

JOURNAL OF WILDLIFE REHABILITATION

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IWRC
INTERNATIONAL WILDLIFE REHABILITATION COUNCIL

THE *Journal of Wildlife Rehabilitation* is designed to provide useful information to wildlife rehabilitators and others involved in the care and treatment of native wild species with the ultimate purpose of returning them to the wild. The journal is published by the International Wildlife Rehabilitation Council (IWRC), which invites your comments on this issue. Through this publication, rehabilitation courses offered online and on-site in numerous locations, and its outreach to those in the profession, the IWRC works to disseminate information and improve the quality of the care provided to wildlife.



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On the cover:

North American Porcupine (*Erethizon dorsatum*). A patient in care at WILDNorth, Northern Alberta Wildlife Rescue and Rehabilitation. Edmonton, Alberta Canada.

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LEFT:

Capybara *(Hydrochoerus hydrochaeris)* and Greater Antillean grackle *(Quiscalus niger)*
IUCN red list category–least concern.

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INTERNATIONAL WILDLIFE REHABILITATION COUNCIL

International Wildlife Rehabilitation Council
PO Box 3197
Eugene, OR 97403 USA
Phone: 866.871.1869
Fax: 408.876.6153
Toll free: 866.871.1869
Email: office@theiwrc.org
director@theiwrc.org
www.theiwrc.org

INTERNATIONAL WILDLIFE REHABILITATION COUNCIL

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

Editor
Kieran J. Lindsey, PhD
Center for Leadership in Global Sustainability
Virginia Tech University
JWR Editorial office: St. Louis, Missouri, USA

Art Director
Julissa Favela
International Wildlife Rehabilitation Council
Eugene, Oregon, USA

Production Consultant
Nancy Hawekotte
Cumulus Creative
Art offices: Omaha, Nebraska, USA

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VOLUME 45, NUMBER 2, 2025

CONTENTS

PEER-REVIEWED PAPERS

7

A case study of a successful blood transfusion in a wild North American porcupine (*Erethizon dorsatum*) to correct severe ectoparasite-induced anemia
Daren Mandrusiak, Carly Lynch

11

Survey of antimicrobial and probiotic use practices in wildlife rehabilitation in the United States
Elizabeth A. Miller, Rachel Amato, Julia B. Ponder, and Irene Bueno

DEPARTMENTS

Editorial	4
Selected Abstracts	22
Tail Ends	28
Submission Guidelines	29

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EDITORIAL

Data Stories

Wildlife rehabilitation is a field full of stories. Each finder, each intake, each day has stories. Some of these stories are narratives, like the phone call about a snake found in a trailer that has just been driven 500 miles; others are told via data, like the chart notes on a red fox showing weight increasing over a series of weeks. Our data, our stories, are valuable and need to be shared in a thoughtful manner.

The last thing we want is to undermine our own message about the value and autonomy of wild animals with an unintentionally misleading photo on social media or misinterpreted data. Many rehabilitators think carefully about each photo they post on social media, but how many of us have decades of valuable stories in the form of charts and medical notes just sitting in the attic?

June's Coffee & Tea was all about leveraging the stories and data we already collect to improve the practice of wildlife rehabilitation. Also in June, I facilitated a series of sessions on data ethics and equity, Data Reframed's Data Equity Skills Workshop, providing people with the tools to think critically on the data they are interacting with. Writing about data feels very full circle for me at this moment as it connects my work and volunteering life; and highlights the importance of perception and story, areas that academically and professionally interest me.

A key principle in Data Reframed's workshops comes from the title of chapter four of Data Feminism "What gets counted counts". This seemingly obvious statement opens the mind to considerations of what we are not saying, not sharing, not making visible. If a human pharmaceutical study subjects are all adult cis men, then, assuming all other study parameters are well designed, we know how the pharmaceutical affects adult cis men. We don't know how that pharmaceutical affects children, teens, transfolk, nonbinary people, women, or the elderly. If we never share our wildlife rehabilitation data, then the work we are doing will not be included in efforts to improve animal welfare and mitigate the harm of negative anthropogenic interference such as wildlife trafficking and climate change. Our work will remain invisible, our impact will be limited, and our voices won't be heard.

There is a bit of a 'chicken and egg' saga to sharing wildlife rehabilitation stories on a larger scale. We know that publishing our data, pursuing research, and participating in collaborative partnerships could not only improve our practices but open the door to attention and funding we need. Yet wildlife rehabilitators are so under–resourced and busy caring for the animals that come through the doors that these things sometimes feel secondary and beyond our reach. Even so, we can, and do, make small positive impacts with the limited resources we have.

Make time for the things we believe are important. Using and sharing our data needs to be a priority, for the future of our field, the conservation of wild ecosystems, and the health of humans and animals both. Start small, but do get started!

Consider putting together a list of the data you have available and the questions you'd like to see answered, and reach out to local universities to find collaborators (a new IWRC website tool is coming soon to support these efforts, keep an eye out for that announcement). Write up your talks, data, and research projects and submit them to IWRC's Journal of Wildlife Rehabilitation, NWRA's Wildlife Rehabilitation Bulletin, and other peer-reviewed journals.

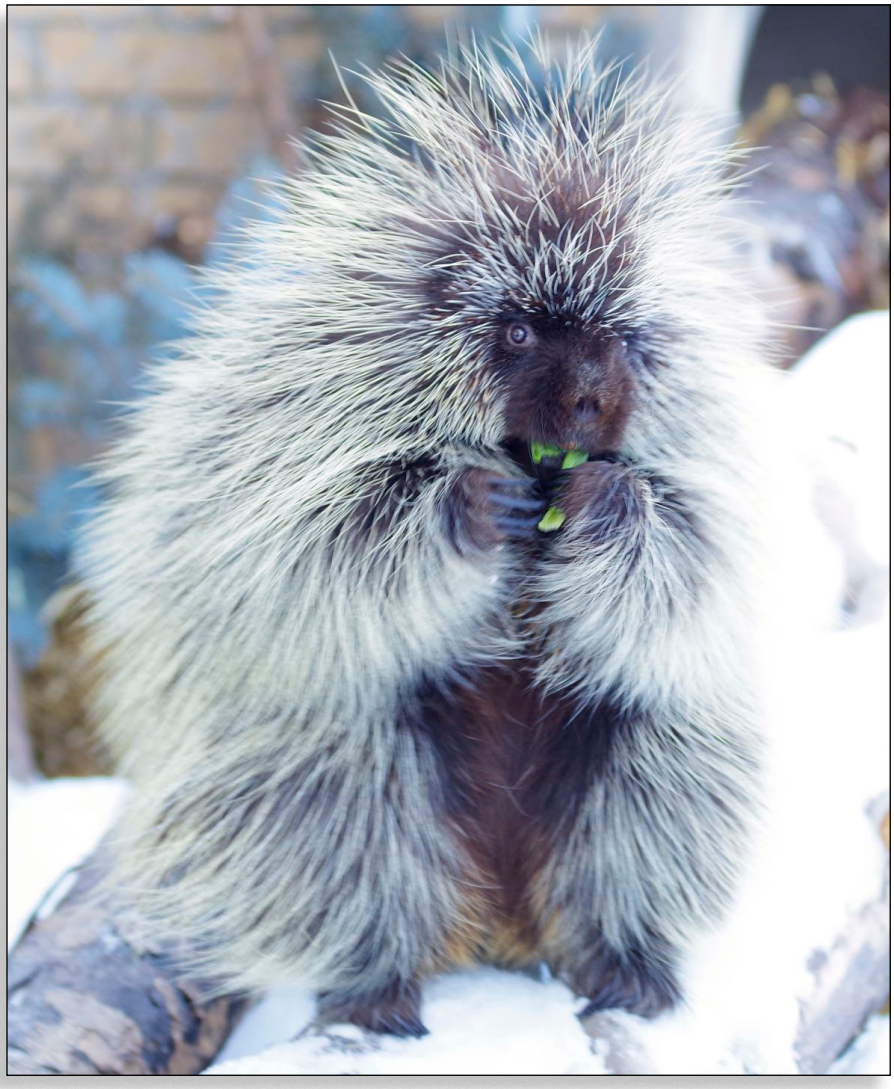
Lets be proactive and ensure the world hears our stories.

Kai Wiliams
Executive Director

A case study of a successful blood transfusion in a wild North American porcupine (*Erethizon dorsatum*) to correct severe ectoparasite-induced anemia

Daren Mandrusiak, Carly Lynch

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NORTH AMERICAN PORCUPINE *(Erethizon dorsatum)*

Introduction

An adult female North American porcupine (*Erethizon dorsatum*) was presented to the WILDNorth Northern Alberta Wildlife Rescue and Rehabilitation hospital for lethargy, weakness, and copious nasal discharge. Spanning several months over the winter, residents who regularly observed the porcupine noted similar clinical signs on multiple occasions. The porcupine was a regular resident in the backyards of a suburban neighborhood in the greater Edmonton area and was reasonably accustomed to being near humans.

AUTHOR AFFILIATION
WILDNorth Northern Alberta Wildlife Rescue and Rehabilitation
Edmonton, Alberta, Canada

ABSTRACT:
A wild adult female North American porcupine (*Erethizon dorsatum*) was presented to a wildlife rehabilitation facility in late winter, where it was diagnosed with an upper respiratory infection, high ectoparasite load, and severe anemia. The respiratory infection was responsive to antibiotic therapy, and the mixed-species parasite load was responsive to anti-ectoparasitic therapy. However, patient improvement lagged. A homologous blood transfusion was performed, dramatically improving the patient's condition, resulting in greater energy, appetite, and weight gain. This ultimately allowed for the release of the porcupine to its natural habitat. Blood transfusions are rarely performed in porcupines, given the challenges in locating an appropriate homologous donor and the technical difficulties in collecting large volumes of blood and maintaining prolonged venous access. Severe anemia secondary to parasitism or chronic infections is a well-described ailment of patients presented to wildlife rehabilitation facilities. This case study describes a rarely performed technique in porcupines, which can be utilized to positively impact recovery and release.

KEY WORDS:
Blood, brachiocephalic, collection, cross-match, *Erethizon dorsatum,* jugular, parasite, pneumonia, porcupine, sedation, transfusion.

CORRESPONDING AUTHOR
Carly Lynch
18515 98 Avenue NW
Edmonton, Alberta, Canada T5T3E6
E: carly@wildnorth.ca

Methods

Upon initial assessment, the porcupine appeared lethargic, weak, and quiet. It also showed substantial nasal discharge accompanied by active sneezing and head shaking. There was thick, crusted, dried serosanguineous debris over the neck and caudal to the ears bilaterally. The porcupine seemed reasonably comfortable around people and was determined to be desensitized to humans. Physical handling of the animal appeared to cause minimal fear and stress.

The rehabilitation team initiated broad-spectrum antimicrobial therapy with trimethoprim-sulfamethoxazole (trimethoprim-sulfamethoxazole compounded oral suspension 8/40 mg/ml, Create Compounding Limited, Calgary, AB, Canada) at 20 mg/kg by mouth twice daily. Anti-inflammatory therapy was also commenced, using intramuscular (IM) injections of 0.7 mg/kg of meloxicam (Rheumocam® 20 mg/ml injection, Chanelle Pharmaceuticals Manufacturing Ltd., Loughrea, Co. Galway, Ireland) under the verbal direction of a staff veterinarian overseeing the case by telemedicine. Over the initial days in rehabilitation, the porcupine ate inconsistently, and there were concerns for clinical dehydration. To help combat this, the patient was offered apples (and the occasional apple branch), syringe-fed strawberry flavored Ensure® (Ensure, Abbott Laboratories, Saint-Laurent, QC, Canada) or apple sauce/Critical Care Herbivore mix (Critical Care Herbivore powdered formula Oxbow Animal Health, Oxbow Enterprises, Inc., Omaha, NE, USA).

Five days after intake, an onsite veterinary assessment was performed. There was minimal improvement in the purulent nasal discharge, and the patient was in poor body condition, with an estimated body condition score of 2/9. Slides were made from nasal swabs and stained using Dip Quick (Dip Quick Stain, Jorgensen Laboratories, Loveland, CO, USA). Microscopic review of in-house cytology showed many degenerate white blood cells, occasional red blood cells, and a well-established homogeneous population of cocci bacteria. There was concern that there may be enough purulent debris that an anaerobic environment could exist. Given the spectrum of activity of trimethoprim-sulfamethoxazole and its poorer in vivo efficacy in anaerobic environments, the decision was made to discontinue this medication in favor of 40 mg/kg chloramphenicol (ChlorPalm 250, 50 mg/ml oral suspension, Vétoquinol N.-A. Inc., Lavaltrie, QC, Canada) given orally twice daily.[1]

Over the next eight days, the patient's purulent nasal discharge and appetite improved, and the patient was deemed stable for sedation to facilitate a complete diagnostic workup. Sedation was given via IM injection, using a combination of dexmedetomidine (Dexmedesed® 0.5 mg/ml injection, Dechra Veterinary Products Inc., Pointe-Claire, QC, Canada) at a dosage of 0.045 mg/kg, ketamine hydrochloride (Ketaset® 100 mg/ml injection, Zoetis Inc., Kalamazoo, MI, USA) at 3.5 mg/kg, midazolam (midazolam 5 mg/ml injection, Sandoz Canada Inc., Boucherville, QC, Canada) at 0.25 mg/kg, and butorphanol tartrate (Torbugesic® 10 mg/ml injection, Zoetis Inc., Kalamazoo, MI, USA) at 0.1 mg/kg. On pre-anesthetic examination, the patient was bright and alert, and 4.7 kg body weight which was low for an adult female of the species.[2] The patient still had some crusts present and was noted to be very pruritic around the head and neck. On sedated assessment, a large amount of thick, dry crusting debris was seen at the base of the quills around the neck and extending to the eyes and nose. There were a significant number of macroscopic parasites seen crawling around the head and neck. Underneath the darkened crust, the skin was pink with mild erythema. A modest amount of dried purulent debris was seen on the medial aspects of the front paws. Examination also revealed that the patient was severely emaciated and cachectic, and auscultation identified mild inspiratory stridor. The rest of the physical examination was within normal limits. Microscopic review of collected parasites revealed that the ectoparasite load was mainly comprised of fleas from the family Dolichopsyllidae.[3] Blood was collected from the left jugular vein to perform a packed cell volume and total serum solids. Thoracic screening radiographs and skull radiographs were captured. Prior to recovery, the patient was administered ivermectin (Ivomec® 10 mg/ml injection, Boehringer Ingelheim, St. Joseph, MO, USA) at a dosage of 0.4 mg/kg by subcutaneous (SC) injection.

Packed cell volume was markedly decreased at 10%, which was consistent with severe anemia; total serum solids were within normal limits at 45 g/L. A board-certified veterinary radiologist reviewed the radiographs taken. No evidence of structural abnormalities of the nasal passages or sinuses were noted. No evidence of pneumonia was appreciated. The radiographs were unremarkable.

It was determined that a blood transfusion was indicated for the anemic porcupine. Fortunately, the rehabilitation facility had another porcupine patient in care who was admitted after an encounter with a dog. At the time, this porcupine was recovering from a successful wound repair surgery, and staff were optimistic about the animal's progress. Weighing 7.5 kg, this porcupine was determined to be a good candidate for blood donation as it was in good body condition, was eating and drinking well, and was rambunctious in health and demeanor.

The day of the transfusion, the donor porcupine was sedated at the rehabilitation society hospital via IM injection with a combination of dexmedetomidine (Dexmedesed® 0.5 mg/ml injection, Dechra Veterinary Products Inc., Pointe-Claire, QC, Canada) at a dosage of 0.05 mg/kg, ketamine hydrochloride (Ketaset® 100 mg/ml injection, Zoetis Inc., Kalamazoo, MI, USA) at 5 mg/kg, midazolam (midazolam 5 mg/ml injection, Sandoz Canada Inc., Boucherville, QC, Canada) at 0.25 mg/kg, and butorphanol tartrate (Torbugesic® 10 mg/ml injection, Zoetis Inc., Kalamazoo, MI, USA) at 0.1 mg/kg. It was maintained under anesthesia with inhaled isoflurane (AErrane®, 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether 99.9%, Baxter Corporation, Mississauga, ON, Canada) at 2%, administered via face mask. The patient's vital statistics remained stable throughout the procedure. Due to the difficulty of peripheral venous access, blood was collected from the left common jugular vein where it meets the brachiocephalic

vein (Fig. 1). This site was accessed at the point where the clavicle meets the first rib; the scapulohumeral joint was used as a lateral marker of the site. The needle was directed perpendicular to the spine. A total of 50 ml of whole blood was collected between two syringes with anticoagulant preservative citrate phosphate dextrose adenine (CPDA-1) at 1 ml of CPDA per 7 ml of whole blood. One hundred milliliters of Plasma-Lyte (Plasma-Lyte®, Baxter, Deerfield, IL, USA) was administered subcutaneously after the procedure. The donor porcupine was reversed with atipamezole hydrochloride (Revertor™ 5 mg/ml injection, Modern Veterinary Therapeutics, LLC, Miami, FL, USA) and recovered uneventfully. The blood was kept cool and immediately transferred with the recipient porcupine to a partner veterinary hospital, which assisted with performing the transfusion. As expected, the collection did not affect the outcome for the donor, who was released successfully later that month with no complications related to the blood collection.

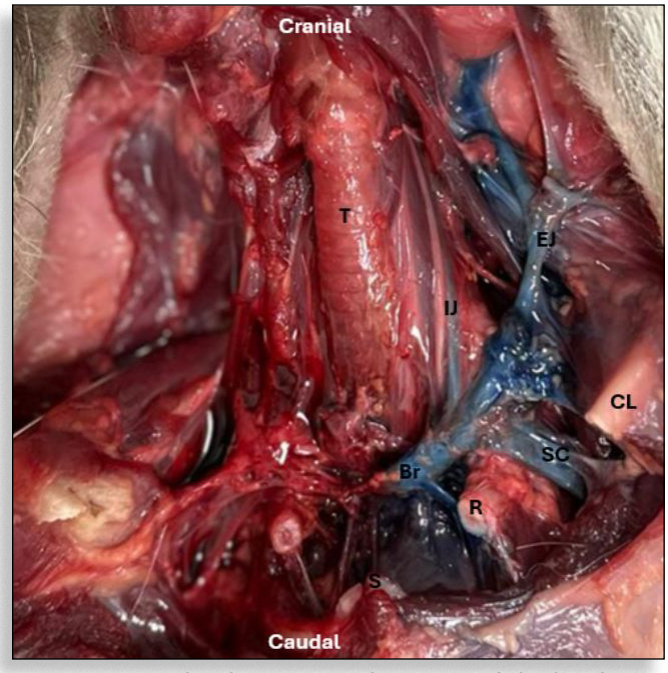


Figure 1. Vascular dissection and staining of the brachiocephalic, subclavian, and jugular veins in an adult male North American porcupine (Erethizon dorsatum). Tissues were stained by injecting the basophilic solution used in Diff-Quik stain into the brachiocephalic vein at the midline.
KEY: T (TRACHEA), EJ (EXTERNAL JUGULAR VEIN), IJ (INTERNAL JUGULAR VEIN), R (1 ST RIB), SC (SUBCLAVIAN VEIN), BR (BRACHIOCEPHALIC VEIN), CL (CLAVICLE), S (STERNUM).

The recipient porcupine was sedated by IM injection using a combination of 0.5 mg/kg midazolam (midazolam 5 mg/ml injection, Fresenius Kabi Canada Ltd., Toronto, ON, Canada), 3 mg/kg ketamine hydrochloride (Narketan® 100 mg/ml injection, Vétoquinol N.-A. Inc., Lavaltrie, QC, Canada), and 0.4 mg/kg butorphanol tartrate (Torbugesic® 10 mg/ml injection, Zoetis Inc., Kalamazoo, MI, USA). An intravenous (IV) catheter was placed into the right cephalic vein. Blood was collected from the IV catheter; a saline agglutination test and major and minor crossmatches were performed; and the donor was determined to be a compatible match.[4]

A complete blood count (Table 1) and serum biochemistry panel (Table 2) were completed on the recipient porcupine. Complete blood count results revealed a severe anemia characterized by a packed cell volume (PCV) of 10.9%, and severe anisocytosis, polychromasia, and poikilocytosis were seen during a microscopic examination of the manual blood smear. No hemoparasites were noted on the manual smear. The white blood cell count was elevated, characterized by neutrophilia and monocytosis. Additionally, there was evidence of toxic change, including large, hypersegmented, vacuolated neutrophils. Serum biochemistry values were generally within normal limits, with minimal deviations from reference values noted; none of the abnormalities were suggestive of significant pathology.

TABLE 1. COMPLETE BLOOD COUNT (CBC) RESULTS OF A FEMALE WILD NORTH AMERICAN PORCUPINE (*Erethizon dorsatum*) COMPARED TO NORMAL VALUES PUBLISHED FOR THE SPECIES.[5]

TEST	UNIT	RESULTS	REFERENCE RANGE (MEDIAN)	QUALIFIER
HEMATOCRIT	%	10.9	24.4-46.1 (36.3)	Low
WBC	x 109/L	18.01	2.78-16.64 (7.65)	High
NEUTROPHILS	x 109/L	11.29	0.51-9.72 (3.28)	High
LYMPHOCYTE	x 109/L	3.69	1.05-9.29 (3.5)	Normal
MONOCYTE	x 109/L HIGH	2.63	0.06-1.051 (0.255)	High
EOSINOPHIL	x 109/L	0.39	0.03-0.925 (0.218)	Normal
BASOPHIL	x 109/L	0.01		
PLATELETS	x 109/L	1135	83-698 (390)	High
% NEUTROPHILS	%	62.6		
% LYMPHOCYTE	%	20.5		
% MONOCYTE	%	14.6		
% EOSINOPHIL	%	2.2		
% BASOPHIL	%	0.1		
CBC COMMENT	Smear morphology: RBC: Severe anisocytosis/polychromasia and poikilocytosis. WBC: Neutrophils are large, hypersegmented, and have toxic changes with vacuolation.			

A syringe pump was used to transfuse the whole blood through an 18 µm blood filter (Hemo-Nate blood filtration system, Utah Medical Products Inc., Midvale, Utah, USA) and an IV catheter. The transfusion rate started at 0.75 ml/kg/hr and then doubled every 5 minutes until a maximum rate of 16 ml/hr was reached. This was lower than the reference rate. However, a

slow transfusion was elected to allow for closer monitoring, given the lack of knowledge regarding transfusion reactions in porcupines.[4] The animal was monitored every 5 minutes for the first 30 minutes and then every 15 minutes thereafter. Vital parameters monitored throughout the procedure included temperature, heart rate, and respiratory rate. Electrocardiogram (ECG) leads were placed, monitored, and maintained throughout the procedure (Fig. 2). Additional sedation was administered at 0.5 mg/kg of midazolam IV two hours after starting the transfusion, and again after an additional two hours had passed. This protocol allowed the patient to be calm and comfortable without disrupting the IV catheter or ECG leads. At the end of the procedure, 0.3 ml of blood was collected from a lateral saphenous vein, and the immediate post-procedure PCV was 18%.

TABLE 2. SERUM BIOCHEMISTRY RESULTS OF A FEMALE WILD NORTH AMERICAN PORCUPINE (*Erethizon dorsatum*) COMPARED TO NORMAL VALUES PUBLISHED FOR THE SPECIES.[5]

TEST	UNIT	RESULTS	REFERENCE RANGE (MEDIAN)	QUALIFIER
GLUCOSE	MMOL/L	8.41	3-14.8 (7.9)	Normal
CREATININE	UMOL/L	43	17.7-132.6 (61.9)	Normal
BUN	MMOL/L	4.3	3.2-13.9 (6.4)	Normal
BUN: CREATININE RATIO		25	12.4-63.8 (26.3)	Normal
PHOSPHORUS	MMOL/L	1.1	0.65-3.1 (1.8)	Normal
CALCIUM	MMOL/L	2.02	2.2-3.1 (2.6)	Low
SODIUM	MMOL/L	141	128-145 (136)	Normal
POTASSIUM	MMOL/L	6.3	3.1-6.7 (4.6)	Normal
NA: K RATIO		22		
CHLORIDE	MMOL/L	109		
GLUCOSE	G/L	56	47-83 (67)	Normal
ALBUMIN	G/L	2.2	23-57 (42)	Normal
GLOBULIN	G/L	32	11-41 (23)	Normal
ALBUMIN: GLOBULIN RATIO		0.8		
ALT	IU/L	49	2-26 (7)	High
ALP	IU/L	52	27-381 (96)	Normal
GGT	IU/L	0	0-13 (6)	Normal
CHOLESTEROL	MMOL/L	2.28	1.08-5.30 (2.90)	Normal

During the first week after the transfusion, the recipient porcupine became more resistant to syringe-feeding and was completely self-feeding by eight days after the procedure. On day



FIGURE 2. A SEDATED NORTH AMERICAN PORCUPINE RECEIVES A BLOOD TRANSFUSION WHILE BEING MONITORED USING AN ELECTROCARDIOGRAM AND RECTAL TEMPERATURE.

10 post-transfusion, the porcupine was sedated by IM injection using a combination of 0.5 mg/kg midazolam (midazolam 5 mg/ml injection, Fresenius Kabi, Canada Ltd. Toronto, ON, Canada), 3 mg/kg ketamine hydrochloride (Narketan 100 mg/ml injection, Vétoquinol N.-A. Inc., Lavaltrie, QC, Canada), and 0.4 mg/kg butorphanol tartrate (Torbugesic 10 mg/ml injection, Zoetis Inc., Kalamazoo, MI, USA) for blood collection to recheck the PCV. Blood was collected from the cephalic vein, and the packed cell volume was 20% (Table 3). Normal range for the PCV in North American porcupines is 24.4–46.1%.[5] The patient received two additional subcutaneous doses of ivermectin (Ivomec 10 mg/ml injection, Boehringer Ingelheim, St. Joseph, MO, USA) at 0.4 mg/kg before being transferred out of the hospital to the long-term rehabilitation facility for pre-release conditioning. Two and a half months after the transfusion was performed, the patient had reached 5 kg of body weight, was eating comfortably, and was released to its natural habitat.

Discussion

Indications for blood transfusions in veterinary medicine can include anemia due to chronic illness, acute or chronic hemorrhage (e.g., gastrointestinal ulcers), immune-mediated anemia, or parasites.[4] There can also be indications for transfusion in cases of hypoproteinemia and/or hypoalbuminemia, or in cases of coagulopathies, which are frequently seen in wildlife patients.[6] In the described case, it is probable that the underlying causes of the anemia were multifactorial, including the ectoparasite load and the infectious rhinitis. Given the time of year (midwinter in a northern climate), it is likely that environmental stressors also contributed to the animal's decompensation through increased energy expenditure. Some interpretations of wildlife rehabilitation ethics would suggest this animal was succumbing to natural death; however, given its proximity to human suburban civilization and the impact of human encroachment on this animal, the decision

TABLE 3. HEMATOCRIT, PACKED CELL VOLUME, TOTAL SERUM SOLIDS, AND TOTAL PROTEIN RESULTS OF A FEMALE WILD NORTH AMERICAN PORCUPINE (*Erethizon dorsatum*) IN RELATION TO WHEN SHE RECEIVED A BLOOD TRANSFUSION TO ADDRESS SEVERE ANEMIA.

TEST	3 DAYS BEFORE BLOOD TRANSFUSION	IMMEDIATELY BEFORE BLOOD TRANSFUSION	IMMEDIATELY AFTER BLOOD TRANSFUSION	10 DAYS AFTER BLOOD TRANSFUSION
Packed cell volume (%)	10		18	20
Hematocrit (%)		10.9		
Total serum solids (g/L)	45		48	50
Total protein (g/L)		50		

was made to proceed with a rehabilitation plan.

Blood transfusion is a well-described medical procedure that is commonplace in both human and small animal medicine. Different types of blood transfusions are utilized in small animal veterinary medicine, including whole blood, plasma, or platelet transfusions.[7] In exotic animal and wildlife medicine, the only practical form of blood transfusion is a fresh whole blood transfusion, as the diversity of species and infrequency with which these procedures occur prevent any blood storing or processing from being a practical option.[8] Blood transfusions are rarely performed in wildlife medicine, given difficulties with the required resources, technical skill, appropriate donor availability, and rarity of indications in these species. Almost all the examples in the literature of wildlife blood transfusion to date have been performed in avian species, including well-described transfusions between members of the same species (i.e., homologous transfusions) and xenotransfusions.[9] There is currently no evidence or information on blood types or blood groups for *Erethizon dorsatum*.

Testing for infectious diseases, particularly blood-borne diseases in donor individuals, is standard in other areas of medicine employing blood transfusions.[4,10-12] In this case, the infrequency of occurrence, lack of knowledge of blood-borne pathogens in porcupines, and urgency for the recipient contributed to the team's decision to forgo any specific disease testing outside of a manual blood film review. Pathogens of concern would include *Toxoplasma*, which has been detected in North American porcupines;[13] *Francisella tularensis* (the causative agent of tularemia), which commonly affects rodent species and has been reported in Alberta;[14] *Dirofilaria subdermata*, for which the North American porcupine serves as the definitive host;[15] and *Babesia* species. *Babesia* species in Canada have been identified in blacklegged ticks, *Ixodes scapularis*.[16] Though there seem to be no published reports on *Ixodes scapularis* parasitizing North American porcupines in Alberta specifically, migratory passerine birds can disperse ixodid ticks as far west and north as Slave Lake, Alberta,[17] and this species of tick has been found to parasitize Canadian porcupines.[18] No evidence of *Babesia* organisms was found on the manual blood smear.

Compared to other wildlife species, additional challenges regarding blood transfusions in porcupines include the collection of a sufficient volume of blood for transfusion and the maintenance of peripheral IV catheterization in a species that can be difficult and hazardous to handle even while sedated.

In this case, the benzodiazepine anxiolytic midazolam was used to keep the recipient porcupine calm, quiet, and comfortable during the procedure. Repeated use of midazolam in this scenario seemed to have no deleterious effects on the recipient. Collecting a substantial volume of blood from the donor proved challenging; while more peripheral vasculature, such as the cephalic and saphenous veins, were options, they did not represent ideal locations from which to collect a large enough volume for an effective transfusion. Extrapolation from more central vascular collection sites, such as those used in rodents and hedgehogs, was utilized to select a site for adequate collection.[19] While hedgehogs are not closely related to porcupines, their apparent convergent evolution has resulted in similar phenotypic anatomy of the neck and chest, thus making this extrapolation reasonable, and in this case, effective and safe.

Management Implications

To our knowledge, there is no documented case of either a blood transfusion or a brachiocephalic vein blood collection having been performed in a North American porcupine. This case demonstrates the practical application of blood transfusions in wildlife medicine, techniques for large-volume blood collection in the North American porcupine, and a protocol for maintaining prolonged, safe sedation to facilitate lengthy nonpainful procedures.

Acknowledgements

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About the Authors

Daren Mandrusiak is a wildlife and exotic animal veterinarian who has been working with Canadian wildlife for the last 10 years. He currently works with WILDNorth as a staff veterinarian. He received his veterinary degree from the Western College of Veterinary Medicine at the University of Saskatchewan and his undergraduate degree in animal health from the University of Alberta. He is a Certified Wildlife Rehabilitator with the International Wildlife Rehabilitation Council.

Carly Lynch is a wildlife rehabilitator and registered veterinary technologist. She is currently the Director of WILDCare at WILDNorth, a nonprofit wildlife rehabilitation center in Alberta, Canada, that admits over 3000 patients annually. She holds a bilingual Bachelor of Science (majoring in conservation biology) from the University of Alberta and an Animal Health Technology diploma from Lakeland College. Carly has been working in the wildlife rehabilitation field since 2013.

Survey of antimicrobial and probiotic use practices in wildlife rehabilitation in the United States

Elizabeth A. Miller[1], Rachel Amato[2], Julia B. Ponder[2,3], and Irene Bueno[4]



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AMERICAN ROBIN (*Turdus migratorius*)

Introduction

Antimicrobial resistance (AMR) is a global public health problem. One of the main drivers of AMR is the "misuse" of antimicrobials in humans and animals, as antimicrobials can exert selection pressures which may promote the emergence and spread of antimicrobial resistant bacteria.[1] This relationship underscores the need for antimicrobial stewardship—a coordinated effort to promote the judicial use of antimicrobial agents in human and animal healthcare settings via policies, guidelines, and interventions.[2,3] Specifically, this involves strategies aimed at optimizing antimicrobial therapy to achieve the best clinical outcomes while minimizing the emergence of AMR and reducing the risks of adverse effects. By emphasizing the importance of evidence-based prescribing practices, surveillance, and education, antimicrobial stewardship programs play a crucial role in combating AMR and preserving the effectiveness of antimicrobial agents for future generations. [2,3] In accordance with the objectives of antimicrobial stewardship, there has been a recent increase in published surveys of human and animal medical practitioners assessing antimicrobial use (AMU) and awareness and understanding

[1] Department of Veterinary and Biomedical Sciences, College of Veterinary Medicine, University of Minnesota, Saint Paul, Minnesota, USA
[2] The Raptor Center, College of Veterinary Medicine, University of Minnesota, Saint Paul, Minnesota, USA
[3] Department of Veterinary Population Medicine, College of Veterinary Medicine, University of Minnesota, Saint Paul, Minnesota, USA
[4] Bristol Veterinary School, University of Bristol, Langford, Bristol, UK

ABSTRACT
Antimicrobial resistance is a global health concern. There is relatively little known about specific prescribing practices in wild animals despite the wide use of antimicrobials and other microbial interventions, such as probiotics to treat captive wildlife. Therefore, the goal of this study was to examine current antimicrobial and probiotic use from a cross-section of wildlife rehabilitation facilities in the United States. An anonymous electronic survey was sent to 105 United States permitted wildlife facilities to collect information about admissions, current antimicrobial and probiotic use practices, and current staff knowledge and attitudes surrounding antimicrobial resistance and probiotic effectiveness. Respondents from over 50% of facilities participated in the survey (54/105). All facilities reported using antimicrobials. Among antibiotics, enrofloxacin and amoxicillin-clavulanic acid were the most commonly used. Over 75% of respondents said that their facilities would benefit from having standardized antimicrobial guidelines in place. The results of this survey are a first step towards understanding antimicrobial and probiotic use practices in the treatment of captive wildlife and developing an antimicrobial stewardship program for wildlife rehabilitation.

Keywords: antibiotics, antifungals, antimicrobial, antivirals, prescribing practices, probiotic, USA, wildlife rehabilitation

CORRESPONDING AUTHOR
Irene Bueno
Bristol Veterinary School
University of Bristol
Langford, Bristol, UK
E: irene.bueno@bristol.ac.uk

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of AMR (e.g., 4–6). For animal-based surveys, the main focus has either been on livestock due to the direct relationship with humans through the food chain (e.g., 7, 8), or companion animals (namely dogs and cats) (e.g., 9–11).

In contrast, there has been little effort to gather information on the practices and opinions of individuals providing veterinary care to wildlife. Wildlife undergo medical care in permanent settings such as zoo collections or sanctuaries, or in more temporary situations such as wildlife rehabilitation facilities where the ultimate goal is the release of these animals back to the wild.[12] In the United States (U.S.) alone, it is estimated that hundreds of thousands of sick, injured, or orphaned animals are presented for rehabilitation every year. [12] The size of the operations, level and experience of professionals involved, and the regulatory environment vary widely. Specifically, facilities can range from small, local operations run by volunteers or a few staff members, to large facilities with extensive resources and professional staff. Funding sources also vary, with most facilities relying on small public donations or grants, while others may also receive government support or operate as part of larger, often non-profit, organizations.

These differences may significantly impact AMU practices, as larger, better-funded facilities may have more resources to implement comprehensive antimicrobial stewardship programs, while smaller facilities with limited funding may face greater challenges in accessing and implementing them. Guidelines put forward by the International Wildlife Rehabilitation Council and National Wildlife Rehabilitators Association acknowledge that in most states, veterinarians are legally responsible for prescribing medical care for wildlife patients and can delegate some responsibilities to rehabilitators through "mutually agreeable" written protocols.[13] However, these guidelines do not include specific treatment protocols, such as which antibiotics to use at what dosage, frequency, and duration for which circumstances. Thus, AMU may vary significantly between rehabilitation facilities based on individual preferences and experiences of the attending veterinarian(s) and staff.

The potential diversity in AMU practices within wildlife rehabilitation facilities prompts critical examination of the possible implications, including the selection for AMR and subsequent introduction of antimicrobial resistant bacteria (ARB) into natural ecosystems upon release of the rehabilitated host.[14] Indeed, wild animals may act as reservoirs for AMR and are thought to contribute to the spread of AMR in the environment.[14–16] Birds, in particular, are hypothesized to play a role in AMR dissemination as many species are in close contact with anthropogenic environments (e.g., gulls, Canada geese) and can travel vast geographic distances during migration.[14–16]

Currently, AMR has been studied in wildlife rehabilitation settings in different parts of the world, highlighting the role these facilities play in terms of AMR surveillance (e.g., 17–20). However, our understanding of the possible contribution of rehabilitation facilities to AMR emergence and spread into the wide environment is lacking. A further consideration of AMU in rehabilitation settings is the negative impact antimicrobials may have on the host gut microbial community (i.e., the "gut microbiome").[21] Antimicrobial therapy can lead to a reduction in microbial diversity, altered composition, and selection for resistant opportunistic pathogens, which may alter host digestion, nutrient absorption, and immunity homeostasis.[22,23] Ultimately, these changes to the gut microbiome could affect the health and fitness of the reintroduced wild animal.[21]

In an effort to mitigate the negative side effects of antimicrobials and improve overall host health, some rehabilitation facilities employ probiotics, which are defined as "live microorganisms that confer health benefits to the host when administered in adequate amounts."[24] Probiotics have been shown to enhance overall well-being and resilience in both domestic and wild animals[25,26] and have demonstrated great potential in disease mitigation and reducing the negative effects of stress, environmental changes, and antimicrobial treatments on wild animals.[25,27,28] However, similar to the lack of standardized AMU guidance, there are no established protocols or guidelines regarding the use of probiotics in wildlife rehabilitation facilities.

Given the limited availability of data concerning the application of antimicrobials and probiotics in wildlife rehabilitation and the importance of antimicrobial stewardship for ongoing efforts to combat AMR, the goal of this study was to investigate antimicrobial and probiotic use practices within wildlife rehabilitation facilities in the United States. Due to the potential role birds play in the dissemination of AMR and the fact that they comprise approximately half of all cases at wildlife rehabilitation facilities,[29,30] particular focus was given to facilities treating birds. The findings of this survey represent a first step towards understanding trends in antimicrobial and probiotic use in wildlife rehabilitation and can serve as a foundation for the development of antimicrobial stewardship initiatives tailored to treatment of captive wildlife.

Methods

Ethics Approval

This study was approved by the Institutional Review Board (IRB) of the University of Minnesota (STUDY00015087). Answers to the survey questions were anonymous.

Study Design

A cross-sectional survey was conducted in 2022 (February–March) to obtain data on antimicrobial and probiotic use within U.S. wildlife rehabilitation. The inclusion criteria for survey recipients consisted of a) permitted U.S. wildlife rehabilitators, b) wildlife facilities that admitted birds, and c) wildlife facilities that were not volunteer run. The list of recipients was obtained through the "Partners for Wildlife" program[31] and reflected all the wildlife rehabilitation facilities in the program's seven state focus area (WI, MN, ND, ID, MT, WA, AK) that met the inclusion criteria. The survey was intended to capture information per wildlife facility,

so if there were several permit holders within one facility, only one of them was requested to answer the survey.

The survey was written in English by the research team (EAM, RA, JP, IB), designed using Web-based survey software (Qualtrics, Provo, UT), and consisted of five sections (general information, antibiotic and antifungal use, disinfectant use, probiotic use, and perceptions about AMR and antimicrobial use) for a total of 26 questions. The questions included open-ended, multiple choice, yes/no, and 5-point Likert scale (from strongly agree to strongly disagree). The approximate time to complete the survey was estimated to be between 15 and 20 minutes. None of the questions were set as mandatory to be completed and questions could be skipped.

An email containing a cover letter explaining the project and a link to the survey in Qualtrics was sent to the survey recipients. An option to send the survey in paper format was also provided. The complete survey is available as supplemental material to this manuscript (S1 File). Prior to sending the final version, the survey tool was beta tested by five wildlife rehabilitators and subsequently improved based on their feedback. After sending the final survey (launched on February 21st, 2022), two weekly email reminders were sent to recipients, allowing a total of three weeks to submit responses.

Data Analysis

All data analyses were conducted within R, version 4.1.2 (R Core Team, 2020). Due to the small number of responses in some categories, response variables for some questions were recoded as either fewer categorical variables or a binary "Yes/No" response. Average annual bird admission number was used as a proxy for overall facility size, with admission ranges grouped into three categories (i.e., sizes) for further analyses: small (0–50 birds admitted annually), medium (51–500 birds admitted annually), and large (501–5000 birds admitted annually). These groupings were based on how the Partners for Wildlife initiative categorizes facilities in their database and generally reflects size of facilities (individual home rehabilitator, small volunteer-led facilities, and larger centers with paid staff).

The linear-by-linear association test with an asymptotic approximation of the exact distribution was used to test for a linear trend between two ordered categorical variables or between ordered categorical and binary variables. Tests were conducted using the *lbl_test()* function from the R package coin, version 1.4–2.[32] Pearson's chi-square test with an asymptotic approximation of the exact distribution was used to test for a trend between two binary variables. Tests were conducted using the *chisq_test()* function from the R package coin. Statistical significance was defined with an α level of 5% and Benjamini-Hochberg adjusted P-values were calculated to correct for multiple testing where applicable. All plots were generated using the R package ggplot2, version 3.3.6.[33]

Results

Invitations to participate in the study were sent to 105 permitted wildlife rehabilitation facilities. A total of 54 responses were received, for a response rate of 51.4% (54/105). The survey was anonymous, and thus no identifiable information regarding individual characteristics of the respondents (e.g., demographics) or the wildlife facility itself (e.g., location) were included in the questionnaire.

Of the 54 responses, 46 (85.2%) treated birds, 33 (61.1%) treated mammals, 21 (38.9%) treated reptiles, 16 (29.6%) treated amphibians, and two (3.7%) treated invertebrates. None of the facilities treated fish. One facility did not respond to all the survey questions and was thus excluded from further analyses. Given the proposed importance of wild birds in the spread of AMR, we pared our dataset down to the 45 facilities that treated birds either exclusively or in addition to other animals (henceforth referred to as "all-taxa facilities"). Of those 45 facilities, 18 (40.0%) only treated birds (henceforth referred to as "bird-only facilities"), while the remaining 27 also treated mammals (n = 26; 57.8%), amphibians (n = 15; 33.3%), reptiles (n = 19; 42.2%), and/or invertebrates (n = 2; 4.44%) (Table 1). Facilities treated a range of bird groups, with 41 (91.1%) treating raptors, 38 (84.4%) small birds, 29 (64.4%)

TABLE 1. GENERAL INFORMATION ABOUT THE WILDLIFE REHABILITATION FACILITIES INCLUDED IN THE SURVEY.

CHARACTERISTIC	ALL-TAXA FACILITIES[a] (N = 45)		BIRD-ONLY FACILITIES (N = 18)	
	N	%	N	%
TYPE OF WILDLIFE				
Birds	45	100		
Mammals	26	57.8		
Amphibians	15	33.3		
Reptiles	19	42.2		
Invertebrates	2	4.44		
Fish	0	0.00		
ANNUAL BIRD ADMISSIONS RANGE[b]				
0–10	5	11.1	2	11.1
11–50	3	6.67	2	11.1
51–100	8	17.8	3	16.7
101–500	15	33.3	6	33.3
501–1000	6	13.3	3	16.7
1001–5000	8	17.8	2	11.1
ACCESS TO VETERINARIAN(S)				
Yes	43	95.6	17	94.4
No	2	4.44	1	5.56

[a]Facilities that treated birds in addition to other animals, including mammals, amphibians, reptiles, and/or invertebrates.

[b]Bird admission number ranges were grouped into three categories for statistical analyses: small (0–10, 11–50), medium (51–100, 101–500), and large (501–1000, 1001–5000).

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waterfowl, 27 (60%) shorebirds, and one (2.2%) seabirds. There were nine facilities that limited specialized treatment to treating only one group of birds: raptors (n = 7; 15.56%) and small birds (n = 2; 4.44%).

When asked about the average number of bird admissions in a typical pre-pandemic year, the ranges varied from 1–10 birds annually (n = 5; 11.1%) up to 1001–5000 birds annually (n = 8; 17.8%) (Table 1). The majority of facilities received between 101–500 birds annually (n = 15; 33.3%). Access to one or more veterinarians was reported by all but two (n = 43; 95.6%) of the facilities (Table 1), with both facilities without veterinary access reporting annual bird admissions between 51–100 birds.

Antimicrobial Use

All 45 facilities (100%) reported use of antimicrobials (antibiotics, antifungals, and/or antivirals) for treatment of admitted animals. Of those, 62.2% (28/45) had antibiotic use protocols written by veterinarians (Table 2). For the subset of bird-only facilities, antibiotic use protocols were reported by 50.0% (9/18) of respondents. Overall, large facilities (based on reported annual bird admission numbers) were significantly more likely to have antibiotic use protocols than medium or small-sized facilities (all-taxa: $p = 0.020$, bird-only: $p = 0.10$).

Compared to antibiotic protocols, written protocols for antifungal use were less common, with 44.4% (20/45) of all-taxa facilities and 38.9% (7/18) of bird-only facilities having them in place (Table 2). Bird admissions were significantly associated with the presence of antifungal use protocols, with larger facilities more likely to have antifungal use protocols than smaller facilities (all-taxa: $p = 0.0015$, bird-only: $p = 0.082$).

All facilities (100%) reported obtaining information about antibiotic and antifungal use from veterinarians, but other sources for information were also used, including peer-reviewed literature (all-taxa: 68.9%; bird-only: 55.6%), continuing education literature (all-taxa: 80.0%; bird-only: 77.8%), other rehabilitators (all-taxa: 64.4%; bird-only: 50.0%), and the internet (all-taxa: 66.7%; bird-only: 55.6%) (Table 2).

Respondents reported a number of factors that contributed to their facility's decision-making concerning use of antimicrobials, with condition treated cited as the most common factor across both all-taxa (93.3%; 42/45) and birds-only (88.9%; 16/18) facilities (Fig. 1). While 66.7% (30/45) of the all-taxa facilities (50.0% [9/18] of bird-only facilities) reported performing some capacity of bacterial culture and sensitivity diagnostic testing, not all of those facilities said bacterial culture and sensitivity results influenced their decision to use antimicrobials (all-taxa: 48.9% [22/45]; bird-only: 27.8% [5/18]). Cost was also reported as a factor to be considered for 40.0% (18/45) of all-taxa facilities and 38.9% (7/18) of bird-only facilities.

The conditions most commonly treated with antibiotics were bite wounds and open fractures, with 53.3% (24/45) and 73.3% (33/45) of facilities, respectively, using antibiotics in 100% of these circumstances (44.4% and 72.22% for bird-only facilities)

TABLE 2. ANTIMICROBIAL USE IN WILDLIFE REHABILITATION FACILITIES INCLUDED IN THE SURVEY.

INFORMATION	ALL-TAXA FACILITIES[a] (N=45)		BIRD-ONLY FACILITIES (N=18)	
	N	%	N	%
Written antibiotic use protocols				
Yes	28	62.2	9	50.0
No	17	37.8	9	50.0
Written antifungal use protocols				
Yes	20	44.4	7	38.9
No	25	55.6	11	61.1
AMU expenses				
0–5%	24	53.3	10	55.6
6–10%	5	11.1	2	11.1
11–30%	5	11.1	2	11.1
Unknown	11	24.4	4	22.2
Bacterial culture and sensitivity testing				
Yes	30	66.7	9	50.0
No	15	33.3	9	50.0
Factors affecting decision-making to stop AMU				
Adverse reaction	27	60.0	10	55.6
Antimicrobial resistance	18	40.0	7	38.9
Bacterial culture/ sensitivity results	19	42.2	4	22.2
Cost	6	13.3	1	5.60
Veterinarian recommendation	1	2.22	0	0.00
Pre-made protocol by veterinarian	19	42.2	5	27.8
Recommended duration	40	88.9	16	88.9
Resolution of clinical signs	34	75.6	13	72.2
Source of information about AMU				
Continuing education courses	36	80.0	14	77.8
Internet	30	66.7	10	55.6
Other rehabilitators	29	64.4	9	50.0
Peer reviewed literature	31	68.9	10	55.6
Social media	0	0.00	0	0.00
Veterinarians	45	100	18	100

AMU, antimicrobial use.

[a]Facilities that treated birds in addition to other animals, including mammals, reptiles, amphibians, and/or invertebrates

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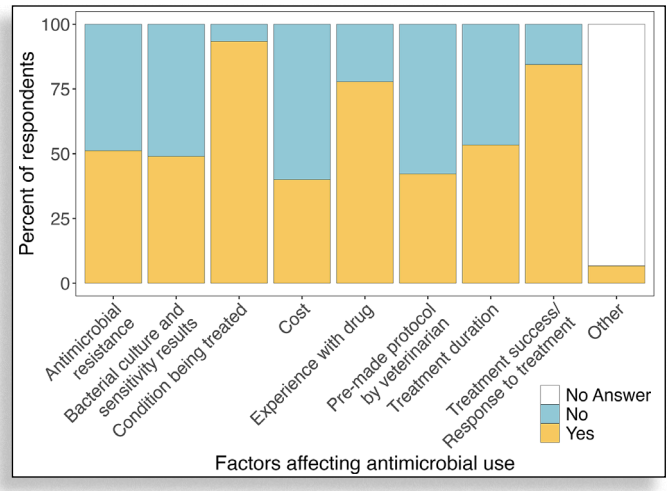


FIGURE 1. Factors that contributed to wildlife rehabilitation facilities decision to use antimicrobials.

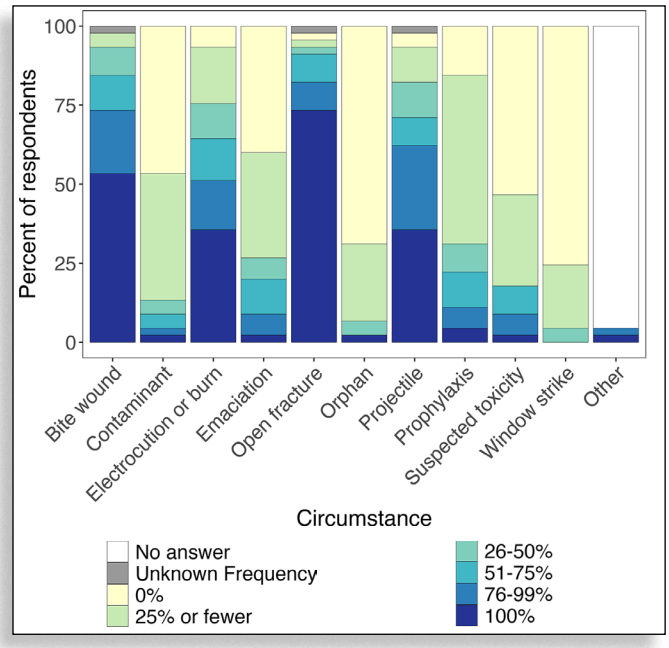


FIGURE 2. Conditions for which wildlife rehabilitation facilities used antibiotics.

(Fig. 2). More than 20% (10/45) of all facilities (33.3% [6/18] of bird-only facilities) reported using antibiotics for prophylaxis in at least 50% of cases. Only 15.6% (7/45) of facilities (27.8% [5/18] of bird-only facilities) reported never using antibiotics for prophylaxis. Size of the facility was not significantly associated with the frequency antibiotics were used as treatment for any of the listed conditions (all adjusted $p > 0.05$).

Overall use of antifungals was lower than use of antibiotics. The condition most commonly treated with antifungals was respiratory diseases, with 11.1% (5/45) of all-taxa facilities (11.1% [2/18] of bird-only facilities) using them in 100% of these cases. Use of antifungals for prophylaxis was considerably less common than for antibiotics with only 40.0% (18/45) of facilities (50.0% [9/18] of bird-only facilities) reporting never using antifungals for prophylaxis. Further, larger facilities were significantly more likely to use antifungals for prophylaxis (adjusted $p = 0.021$) and in cases of emaciation (adjusted $p = 0.023$).The factors most commonly reported as affecting a facility's decision to stop antimicrobial treatment were the recommended duration (all-taxa: 88.9% [40/45]; bird-only: 88.9% [16/18]) followed by the resolution of clinical signs (all-taxa: 75.6% [34/45]; bird-only: 72.2% [13/18]) (Table 2). Cost was indicated as a factor affecting when to stop antimicrobial treatment for 13.3% (6/45) of all facilities (5.6% [1/18] of all-bird facilities). Larger facilities were significantly more likely to consider veterinarian-written AMU protocols with set time frames than smaller facilities (adjusted $p = 0.034$).

The most commonly used antibiotic drugs were enrofloxacin and amoxicillin-clavulanic acid, with more than 40% of all-taxa facilities (over 30% of bird-only facilities) reporting use of them "frequently" or "very frequently" (Fig. 3). Trimethoprim/ sulfamethoxazole (TMPS) was also used "frequently" or "very frequently" in over 30% of all-taxa facilities (16.7% of all-bird facilities). Gentamicin was either "rarely" used (all-taxa: 53.3% [24/45]; bird-only: 38.9% [7/18]) or "never" used (all-taxa: 44.4% [20/45]; bird-only: 61.1% [11/18]). Larger facilities were significantly more likely than medium or small ones to use amoxicillin-clavulanic acid, TMPS, and metronidazole (all adjusted $p = 0.041$). Additional antibiotics listed by respondents in the "Other" category included third-generation cephalosporins (n = 4), penicillin (n = 2), and clindamycin (n = 5).

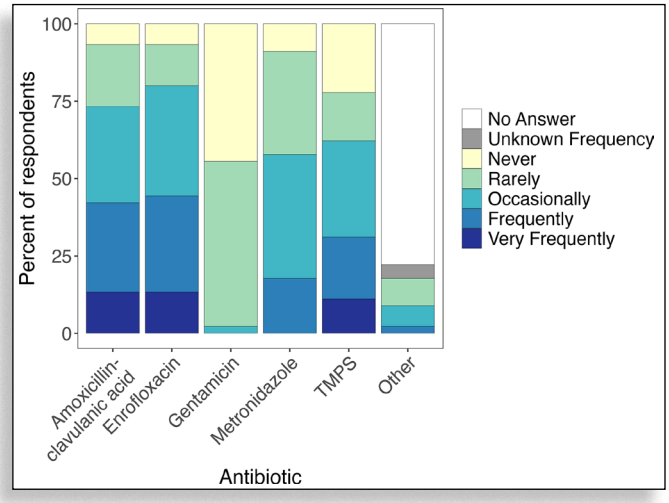


FIGURE 3. Antibiotics used by the wildlife rehabilitation facilities.

For antifungals, itraconazole was the most commonly used, with 4.4% (2/45) of facilities using it "very frequently," 15.6% (7/45) using "frequently," and 37.8% (17/45) using "occasionally" (5.6%, 11.1%, and 27.8% for bird-only facilities, respectively). Other listed antifungals, including voriconazole, terbinafine, and nystatin, were typically used (>50% of facilities) "rarely" or "never" by facilities.

Probiotic Use

Out of the 45 facilities, 66.7% (30/45) reported using probiotics, including 50% (9/18) of the bird-only facilities. Of those facilities

that used probiotics, the most commonly used ("frequently" or "very frequently") were PetAg Bene-Bac Plus® (all-taxa: 50%; bird-only: 33.3%), followed by Fox Valley (all-taxa: 30%; bird-only: 0%) (Fig. 4). Plain yogurt was also used "frequently" or "very frequently" by 30% of facilities (11.1% of all-bird facilities). The most frequent use of probiotics was for diarrhea and emaciation, followed by concurrent antibiotic use and constipation (Fig. 5). Five facilities (16.7%), including two all-bird facilities (22.2%), reported giving probiotics in some capacity as a calming agent.

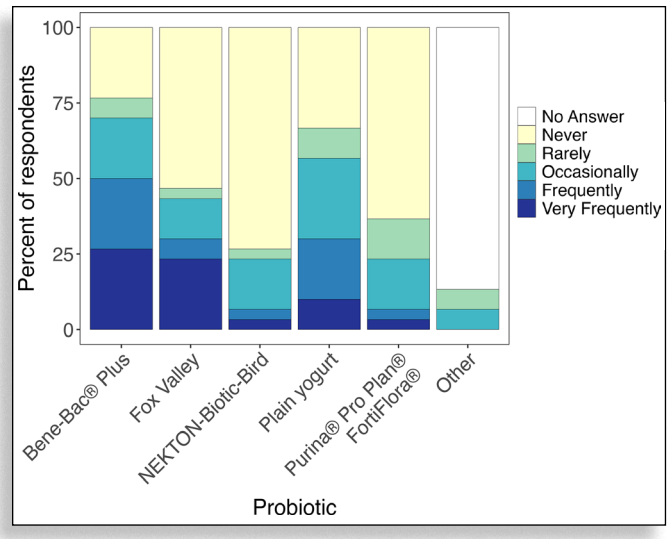


FIGURE 4. Probiotics used by the wildlife rehabilitation facilities.

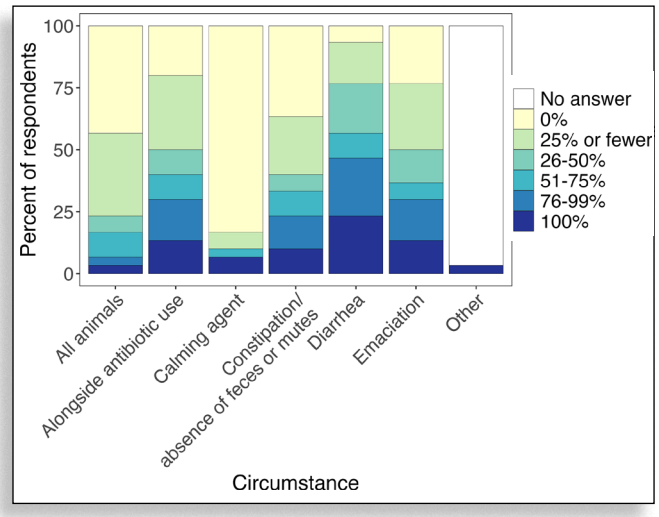


FIGURE 5. Conditions for which wildlife rehabilitation facilities use probiotics.

Disinfectant Use

All 45 facilities reported using disinfectants for cleaning. Among the disinfectant types, 11 facilities reported using at least one type of quaternary ammonium compound (QAC), specifically Roccal D (n = 5, 11.6%), Parvosol (n = 3, 6.9%), Kennel Kare (n = 1, 2.3%), Chlorhexidine (n = 2, 4.7%), HDQ Neutral (n = 1, 2.3%), Basic-G (n = 1, 2.3%), and KennelSol (n = 1, 2.3%). The majority of those facilities used the QACs daily (n = 8, 72.7%).

Perception and Knowledge About AMR and AMU

Out of the 45 respondents, 77.8% (35/45) "somewhat agreed" or "strongly agreed" that their facility would benefit from having standardized antimicrobial and antifungal guidelines (Fig. 6). When asked if the facility had general knowledge of AMR in relation to antibiotic and antifungal use, 82.2% (37/45) "somewhat agreed" or "strongly agreed" with the statement. Interestingly, while only 11.1% (5/45) agreed ("strongly" or "somewhat") that AMR was a problem at their facility, 53.3% (24/45) agreed that AMR posed a high risk for the wildlife rehabilitation field as a whole. Of the 30 respondents who reported using probiotics in their facilities, 56.7% (17/30) agreed that probiotics improve a patient's clinical outcome.

Discussion

In this study, we used a cross-sectional survey to investigate antimicrobial and probiotic use practices in wildlife rehabilitation in the U.S., with special focus on those facilities that treated birds. The response rate of 51.4% is fairly decent and can even be considered above average for online surveys.[34] However, this response rate could have been influenced by the enhanced commitment of wildlife rehabilitators toward improving animal welfare, as well as AMR being a frequently discussed topic within the sector. Indeed, given participation in the survey was voluntary, one of the main limitations of this study is the potential overrepresentation of facilities with stronger interest in the topics of AMU, AMR, and probiotics.

Results may also not be representative of the entire U.S. rehabilitation community given that wildlife facilities were selected based on specific criteria (i.e., permitted, not volunteer run), which may have restricted inclusion to those with more veterinary access. The focus on rehabilitation facilities that admit birds could also have skewed our findings, potentially overlooking valuable data from other facilities, such as those that only treat mammals. That being said, the subset of 45 wildlife rehabilitation facilities we included in our study reported a wide range of practices and perspectives, offering valuable insights despite potential limitations in generalizability to the entire U.S. (and global) rehabilitation community.

In our study, antimicrobials (specifically antibiotics and antifungals) were used in all facilities with more or less frequency and for a variety of reasons. The reported use of antimicrobials prophylactically was of particular interest given the general veterinary recommendation to avoid prophylactic use of antimicrobials whenever possible.[35] Among specific antibiotics, amoxicillin-clavulanic acid and enrofloxacin were routinely used across all facilities. These are among the most commonly used antibiotics in small animals worldwide[36] and have been reported as frequently used by veterinarians in other surveys as well.[10]

Enrofloxacin in particular is widely prescribed for the treatment of both domestic and exotic pet birds.[37–39] This drug belongs to the fluoroquinolone class, and although it is not used

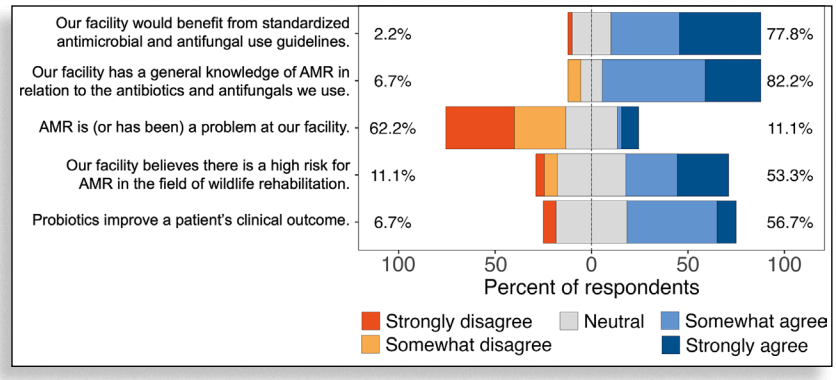


FIGURE 6. Respondents' opinions about different aspects related to antimicrobial resistance and antimicrobial and probiotic use in wildlife rehabilitation.

in humans, similar compounds within the same class (e.g., ciprofloxacin) are classified under the "Watch" category established in the AWaRe (Access, Watch, Reserve) classification by WHO.[40] This group includes antibiotics considered "Critically Important for Human Medicine" and/or those that have a higher potential of selection of ARB.[40] Within the U.S., the use of fluoroquinolones is highly restricted in animals and is not approved for any extra label use in food-producing animals due to concerns of increasing antimicrobial resistant pathogens.[41] This includes prohibition of fluoroquinolones such as enrofloxacin in rehabilitated wild animals if the animal "has any possibility of being hunted or harvested for food by a human" (i.e., minor food animal species).[42,43]

Under the same regulations, use of metronidazole in wild minor food animal species is also prohibited,[42,43] yet more than 90% of surveyed facilities reported using the drug. Three facilities also reported using third-generation cephalosporins, which are permitted for use in wild animals in the U.S.[42, 43] but do fall within the WHO's AWaRe "Watch" category.[40] The remaining antibiotics fell into the AWaRe "Access" category, which are those drugs that show lower antibiotic resistance potential.[40] While some U.S. rehabilitation facilities have stopped all use of restricted drugs in response to government regulations, the high number of facilities reporting the use of enrofloxacin and metronidazole in the current study suggests there is clearly a need to reevaluate some antibiotic usage practices within rehabilitation facilities. A limitation of this study is that we did not ask respondents to identify which species they use various antimicrobials in or their familiarity with restrictions in wild minor food animal species.

Interestingly, approximately one third of facilities reported not performing any bacterial culture and sensitivity testing. An additional 51% of facilities that did conduct bacterial culture and sensitivity testing said that the results of those diagnostics were not considered when making decisions concerning antimicrobial use. Antimicrobial sensitivity testing determines the effectiveness of the chosen antimicrobials against the bacterial strains cultured. This information is not only vital for accurate diagnosis and provision of appropriate targeted treatments for patients but is also necessary information for developing appropriate antimicrobial use guidelines.[44]

In addition to antibiotic use, results from this survey also provided a general overview of antifungal and QAC applications in rehabilitation facilities. Among antifungals, itraconazole use was frequently reported. This drug is routinely used for prevention and treatment of aspergillosis, one of the most common fungal diseases affecting avian species in captivity.[45–47] This likely explains why our survey found that facilities with higher bird admissions were more likely to use antifungals for prophylaxis and emaciation and were more likely to have antifungal protocols in place compared to facilities with fewer bird admissions. Even though research and AMR guidelines have mostly focused on resistant bacteria, antifungal resistance is a rising concern in human health.[48] Yet, there is limited understanding of the potential emergence of antifungal resistance, particularly concerning the role that wild birds might play in disseminating azole-resistant strains (azoles such as itraconazole).[49]

For QACs, only about 25% of respondents reported using QAC disinfectants to clean their facilities. QACs are common ingredients in cleaning products, such as disinfectants, due to their broad-spectrum antimicrobial properties.[50] However, QACs can potentially select and enrich for ARB through different mechanisms, sparking concern over possible adverse environmental and human health impacts.[50–52] While real-world evidence for the use of QAC disinfectants promoting AMR emergence is still quite sparse,[51] QACs should be considered in future assessments of AMR in wildlife rehabilitation until more comprehensive studies can provide a better understanding of the link between QACs and AMR.

To date, there are no antimicrobial stewardship policies specific to wildlife species in rehabilitation settings. Yet AMU guidelines would be beneficial given that animals often present with severe traumatic injuries, requiring intensive treatment frequently requiring antimicrobials. This was highlighted in the survey by the high frequency some case types were treated with antibiotics, including bite wounds, open fractures, projectiles, and burns. Examples of AMU guidelines are becoming increasingly common in veterinary settings, especially for treatment of food-producing and small domestic animals.[35, 53] Further, the evaluation of antimicrobial prescribing practices before and after implementation of such guidelines shows a decline in AMU and a shift towards the use of less clinically important antibiotics.[54–56] The wide range of AMU practices observed in this study suggests there is a need to develop standardized AMU guidelines specifically for wildlife rehabilitation settings. This is highlighted by our findings that larger facilities, which may have access to more resources, were more likely to have and utilize AMU protocols written by veterinarians than smaller facilities. Overall, given the high number of respondents who said their facilities would benefit from standardized antimicrobial and antifungal guidelines, we believe formal AMU guidelines would be well-received within

the entire rehabilitation community.

Probiotic use was reported in more than half of the facilities surveyed. Probiotic therapy is increasingly used in human medicine and domestic animals to modulate the gut microbiota and host immune system with the goal of improving host health.[57–59] In particular, probiotics can be used to treat specific diseases as an alternative to antibiotics or chemotherapy or used in conjunction with antibiotics to mitigate the negative gastrointestinal side effects.[60, 61] In food animals, including ruminants, poultry, and swine, probiotics are frequently used as nutritional supplements or feed additives for both disease prevention and improved performance, such as growth promotion.[57, 61, 62] Similarly, there are a wide range of commercial probiotic products available for use in companion animals, particularly dogs and cats, for a variety of health benefits.[59] In contrast, research of probiotic applications in wild animals is in the early stages of validation, standardization in approaches, and risk assessment.[27] A small number of studies provide promising evidence that probiotics can be used for wildlife disease treatment and management. Laboratory assessments and field trials in bees, bats, and amphibians showed probiotic applications can lead to host improvements in immune response, increased survivorship, and reduced pathogen load and disease severity.[28,63] Further, data extrapolated from humans and domestic animals suggest probiotics may be useful in wild animals for mitigating the negative effects of captivity including environmental and dietary changes, stress, and antimicrobial treatments.[27, 28] Among the facilities surveyed in this study, probiotics were reportedly used for a wide range of circumstances, from treatment of diarrhea to calming agents. Yet only 56.7% (17/30) of those agreed that probiotics had a positive clinical outcome in their patients. The remaining facilities using probiotics either were neutral or strongly disagreed with probiotic effectiveness. This disjuncture between facility probiotic practices and practitioner beliefs warrants further attention in the future.

The specific types of probiotics facilities reported using are also worth addressing. When selecting probiotic candidates, host specificity is an important criterion due to host differences in anatomy (e.g. complexity of GI tract), metabolism, immune function, and resident microbiota.[64, 65] Bacterial strains that have coevolved with a host species may be better able to colonize and persist in that respective host compared to strains derived from distantly related species.[66, 67] Probiotics used by the facilities appeared to be largely non-host-specific and thus it is unclear whether they are suitable for the animal species being treated. For example, 11 facilities, including three bird-only facilities, reported using Purina® Pro Plan® Forti-Flora® probiotics, which include products formulated for use in canines and felines. To our knowledge, there are no studies of these products in other species, including small wild mammals and birds. Plain yogurt was also reportedly used in 20 facilities, including four all-bird facilities. However, standard yogurt likely provides little benefit to the host because the starter bacteria (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) typically do not survive and colonize the GI tract.[68] Further, while there is some evidence that commercially available probiotic-enriched yogurt is beneficial for human health,[69] there has been little investigation into the efficacy of yogurt as a probiotic in other species beyond animal models and poultry.[70–73] In the best-case scenario, administration of unsuitable probiotics may simply provide no benefit to the treated host. In the worst case, inappropriate probiotic use may result in negative health consequences, including systemic or localized infections, metabolic disturbances, excessive immune stimulation in susceptible individuals, or transmission of antibiotic resistance genes.[74, 75] Clearly, there is a strong need for further research into the efficacy of probiotics currently being used in captive wildlife and development of host-specific probiotics.

Moving forward, there are some insights gained from this survey. First, the use of probiotics is quite widespread in wildlife facilities despite there being little evidence of their efficacy and the lack of species-specific products. Second, aside from antibiotics from clinically relevant antibiotic classes, antifungals and QACs are also commonly used. All of these antimicrobials need to be considered when assessing the emergence of AMR in wildlife settings and its potential spread into the environment. Finally, survey respondents stated that they would benefit from having standardized antimicrobial use guidelines in place. Quantifying the use of antimicrobials and probiotics, which is something this survey did not address, could be a relevant next step towards that goal. This should also include plans to monitor changes in antimicrobial and probiotic use over time to evaluate the effectiveness of any new implemented guidelines.[44] Additionally, more targeted training for veterinarians and wildlife professionals on AMU and probiotic use in wildlife rehabilitation would be beneficial. This would be especially helpful given the resource-limitations of many wildlife facilities and the varying degrees of direct veterinary involvement in the day-to-day medical care of wildlife patients. Ultimately, implementing use guidelines could improve therapeutic strategies for wildlife species while also promoting the prudent use of antibiotics and other microbial interventions.

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EUROPEAN MOOSE (*Alces alces*)

Where there are moose (*Alces alces*) in Eurasia, there are moose nose botflies: First morphological and molecular identification of *Cephenemyia ulrichii* (Brauer, 1862) in Kazakhstan

Bauer C, Uakhit R, Smagulova A, Jazina K, Lyalchenko A et al. Int J Parasitol Parasites Wildl. 2025;27(101086):101086. https://doi.org/10.1016/j.ijppaw.2025.101086

In recent years, the Eurasian moose (*Alces alces)* population in Kazakhstan has increased significantly. According to 2024 estimates, there are now approximately 8960 individuals, primarily in the northern and eastern regions of the country. However, there is limited information on moose parasites in Kazakhstan. Four of seven moose hunted in the Akmola and Kostanay provinces in July 2023 and May 2024 were found to be infested with 8–12 dipterous fly larvae in the nasopharynx. The larvae were morphologically identified as *Cephenemyia ulrichii* (Oestridae: Oestrinae) third-instar larvae. Molecular characterization through polymerase chain reaction amplification and partial sequencing of the mitochondrial cytochrome oxidase subunit I gene from the larvae showed that it was 99 % identical to a reference *C. ulrichii* isolate from Sweden. The gene sequences of the Kazakh isolates clustered in a clade with the reference sample, distinct from other *Cephenemyia* species. This is the first report of *C. ulrichii* nasopharyngeal myiasis in moose in Kazakhstan, marking the first such report in Central Asia and expanding the known geographical range of this parasite.

Survival of white-tailed eagles tracked after rehabilitation and release

Rozsypalová L et al. J Raptor Res. 2024;59(1):1–16. https://doi.org/10.3356/jrr2417

There are many raptor rehabilitation centers around the world that receive and care for wild raptors. Wildlife rehabilitation is a labor- and cost-intensive part of addressing animal welfare. Apart from the compassionate aspect of taking responsibility for an injured animal, there remains an open question as to whether doing so contributes to animal conservation. The fates of such animals after their rehabilitation and release have rarely been studied. Long-term post-release monitoring is needed to assess survival and reproduction. Here, we investigate the post-release fates of 22 White-tailed Eagles (*Haliaeetus albicilla*), including juveniles, immature birds, and adults in Austria, the Czech Republic, Germany, and Slovakia. Using GPS tracking, we monitored the eagles for 2–2639 d (median = 340 d) between 2005 and 2023. The longest-surviving eagle was tracked for more than 7 yr. Release was followed by a short 6-d period of high mortality, followed in turn by a long-term annual adult survival rate of 74.6%. Anthropogenic factors contributed to 70% of the long-term mortality cases. Reason for admission, length of hospital stay, and use of flight aviaries had no statistically significant effect on long-term survival. Five eagles successfully bred and produced a total of 10 fledglings. Traveling as much as 1378 km, the released eagles dispersed throughout central, northern, and eastern Europe. Thus, it can be concluded that successful rehabilitation of White-tailed Eagles resulted in high survival rates; and in five cases, successful reproduction indicated effective reintegration into the wild population.

Examining inter-regional and intra-seasonal differences in wintering waterfowl landscape associations among Pacific and Atlantic flyways

Hardy MJ, Williams CK, Ladman BS, Pitesky ME, Overton CT et al. J Avian Biol. 2025;2025(3):e03296. https://doi.org/10.1111/jav.03296

The Central Valley of California (CVC) and Mid-Atlantic (MA) in the U.S. are both critical sites for nationwide food security, and many waterfowl species annually, especially during the winter, providing feeding and roosting locations for a variety of species. Mapping waterfowl distributions, using NEXRAD, may aid in the adaptive management of important waterfowl habitat and allow various government agencies to better understand the interface between wild and domestic birds and commercial agricultural practices. We used 9 years (2014–2023) of data from the US NEXRAD network to model winter waterfowl relative abundance in the CVC and MA as a function of weather, temporal period, environmental conditions, and landcover characteristics using boosted

regression tree modelling. We were able to quantify the variability in effect size of 28 different covariates across space and time within two geographic regions which are critical to nationwide waterfowl management and host a high density of nationally important commercial agriculture. In general, weather, geographic (distance to features), and landcover condition (wetness index) predictors had the strongest relative effect on predicting wintering waterfowl relative abundance in both regions, while effects of land cover composition were more regionally and temporally specific. Increased daily mean temperature was a major predictor of increasing relative waterfowl abundance in both regions throughout the winter. Increasing precipitation had differing effects within regions, increasing relative waterfowl abundance in the MA, while decreasing in general within the CVC. Increasing relative waterfowl abundance in the CVC are strongly tied to the flooding of the landscape and rice availability, whereas waterfowl in the MA, where water is less limiting, are generally governed by waste grain availability and emergent wetland on the landscape. Waterfowl relative abundance in the MA was generally higher nearer to the Atlantic coast and lakes, while in the CVC they were higher nearer to lakes. Our findings promote a better understanding of spatial associations of waterfowl to landscape features and may aid in conservation and biosecurity management protocols.

Between- and within-population drivers of haemosporidian prevalence and diversity in American robins *Turdus migratorius*

Jahn AE, de Angeli Dutra D, Bell JA, Dispoto JH, Fecchio A et al. J Avian Biol. 2025(3):e03430. https://doi.org/10.1002/jav.03430

Avian haemosporidians are a diverse group of parasites that infect birds worldwide and have been a major focus of research for decades. Yet, few studies have identified the drivers of infection at the intraspecific host level. We aimed to study the drivers of prevalence and diversity of haemosporidian parasites infecting a common North American songbird species, the American robin Turdus migratorius, which breeds across most of the continent. We found little seasonal variation in haemosporidian prevalence in robins, although we detected a significantly positive relationship between robin breeding latitude and co-infection with different haemosporidian parasite lineages. Additionally, robins infected with Plasmodium had substantially better body condition than uninfected robins, which could be due to migratory culling. We detected 31 haemosporidian lineages among the robins we sampled, of which eight were novel. When matched against known haemosporidian lineages, our results suggest that robins harbor a higher diversity of haemosporidian parasites than previously known. The results of this study suggest that comparisons of common, widespread bird species such as robins across their range could help unveil novel aspects of the haemosporidian–host relationship and how such a relationship may change under current and future rapid environmental change.

Fatal babesiosis in a free-ranging Iberian wolf co-infected with *Hepatozoon canis* and *Leishmania infantum*: Epidemiological Implications for the Cantabrian Wolf Population

Fayos M et al. Int J Parasitol Parasites Wildl. 2025;(101080):101080. https://doi.org/10.1016/j.ijppaw.2025.101080

Health surveillance of large carnivores, such as the Iberian wolf (*Canis lupus signatus*), allows the early detection of emerging and established pathogens in natural environments, due to their position in the top of the food chain. In 2022, the carcass of a wild wolf was found in Cantabria, Northwest Spain. A complete post-mortem investigation, including full necropsy, histopathological and molecular analysis concluded that the cause of death was a systemic hemolytic disease caused by *Babesia canis*. Furthermore, the wolf was co-infected with *Hepatozoon canis* and *Leishmania infantum*. Consequently, a molecular investigation of *Babesia* spp., *Hepatozoon* spp., *Leishmania* spp., *Ehrlichia* spp., *Anaplasma* spp., and *Rickettsia* spp. was performed in the Cantabrian wolf population (n = 91). The prevalences found were 6.3 % (5/79) for B. canis, 96.3 % (78/81) for H. canis, and 23.8 % (21/88) for L. infantum. None of the wolves were positive to *Ehrlichia* spp., *Anaplasma* spp., or *Rickettsia* spp. The co-infection prevalences were also investigated. To our knowledge, this is the first description of a fatal babesiosis in a wild wolf, as well as the first detection of *B. canis* and *H. canis* infection in the Iberian wolf population. We have found a low *B. canis* prevalence, while the *H. canis* prevalence is the highest recorded so far. The detection of *L. infantum* highlights the circulation of this zoonotic pathogen in a non-endemic region.

Case Report: High burdens of air sac worms (*Diplotriaena* sp.) in three northern flickers (*Colaptes auratus*) and a pileated woodpecker (*Dryocopus pileatus*)

Connolly A et al. Front Parasitol. 2025;4:1547153. https://doi.org/10.3389/fpara.2025.1547153

Diplotriaena spp. are nematode parasites of the abdominal and thoracic air sacs of numerous avian species worldwide. *Dipoltriaena* infections are generally subclinical, but high worm burdens can lead to morbidity and mortality. In this case series, *Diplotriaena* were recovered from a pileated woodpecker (*Dryocopus pileatus*) in 2017 and three northern flickers (*Colaptes auratus*) in 2023 and 2024 from Washington, USA. All four presented to a wildlife rehabilitation center with either respiratory signs or trauma with varied severity. A large number of worms (>44 worms) were surgically removed from the pileated woodpecker. The bird improved and was subsequently released. All three northern flickers were humanely euthanized due to poor prognosis and worsening conditions. Nematodes from Cases 1 and 4 were identified as a *Diplotriaena* sp. but they did not match any described species. Ethanol-fixed worms were available from one flicker case for genetic characterization. Partial 18S rRNA sequences (888bp) from two worms from a flicker

were identical and 98-98.5% similar to numerous Diplotriaena obtusa sequences. The sample *Diplotriaena* sp. grouped separately from the three closest matches in the GenBank database, *Diplotriaena anthreptis* and two clades of *Diplotriaena obtusa* and Diplotriaena bargusinica. The partial COI sequences (674bp) were identical to each other and ~80-85% similar to numerous Spiruromorpha representatives. Due to a lack of available samples in the GenBank database and incomplete morphological descriptions of the genus, identification to species was not possible. In summary, all four cases in this case series occurred in free-ranging birds in Washington state and represented unusually high burdens of *Diplotriaena* sp. We believe that the high worm burden contributed to trauma, respiratory pathology, and weight loss. Additional surveillance is needed to determine the prevalence and impact of this parasite on woodpecker populations and to more accurately identify the parasite species in these two species of woodpeckers.

Analysis of the protocols for action against strandings of sea turtles and their evolution in rehabilitation on Tenerife island (Canary Islands, Spain)

López Vega B, Hurtado-Pampín C, de la Cruz-Modino R. Ecologies. 2025;6(1):9. https://doi.org/10.3390/ecologies6010009

Numerous interactions between human activities and wildlife currently impact various species. In recent decades, these activities have contributed to declining sea turtle populations. The waters around Spain serve as important staging areas for sea turtles, particularly Caretta caretta, which spend part of their life cycle there. However, these same waters threaten turtles because of various causes of stranding. This study aims to comprehensively understand the rehabilitation process for these animals at the Wildlife Rehabilitation Center (WRC) La Tahonilla in Tenerife, Canary Islands. It also seeks to explore rehabilitation efforts at different centers focused on recovering sea turtles in both the mainland and the Canary Islands. Additionally, we have examined the procedures for addressing stranded sea turtles where a recovery center does not exist. Our findings reveal the existence of varying protocols among different centers in Spain's mainland and islands. Improving and unifying these protocols is essential for enhancing the rehabilitation of sea turtles in Spain.

No country for small cats: Systematic analysis of media-reported incidents unravel a troubled scenario for the fishing cat *Prionailurus viverrinus* in Bangladesh

Akash M, Zakir T, Saniat T, Dheer A, Srivathsa A. Glob Ecol Conserv. 2025;59(e03505):e03505. https://doi.org/10.1016/j.gecco.2025.e03505

Several recent commentaries by conservationists underscore the inadequacy of scholarly investigations on the ecology and conservation of non-apex carnivores. This bias spells multi-arrayed challenges for carnivores living in anthropized landscapes. The globally Vulnerable fishing cats (*Prionailurus viverrinus*) living across human-dominated South Asian wetlands exemplify this problem. Bangladesh, a densely populated, tenuous place for human-wildlife coexistence, constitutes ~30 % of the fishing cat's known distribution range. Based on systematic surveys of media reports (n = 361; 2005–2021), we implemented a novel application of predictive modeling to map fishing cat presence, and hotspots of human–fishing cat negative interactions across Bangladesh. The distribution of fishing cats was best explained by the extent of wetlands and dry-season precipitation. Negative interactions were associated with patchy mosaics of wetlands, croplands, and road networks. Around 47 % of the reported negative interactions were triggered by mere sightings of the cat and 26 % involved transactional costs. Chase-and-capture of the 'problem' animal ensued in > 50 % of reported cases; 26 % mentioned the use of traps or other gears. From 31 % of reports, we recorded 160 fishing cat mortality incidents, but no human fatalities. Our results show that around one-third of Bangladesh likely has breeding fishing cat populations; > 95 % of these regions are outside Protected Areas. We recommend formulating an action plan to strategize a redressal policy, enhance public perception of coexistence, and increase conservation units. We suggest applying this case study to other fishing cat range countries, or other carnivores in the Global South, where data deficiency and lack of systematic large-scale assessments often hinder conservation interventions.

Migratory birds spread their haemosporidian parasites along the world's major migratory flyways

Perrin A, Glaizot O, Christe P. Oikos. 2025;2025(5):e11012. https://doi.org/10.1111/oik.11012

Parasites circulate on a large scale through migrating hosts that encounter a wide diversity of parasites along their travels. This interaction can lead to greater similarity of parasite communities between regions connected by major migration routes. Additionally, migratory species may have higher importance (network centrality) within host–parasite networks. In this study, we test these two assumptions using globally recorded data on interactions between birds and avian malaria parasites (i.e. Plasmodium and Haemoproteus). We first determined the similarity of haemosporidian parasite community between each biogeographic realm and the network centrality of each bird species within both the Americas and African–Eurasian flyways. Network centrality was measured by both the number of direct links involving a given species (degree centrality) and the extent to which that species indirectly links other species (betweenness centrality). Despite a high overall dissimilarity in haemosporidian parasite community compositions between biogeographic realms, we found lower values between areas connected by a known migratory flyway compared to non-connected areas. Our results indicate that migratory species, when compared to sedentary ones, are more central both because they are connected to more parasites and connect other species in the interaction network of both

the Americas and African–Eurasian flyways. Long-distant migrants may directly affect the communities they visit by introducing high number of haemosporidian parasites, while at the same time they may become infected with the parasites present in these communities. Migrants therefore facilitate the spread of pathogens to some extent, and their presence can directly influence the dynamics and structure of local host–parasite networks.



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EUROPEAN BROWN HARE (*Lepus europaeus*)

European Brown hare (*Lepus europaeus*) as an accidental host of *Trypanosoma pestanai*

Veitova L, Pikula J, Votýpka J, Linhart P, Kokesova V, Lesiczka PM et al. Int J Parasitol Parasites Wildl. 2025;27(101079):101079. https://doi.org/10.1016/j.ijppaw.2025.101079

In Europe, trypanosomes are not considered a serious threat to humans or domestic animals; however, their potential ecological impact on wildlife remains largely unknown. This study investigates presence of trypanosomes in European brown hare (*Lepus europaeus*) in Czechia, where this species is an important game species and plays a significant role in ecosystems. Using nested PCR targeting 18S rDNA, trypanosome DNA was detected in two of 435 blood samples, representing the first confirmation of trypanosomes in the genus Lepus. Subsequent sequencing identified *Trypanosoma pestanai*, a species previously reported in the European badger (*Meles meles*). These findings suggest that *T. pestanai* may have a broader host range than previously recognized, emphasizing the need for further research into its ecological impact and its potential transmission dynamics in wildlife populations.

Beware of hitchhiking ticks? Clarifying the variable roles of bird species in tick movement along migratory routes

Burnus L, Wynn J, Liedvogel M, Rollins RE. J Avian Biol. 2025;2025(3):e03275. https://doi.org/10.1111/jav.03275

Ticks are blood-feeding parasites which act as major vectors for various pathogenic microorganisms affecting both animal and human health. Hard ticks are known to move passively (i.e. 'hitchhike') on migratory birds as they transit between breeding and non-breeding grounds. This potentially leads to exchange and establishment of non-endemic tick species in novel environments. However, it is not yet clear if all migratory bird taxa play an equal role in movement of specific tick species, especially outside of medically important tick taxa. To clarify these interactions, we performed a systematic literature review regarding primary data of ticks moving on migratory birds within the African–Western Palearctic flyways. In total, 35 studies were found which showed 123 bird species from 37 families and 12 orders connected to potential movement of 30 tick species representing six genera (*Amblyomma, Dermacentor, Haemaphysalis, Hyalomma, Ixodes, Rhipicephalus*). Most tick species did not show high abundance for any bird species, or, if they did, only on very few. Only *Ixodes ricinus* and *Hyalomma marginatum* were estimated to be carried at above average burdens by multiple bird species. This could indicate an increased likelihood of these species to be moved during migration. Specific tick species or whole genera were only found in certain migratory seasons as expected based on their geographic distributions. Even so, species found in both migratory seasons did not differ in their estimated abundances on birds between seasons. This result could suggest that tick abundance on migrating birds is not always a direct result of geographic distribution and may suggest an understudied importance of stopover sites towards potential tick introduction or turnover. Taken together, the results presented here provide guiding information for future analyses integrating individual level variation into the current understanding of tick movement with migratory birds.

Same-sex partnerships in birds: a review of the current literature and a call for more data

Gillies N, Siddiqi-Davies K. J Avian Biol. 2025;2025(3):e03452. https://doi.org/10.1002/jav.03452

Same-sex sexual behaviour (SSB), encompassing actions such as courtship, pair bonding, and parenting between individuals of the same sex, has been observed across numerous taxa, including birds. Yet despite its widespread occurrence, SSB remains poorly understood, often dismissed as maladaptive or the result of errors in sex discrimination. However, instances of same-sex partnerships – persistent pair bonds between same-sex individuals – challenge these assumptions, particularly in birds, whose diverse mating systems and high level of monogamy imposes strong selective pressures on pair formation and maintenance. This review synthesises our

current knowledge of same-sex partnerships in birds, addressing their evolutionary origins, adaptive benefits, and broader ecological significance. We argue that the prevalence of same-sex partnerships has likely been underestimated, hindered both by historical biases in interpretation and, especially more recently, logistical challenges in data collection. Drawing on examples from across the avian class, we explore the potential reproductive and social benefits of same-sex partnerships. By reframing these behaviors as potentially adaptive rather than anomalous, we aim to advance understanding of their evolutionary persistence and encourage more systematic research into their occurrence and implications.

Life history traits, habitat characteristics, and phylogeny influence tick infestation probability in tropical wild birds

Busi A, Martínez-Sánchez ET, Alvarez-Londoño J, Molina-Marin DA, Betancurt-Grisales JF et al. J Avian Biol. 2025;2025(3):e03315. https://doi.org/10.1111/jav.03315

Interactions between wild birds and ticks exert significant selective forces, influencing the host's evolution and fitness. Tick infestation rates vary among bird species due to life history and morphology. Understanding tick infestation probability is crucial for conservation efforts, as birds play an important role in the tick life cycle and can transmit tick-borne pathogens. In this context, it is essential to understand how life history traits or phylogenetic relationships determine tick infestation probability in the tropics. This study aims to identify wild bird life history traits and habitat characteristics associated with tick infestation probability in the Colombian tropical region. We hypothesized that larger body size, migratory behavior, foraging in lower vegetation stratum, seasonal aggregation, and inhabiting natural habitats increase tick infestation probability. We used a dataset with 3488 wild bird records from 322 species and 41 families, obtained from 61 Colombian localities (26 in the Orinoquia and 35 in the Andean regions). We used phylogenetic generalized linear mixed Bayesian models to assess tick infestation probability based on life history traits, body size, and geographic distribution. Of the birds analyzed, 3.2% were infested by ticks, mainly in immature stages (95%). Our results indicated a lower probability of tick infestation in agricultural habitats and higher elevations. Ground-foraging species exhibited a lower infestation probability, contrary to previous reports. We found a significant phylogenetic relationship, indicating that related species have similar probabilities of tick infestation compared to more distantly related species. This study provides valuable insights into the bird–tick association, with implications for disease management and bird conservation.

Seasonal activity changes in raccoon dogs and influences of environmental factors from autumn to winter

Miyamoto K, Chen C, Luan X. Wildl Biol. 2025:e01463. https://doi.org/10.1002/wlb3.01463

Raccoon dogs Nyctereutes procyonoides are on the List of National Key Protected Wild Animals as Grade II in China; research on their wild populations is limited despite their conservation significance. In this context, we focused on seasonal activity changes from autumn to winter and their relationship to environmental and mammalian factors. Using 71 trail cameras from 15 October 2023 to 29 February 2024, in the Sizuolou Nature Reserve in Beijing, China, this study is the first to examine these specific aspects within the country. Our findings revealed a statistically significant change in raccoon dog activity from autumn to winter. This suggests they may enter short periods of winter sleep, as indicated by the 20-day intervals without camera detections. The average re-photographing interval was 2.62 ± 3.41 (SD) days. In the daily activity pattern, kernel density estimation indicated that raccoon dogs were nocturnal in both seasons; however, daytime activity was observed only in autumn. Our results revealed that proximity to agricultural land negatively affected, and the presence of Siberian roe deer positively influenced, the number of raccoon dog events. Additionally, our results supported the previous categorization of raccoon dogs into two habitat types, with our study population being near the type that avoids agricultural land. Our findings suggested that raccoon dogs and Siberian roe deer co-occur due to raccoon dogs preferring habitats that were also favored by deer.

Citizen science project on urban canids provides different results from camera traps but generates interest and revenue

Taraporevala NF, Beckmann JP, Young JK. Wildl Biol. 2025 Mar 7:e01382. https://doi.org/10.1002/wlb3.01382

As urbanization increases, wildlife increasingly encounters people. Coyotes Canis latrans and red foxes Vulpes vulpes are two canid species that have readily adapted to urban environments. Citizen science has emerged as a low-cost method of collecting data on urban-adapted species that can benefit management agencies but may provide different results than traditional methods. We analyzed data collected by citizen scientists and via motion-triggered camera traps to see how each related to the anthropogenic features of distance to roads, building density, and median household income and the natural feature of distance to water. We also investigated the potential benefits of advertising the citizen science project on social media. We used occupancy models to analyze data from a grid of 67 cameras across Wichita, Kansas, USA, from March 2023 to February 2024. We used generalized linear models to evaluate data collected simultaneously from a website we created and advertised on social media where members of the public could report sightings of urban canids. The camera-trap occupancy models suggested that red fox occurrence was only related positively to building density and coyote occurrence was related negatively to building density and positively to income. The citizen science models suggested that sighting reports of both species were more likely closer to roads, at intermediate building densities, and

in high income neighborhoods. Coyotes and red foxes were both most likely to be detected by people during crepuscular periods but most likely to be detected by cameras at night. We also found that advertisements increased sighting reports and generated six times as much revenue for the wildlife agency than was spent. Our study suggests that citizen science data differ from camera-trap data by tracking human activity patterns and distribution, but citizen science projects can provide other benefits such as generating interest in and revenue for management agencies.



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ALPINE MARMOT (*Marmota martmota*)

How absolute biomass intake can alter nutrient profile interpretation in free-ranging species: the case of protein intake in brown bears

De Cuyper A, Janssens GPJ, Clauss M. Wildl Biol. 2025 Apr 21:e01458. https://doi.org/10.1002/wlb3.01458

If an animal eats a large amount of a diet of a low content of a macronutrient, it can still ingest a considerable amount of that macronutrient. Various animals have been shown to balance nutrient content with intake in this way. We use the brown bear *Ursus arctos* as a model species, given their recent classification as 'low protein omnivores', to show how taking biomass intake into account can affect macronutrient intake interpretation. We 1.) calculated absolute protein intake from published results of self-selection diet studies with bears in captivity and 2.) modeled absolute protein intake of Swedish brown bears in autumn while binging on a berry diet of low protein concentrations. In feeding experiments in captivity, the self-selected macronutrient composition of brown bear diets are characterized by protein percentages (both on a dry matter and metabolizable energy basis) that appear low when compared to diets of carnivores. However, when taking into account absolute food intake and expressing this as daily protein intake per metabolic body mass (33–117 g/kg0.75/day), protein intake was considerably higher than established minimum requirements for domestic dogs and cats (2.6–3.8 g/kg0.75/day) – carnivores one would not consider 'low protein specialists'. Our hypothetical berry model yielded a protein intake of 3.2–9.7 g/kg0.75/day, which is lower than the outcomes from the self-selection trials but still comparable to established requirements of domestic dogs and cats. Instead of perceiving bears as low-protein consumers, it might be more accurate to perceive them as temporary hyperphagia specialists for which low protein concentrations are necessary to avoid dramatically overshooting protein requirements. Including absolute food intake in diet determination offers important nuances in result interpretation. When coining labels to categorize animals, it may be advisable to not only consider nutrient concentrations but also absolute intake.

Hunting, but not outdoor recreation, modulates behavioral tolerance to human disturbance in Alpine marmots *Marmota marmota*

Zenth F, Giari C, Morocutti E, Storch I, Blumstein DT et al. Wildl Biol. 2025 May 15:e01397. https://doi.org/10.1002/wlb3.01397

Humans are often perceived as predators by free-living animals, and thus, even non-consumptive human activities such as outdoor recreation may trigger behavioral and physiological responses, often with negative consequences on individual fitness and population persistence. Nonetheless, there is growing evidence that wildlife can also have remarkable behavioral tolerance, but no clear picture has yet emerged regarding the mechanisms explaining different responses to humans. We investigated the effect of different types of human activity – hunting and outdoor recreation – on behavioral tolerance to humans in Alpine marmots *Marmota marmota*. Marmots were studied in areas with contrasting protection regimes and under different levels of outdoor recreation in northern Italy over three seasons (2021–2023). Flight initiation distance (i.e. the distance at which an animal escapes from an approaching person) was used as a proxy of tolerance to human disturbance and tested against levels of outdoor recreation and hunting using linear mixed modeling. Marmots were more sensitive to human disturbance in hunted as compared to protected areas, whereas we did not find evidence for changes in behavioral tolerance when exposed to varying levels of outdoor recreation. In turn, our study suggests that hunting, by reducing behavioral tolerance to humans, could exacerbate the negative effects of non-lethal human activities on wildlife. This has implications for conservation and management strategies aimed at promoting coexistence in human-altered landscapes. ◆

TAIL ENDS



I feel like the summer is already closing in on me!

Marsh Tit
Poecile palustris
IUCN Red List–Least Concern, Population Trend – Decreasing

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POLICY Original manuscripts on a variety of wildlife rehabilitation topics (e.g., husbandry and veterinary medicine) are welcomed. Manuscripts that address related topics such as facility administration, public relations, law, and education are invited as well.

Associate editors and anonymous reviewers, appropriate to the subject matter, evaluate each submitted manuscript. Concurrent submission to other peer-reviewed journals will preclude publication in the Journal of Wildlife Rehabilitation (JWR). The International Wildlife Rehabilitation Council (IWRC) retains copyright on all original articles published in the JWR but, upon request, will grant permission to reprint articles with credit given to the IWRC–JWR.

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NORTH AMERICAN PORCUPINE *(Erethizon dorsatum).* Pre-release blood transfusion patient at WILDNorth Edmonton, AB Canada.

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International Wildlife Rehabilitation Council
PO Box 3197
Eugene, OR 97403 USA
Voice/Fax: 408.876.6153
Toll free: 866.871.1869
Email: office@theiwrc.org
www.theiwrc.org

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