME, ITALY

Yellow-legged gull
Larus michahellis
IUCN Red List–Least Concern, Population Trend – Increasing

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Include an abstract that does not exceed 175 words and choose several (up to 14) key words.

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American three-toed woodpecker *(Picoides dorsalis)* stunned after a window strike, Quebec City, Canada.



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