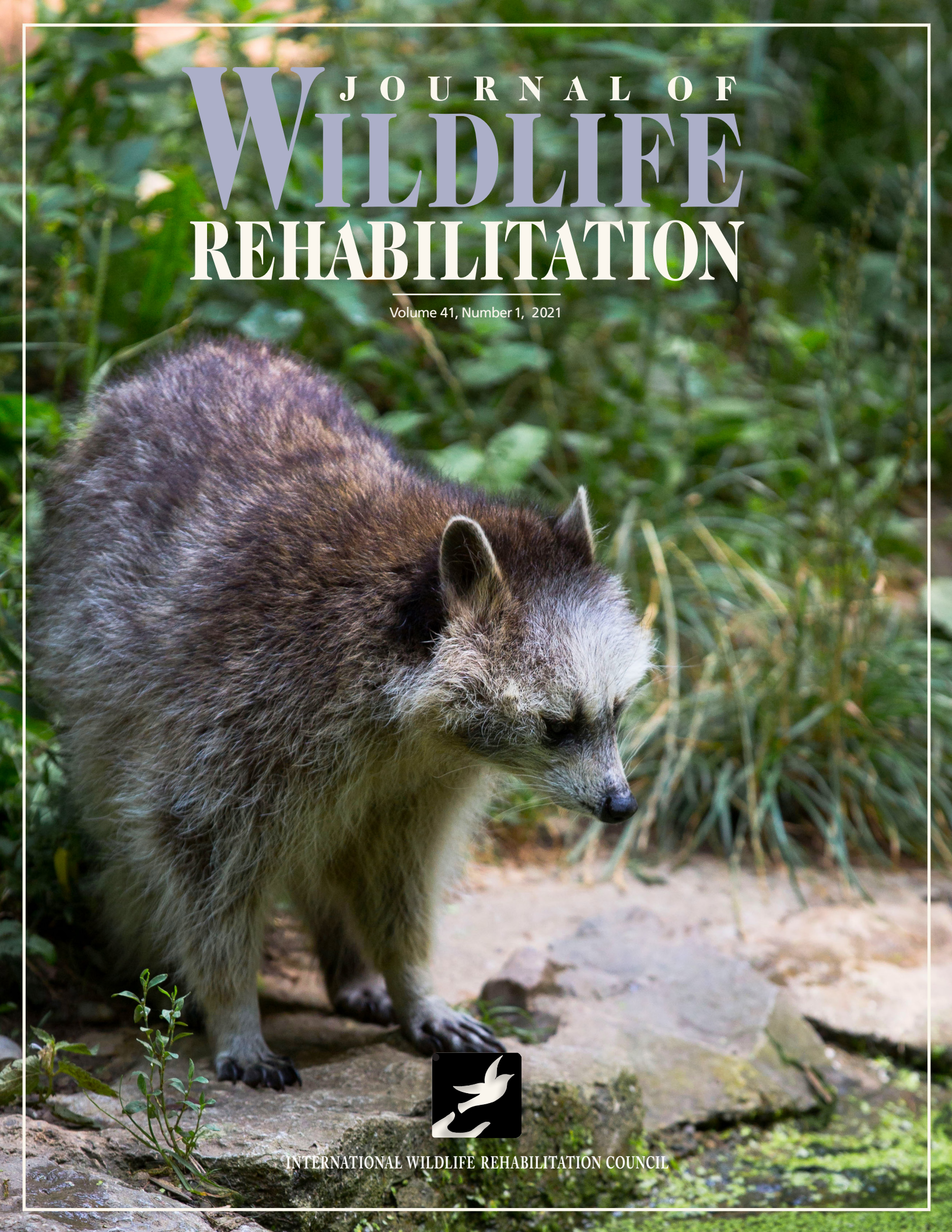


JOURNAL OF WILDLIFE REHABILITATION

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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.



ON THE COVER:

Northern raccoon (*Procyon lotor*) considering a wet supper.

PHOTO ©CLOUDTAIL THE SNOW LEOPARD. CC BY-NC-SA 2.0

LEFT:

Myotis nimbaensis, a newly discovered species of bat named for its mountain home, West Africa's Nimba Mountain.

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IWRC

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.

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JOURNAL OF WILDLIFE REHABILITATION

Volume 41(1)

CONTENTS

PEER-REVIEWED PAPERS

7

Raccoon roundworm as an occupational hazard to caregivers of captive wildlife
Tiffany Pope, Austin A. Killam, Victoria M. Cavazos, Scott E. Henke, David B. Wester, Humberto L. Perotto-Baldivieso, and Clayton D. Hilton

15

Euthanasia as a benchmark for animal welfare and wild bird rescue protocols and facilities in Japan
Nana Ushine, Aki Tanaka, and Shin-ichi Hayama

DEPARTMENTS

Editorial	4
In the News	5
Selected Abstracts	28
Tail Ends	34
Submission Guidelines	35

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EDITORIAL

Adapting to the Pandemic

For all the wrong reasons, the year 2020 will be one to remember. The global pandemic caused by COVID-19 has been felt deeply by many of us, and especially those who have lost loved ones to the virus.

Wild animals have also been affected. Although we don't know the route COVID-19 took to cross the species gap between bats and people, there is no doubt that it originated from one of the viruses circulating in bats. As a result, the pandemic has generated much discussion about our interactions with wild animals, and how we exploit them and the habitats they depend on. It is time for a re-evaluation of our species' relationship with Earth and the non-human life that we share it with. The last year warned us that without a better understanding of the ecology of our world and our role in that ecology, similar pandemics will occur in the future. Re-evaluating our role not only requires us to stop the exploitation of wildlife, but to consider the impacts of our activities—such as land clearances for agriculture and industry—that result in increased contacts between humans, animals, and the often-undetected pathogens we can potentially share.

Often seen as benign, human interactions can have negative impacts on wild animals, especially in terms of their welfare. Wildlife rehabilitation necessarily involves relationships between humans and wildlife. Now, the news that COVID-19 can infect other mammals, such as mustelids and felids (especially in captive situations such as zoos and fur farms), has raised the prospect that wildlife rehabilitators could potentially pass the disease to some of their charges. The issuing of statements by some authorities proposing restrictions on what species could be treated and released was one outcome of this news—one received with shock by the rehabilitation community. Yet, the need for precautionary measures by rehabilitators is sensible, especially following the discovery of a wild mink in Utah that tested positive for the disease. The need to respond to such events as responsible professionals is essential to prevent the disease becoming established in a wild animal population.

The IWRC has responded to the pandemic by providing resources for our members to help them cope during the event. One important development was a forum for rehabilitators to meet and discuss the problems they encountered during the year. These "coffee and tea" events were clearly very important, as shown by their popularity. Initial topics were directly relevant to the operation of rehabilitation establishments during the pandemic, but subjects expanded in scope as 2020 progressed. Some sessions were recorded and are available to members on The IWRC's website, along with many other resources for rehabilitators working during the pandemic.

The IWRC has also had to adapt. Part of our long-term strategy was to develop an online platform, allowing course delivery to many more across the globe. COVID-19 forced us to accelerate our plans. This year we recreated our flagship course, "Basic Wildlife Rehabilitation," to be completely online, including the lab elements. We've now delivered the course five times and will continue in 2021, hopefully alongside in-person courses once they are feasible.

We've also improved other online courses, adding lab components to the on-demand "Wound Management" class (and soon "Parasitology" and "Fluid Therapy"). Online courses allow us to widen our portfolio: we can develop more courses for an online audience, and deliver them in any part of the world.

For us all, 2020 has been a year of change. The pandemic has forced us—individually, organizationally, and even per species—to adapt to a new way of working. For The IWRC, there have been positives as well as negatives, and we find ourselves in a good place to take on the challenges of the next year. Let us hope it is better than 2020.

—Adam Grogan
President

Link found in Coastal Dolphin Skin Disease

SAUSALITO, USA *(December 18, 2020)*—Scientists in the US and Australia have identified a novel skin disease in dolphins that is linked to climate change. Due to the decreased water salinity brought upon by climate change, the dolphins develop patchy and raised skin lesions across their bodies—sometimes covering upwards of 70 percent of their skin.

The international study was co-authored by three internationally respected scientists: Dr. Pádraig Duignan, Chief Pathologist at The Marine Mammal Center (Sausalito, United States); Dr Nahiid Stephens, a veterinary pathologist at Murdoch University (Perth, Australia); and Dr. Kate Robb, Founding Director, zoologist, and geneticist of the Marine Mammal Foundation (Victoria, Australia). The study, published in *Scientific Reports*, a peer-reviewed natural sciences journal, provides the first-ever case definition for fresh-water skin disease in bottlenose dolphins.

This study comes on the heels of significant outbreaks in Louisiana, Mississippi, Alabama, Florida and Texas, and Australia in recent years. In all of these locations, a sudden and drastic decrease in salinity in the waters was the common factor. Coastal dolphins are accustomed to seasonal changes in salinity levels in their marine habitat, but they do not live in freshwater. The increasing severity and frequency of storm events like hurricanes and cyclones, particularly if they are preceded by drought conditions, are dumping unusual volumes of rain that turn coastal waters to freshwater. Freshwater conditions can persist for months, particularly after intense storms such as hurricanes Harvey and Katrina. With the increasing climate temperatures, climate scientists have predicted extreme storms like these will occur more frequently and, consequently, will result in more frequent and severe disease outbreaks in dolphins.

"This devastating skin disease has been killing dolphins since Hurricane Katrina, and we're pleased to finally define the problem," said Duignan. "With a record hurricane season in the Gulf of Mexico this year and more intense storm systems worldwide due to climate change, we can absolutely expect to see more of these devastating outbreaks killing dolphins."



PHOTO ©INSTITUTE FOR MARINE MAMMAL STUDIES. USED WITH PERMISSION.

Dead dolphin washed ashore in the Mississippi Sound, victim of a deadly skin disease that is affecting marine species worldwide, where fresh water is overwhelming the salinity of their normal marine habitats. Victims include the endangered Kemp's ridley sea turtle and the newly discovered Burrunan dolphin in Australia.

The study has major implications for the current outbreak in Australia, which is impacting the rare and threatened Burrunan dolphin in southeast Australia, and could provide professionals with the information needed to diagnose and treat affected animals. Currently, the long-term outlook for dolphins affected with the skin disease is poor. This is especially true for the animals suffering from prolonged exposure to freshwater.

The deadly skin disease was first noted by researchers on approximately 40 bottlenose dolphins near New Orleans after Hurricane Katrina in 2005.

"As warming ocean temperatures impact marine mammals globally, the findings in this paper will allow better mitigation of the factors that lead disease outbreaks for coastal dolphin communities that are already under threat from habitat loss and degradation," said Duignan. "This study helps shed light on an ever-growing concern, and we hope it is the first step in mitigating the deadly disease and marshalling the ocean community to further fight climate change."

New findings of SARS-CoV-2 in Felids and Mustelids

EUGENE, USA *(December 31, 2020)*—Even as the first round of vaccines is being distributed to essential workers, new updates on SARS-CoV-2 infection in wild and zoo animals are being released. Approximately

2 weeks ago, news of a wild mink in Utah, USA testing positive for SARS-CoV-2 was released.

The USDA reported in an announcement, "The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service conducted wildlife surveillance for SARS-CoV-2 in meso-carnivores and other species around infected mink farms in Utah, Michigan, and Wisconsin, USA between 24 Aug–30 Oct 2020. Surveillance was conducted as part of One Health investigations involving the Centers for Disease Control and Prevention, the United States Geological Survey, and State Departments of Agriculture, Natural Resources, and Health."

Additionally, this week the first confirmed case of SARS-CoV-2 was diagnosed in a snow leopard at the Louisville Zoo in Kentucky, USA. The leopard was tested after displaying mild respiratory symptoms, and is expected to recover fully. At this time it is believed it was exposed to the virus via an asymptomatic employee.

When asked for comment, IWRC veterinarian Katie McInnis stated, "Such cases further emphasize continued caution when treating animals in our care. Rehabilitators should remain calm and continue to utilize biosecurity protocols, personal protective equipment, and best practices when caring for animals. If a rehabilitator is caring for a susceptible species it is critical that they are in contact with their local permitting body and government wildlife veterinarian to ensure they are following guidelines on quarantine, testing, and release criteria."



PHOTO © MARTINUS SCRIBLERUS. CC BY 2.0 LICENSE.

Snow leopards (*Panthera uncia*).

Native California Wildlife Rehabilitation Voluntary Tax Contribution Fund

SACRAMENTO, USA (December 9, 2020)—The California Department of Fish and Wildlife (CDFW) is directing approximately $550,000 in grant funding to 45 nonprofit wildlife rehabilitation organizations to immediately support care for injured, sick and orphaned wildlife. The funds are made available from taxpayer contributions to the Native California Wildlife Rehabilitation Voluntary Tax Contribution Fund.

"California's injured, sick, and orphaned native wildlife need our help now more than ever," said CDFW Director Charlton H. Bonham. "We are proud to quickly make funds available to help these important partner organizations operate during difficult economic times."

In 2017, Assemblymember Marie Waldron's Assembly Bill 1031 created the Native California Wildlife Rehabilitation Voluntary Tax Contribution Fund on the state's income tax form, and thanks to taxpayers' generosity, more than $820,000 has been donated as of October 2020.

"I am so pleased these organizations will receive the funding they desperately deserve," Waldron said. "Without them, California's wildlife would suffer, which would mean we all suffer. I'm honored to have played a role in conserving California's abundant natural beauty."

In 2019, these 45 organizations collectively cared for nearly 112,000 orphaned or injured wild animals, including bats, opossums, skunks, raptors, reptiles, foxes, songbirds, fawns, sea birds, coyotes, bears, and many other native species.

CDFW acted swiftly to stand up the new competitive grant program to support and advance the recovery and rehabilitation of injured, sick, or orphaned wildlife and conservation education. Funds may be used to support activities such as operations and ongoing facility needs, innovation in animal care (e.g., wildlife rehabilitation techniques, enclosure designs, diet and behavioral enrichment), post-release monitoring, and conservation education for the public.

"The California wildlife rehabilitation community is incredibly grateful for this much-needed support," said Rachel Avilla, president of the California Council for Wildlife Rehabilitators Board of Directors. "While 2020 has certainly taken its toll on many small organizations, our commitment to helping wildlife remains strong as injured and orphaned animals continue to need our help daily. We want to thank Assemblymember Waldron and her team for pushing this landmark legislation through and CDFW for being an excellent ally. We are profoundly grateful for their continued collaboration and support to help care for California's precious wildlife."

Consistent with the legislation, eligible organizations were required to document their status as a nonprofit organization that operates a permitted wildlife rehabilitation facility, complies with all conditions of its Wildlife Rehabilitation Memorandum of Understanding, and maintains active participation in the Wildlife Rehabilitation Medical Database.

CONTINUED ON PAGE 25

Raccoon roundworm as an occupational hazard to caregivers of captive wildlife

Tiffany Pope,[1] Austin A. Killam,[2] Victoria M. Cavazos,[3] Scott E. Henke,[2] David B. Wester,[2] Humberto L. Perotto-Baldivieso,[2] and Clayton D. Hilton[4]

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Introduction

Baylisascaris procyonis is a large parasitic nematode that is found in the small intestine of raccoons (*Procyon lotor*), the definitive host, and is considered a zoonotic threat.[1] The parasite infects its definitive host through direct and indirect life cycles. Both cycles begin with the deposition of infective eggs into the environment via raccoon feces. Once deposited in the environment, *B. procyonis* eggs can remain viable for years[2] and reach high concentration levels in communal raccoon defecation sites known as latrines.[2,3] An infected raccoon sheds 20,000–26,000 eggs/gram of feces and may shed >1,000,000 eggs/day,[4] resulting in high levels of contamination at raccoon latrine sites.[5] Raccoon latrines may serve as foci for *B. procyonis* exposure and play an important role in transmission dynamics in both direct and indirect life cycles of the parasite.[3,6] In most cases, juvenile raccoons are directly infected by ingesting infective eggs, while adult raccoons are indirectly infected by ingesting encysted larva within

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ABSTRACT: Caregivers of captive wildlife are at risk of zoonotic diseases because they have prolonged contact with and potential exposure to many species of wildlife, their bodily fluids, and feces. One such zoonosis is *Baylisascaris procyonis*, an intestinal parasite of raccoons (*Procyon lotor*). Larvae of *B. procyonis* can cause blindness, paralysis, and death in intermediate hosts, including humans. An infected population of raccoons can contaminate a wildlife facility, and thus expose the animals and their caretakers to a potentially debilitating and fatal parasite. Our objectives were to 1) determine the prevalence of *B. procyonis*-positive scats and raccoons within a wildlife facility, 2) determine the potential exposure of *B. procyonis* to captive wildlife and human caregivers, and 3) determine the most effective

CONTINUED ON PAGE 8

KEYWORDS: animal caregivers, *Baylisascaris procyonis*, contaminated soil, *Procyon lotor*, raccoon feces, raccoon roundworm, wildlife rehabilitation, zoonotic parasite.

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paratenic hosts. A paratenic host is a special kind of intermediate host that is not required for development of the parasite but may aid in transmission. *Baylisascaris procyonis* infects small vertebrates, usually small mammals or birds, as paratenic hosts. Paratenic hosts often become infected by foraging for undigested seeds in raccoon feces.[7,8] Also, as the non-raccoon vertebrate walks through an area contaminated with eggs, such as when scavenging for food near a latrine, those eggs are ingested via contaminated food items, or the eggs adhere to the feet and fur of the animal, and are later ingested during grooming. After ingestion, the eggs hatch in the small intestine as they would in the definitive host. However, instead of continuing to develop normally, the larvae undergo aberrant somatic migration resulting in a condition called larva migrans.[5]

Baylisascaris procyonis is highly indiscriminate and infects diverse paratenic hosts, including rodents, lagomorphs, other mammals, birds, and humans.[5] Ingestion of infective *B. procyonis* eggs by paratenic hosts may result in visceral (VLM), ocular (OLM), and neural larva migrans (NLM), and are considered the most common cause of severe-to-fatal neurologic disease in animals.[9] Raccoons are generally left unharmed by *B. procyonis,* but paratenic hosts can suffer debilitating effects due to NLM such as head and body tilt, circling, recumbency, ataxia, nervous behavior, coma, and death.[5,10]

Baylisascaris procyonis has a widespread distribution and is found throughout most of the United States, with high prevalence in the Atlantic states, Midwestern states, and Pacific western states.[2] *Baylisascaris procyonis* is also found in Canada, Germany, Poland, the Czech and Slovak Republics, Japan, and Norway.[2,11] In the United States, *B. procyonis* prevalence decreases from northern to southern states, and has not been documented in the Rocky Mountain region even though this is within the range of the definitive host.[12] The parasite was first documented to occur in southern Texas by Kerr et al.[13] The presence of *Baylisascaris procyonis* in southern Texas was most likely due to a recent range expansion because typically within established populations, juvenile raccoons have greater prevalence and intensities of infections than adult raccoons, but the opposite trend was found in raccoons from southern Texas.[14] Hence, the parasite is either spreading or simply being discovered in areas that previously lacked detection efforts.

The potential risk to humans and managed animals in outdoor wildlife facilities is great given the adhesive properties of *B. procyonis* eggs[9] and their ability to persist in the environment for years.[5] Additionally, it is unlikely that environmental temperatures will exceed the lethal limit for *B. procyonis* eggs,[15] and a single *B. procyonis*-infected raccoon can contaminate 0.03 ha/year.[16] At least 20 human cases of *B. procyonis* NLM infection have been documented, with 13 cases in the United States.[9,17] Most documented cases of *B. procyonis* NLM infection involved small children or individuals with developmental delays because they are at higher risk of accidentally ingesting *B. procyonis* eggs from contaminated objects and environments.[9] Low-level infections of *B. procyonis* in humans is speculated to be more common in endemic areas, especially among managed wildlife caregivers, such as zookeepers and wildlife rehabilitators.[18] However, low-level *B. procyonis* infections in humans are unlikely to produce clinical manifestations and may go undiagnosed.[2,17]

Our objectives were to 1) determine the prevalence of *B. procyonis*-positive scats and raccoons within the Tio and Janell Kleberg Wildlife Research Park, a wildlife research facility owned by Texas A&M University–Kingsville (TAMUK), 2) determine the potential exposure of *B. procyonis* to managed wildlife and human caregivers, and 3) determine the most effective method to neutralize potential transmission of *B. procyonis* to humans and managed animals. Use of animals and personnel involved with this project were approved by the TAMUK Institutional Animal Care and Use Committee (IACUC#2018-02-26) and Institutional Biosafety Committee (IBC# 2018-02-26), respectively.

ABSTRACT, continued

method to neutralize potential transmission of *B. procyonis*. During a 12-month period from July 2017 through June 2018, we captured 50 wild raccoons, 23 (46%) of which were infected with a total of 295 *B. procyonis* roundworms. Eighteen of 120 raccoon scats (15%) collected throughout the facility during the same period were infected with *B. procyonis*. We estimated about 20% of the total areas that house animals within the facility have *B. procyonis*-contaminated soil. Therefore, captive animals have the potential of contracting the parasite. A disproportionally greater number of *B. procyonis*-contaminated scats were found in and around food bins within the facility; thus, wildlife caregivers were exposed to potential *B. procyonis* infection. Flaming soil with a propane pear burner (i.e., gas-injected flaming torch) followed by discing (i.e., tilling the soil) and re-flaming the contaminated area for at least 1 minute/m^2 was successful in rendering the majority of *B. procyonis* eggs within the top 2.5 cm of the soil column unviable. Soaking the contaminated area with water prior to flaming reduced the time needed to render eggs unviable. Personnel should always wear disposable gloves within a wildlife facility and thoroughly wash their hands upon leaving the facility to reduce their transmission risk to this zoonotic parasite.

Materials and methods

The Tio and Janell Kleberg Wildlife Research Park (hereafter, park) is a managed wildlife research facility operated by the Caesar Kleberg Wildlife Research Institute of TAMUK. It is a 16 ha facility that maintains white-tailed deer (*Odocoileus virginianus*), avian species, an American alligator (*Alligator mississippiensis*) colony, and a wildlife necropsy facility. The surrounding habitat consists of native and exotic grasses intermixed with honey mesquite (*Prosopis glandulosa*) and prickly pear (*Opuntia* spp.) shrubland. Typical fauna found on the property is consistent with the South Texas Plains ecoregion, including raccoons.[19]

Raccoon surveillance

Raccoons were captured during 30-day periods every three months on the park property in Havahart® (Woodstream Corporation, Lancaster, PA) live traps baited with sardines and cat food from July 2017 through June 2018. Ten traps were placed in locations that appeared to have the greatest chance for trap success based on scatalogic evidence. All 10 traps were open daily for the

duration of each capture period, resulting in 300 trap occurrences each period and 1200 trap occurrences total. Raccoon population was estimated via the removal option outlined in Program CAPTURE.[20] Program CAPTURE uses model selection algorithms that examine the data set through a series of tests reviewing time, behavior, and heterogeneity, and their interactive effects.[21] The removal option was chosen by Program CAPTURE as the best model for the trap data. Raccoons were anesthetized with ketamine hydrochloride (15 mg/kg) and xylazine (1 mg/kg) administered intramuscularly in a hind leg via a pole syringe.[22] Once anesthetized, raccoons were euthanized with a .22 caliber gun shot to the head.[23] After sex was determined, raccoons were weighed, age-classed (i.e., juvenile or adult) by tooth wear,[24] and necropsied. Intestinal parasites were enumerated by the centrifugal sedimentation-flotation method.[25] *Baylisascaris procyonis* was identified in lactophenol wet mounts using nematode characteristics[26,27](Fig. 1).

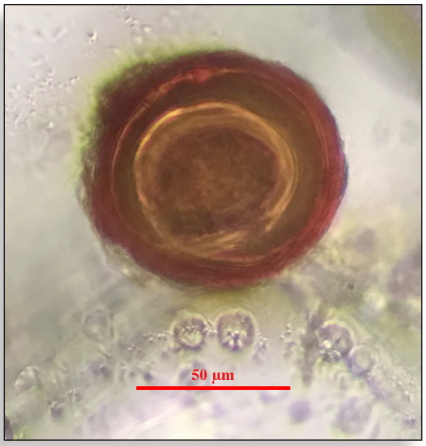


FIGURE 1. *Baylisascaris procyonis* unembryonated ova viewed at 400x magnification after centrifugal fecal flotation with Sheather's sugar solution from a southern Texas sample in 2017.

Scat surveillance

We conducted grid searches of the entire study area for raccoon scats and latrine sites during the same 30-day periods, collected individual scat samples, and obtained GPS locations of the samples (GeoExplorer III DGPS; Trimble, Sunnyvale, CA). Visual scat identification as to species was determined based on characteristics.[28] To aid precision and accuracy in scat identification, one person [SEH], who has 25 years experience identifying species and their signs, made all determinations as to species. Samples for parasitic analysis were stored in individual containers containing 10% neutral buffered formalin.[29] Approximately 2 grams of scat were placed into 20 ml of 10% neutral buffered formalin via a sterile wooden tongue depressor. The containers were then sealed and stored at 18°– 26° C. Each sample of scat, stored in formalin (n = 120), was analyzed using standard centrifugal fecal flotation for identification of parasite ova and oocysts using Sheather's sugar solution (specific gravity 1.27).[30,31] About 1 gram of the preserved scat was placed into a disposable cup along with approximately 1 ml of the formalin. Twenty ml of Sheather's sugar solution was added to the cup and homogenized with a wooden tongue depressor. A 4 by 4-inch woven gauze was used to strain the mixture into a 15-ml conical polystyrene centrifuge tube until formation of a positive meniscus. A glass cover slip was pressed onto the top of the centrifuge tube, and the tube was placed into a swing-out centrifuge (C5 Centrifuge, LW Scientific, Lawrenceville, GA). Samples were spun at 1300 rpm for 6 minutes. Cover slips were removed and placed individually onto labeled glass microscope slides. Each sample was processed with its own materials and disposable nitrile gloves to prevent cross-contamination. Presence of parasite ova was determined by light microscopy on 10x objective and confirmed on 40x objective. *Baylisascaris procyonis* has several unique identifying characteristics, including a general size of 80 µm x 70 µm, ovoid shape, dark pigmented center, lack of embryonation in fresh fecal samples, and a rough outer shell (Fig. 1).[31,32]

Raccoon demographics

We used chi-square analysis to determine if the proportions of raccoon age and sex data, parasite parameters, and *B. procyonis*-infected scats and raccoons were equal among the quarterly collection periods.[33] Yates correction for continuity was conducted when a single degree of freedom was determined.[34] Definitions of parasite parameters of abundance, prevalence, and intensity followed those provided by Bush et al.[35] We also used chi-square analysis to determine if proportions of *B. procyonis*-infected and non-infected raccoon scats were evenly distributed throughout high, medium, and low human exposure areas within the park facility. We defined areas of high, medium, and low exposure if human activity within the area of each designated scat location was daily, weekly, or monthly, respectively. On average, an infected raccoon scat upon decay can contaminate 0.75 m^2 of soil.[16]

Expected counts were calculated as the total number of raccoon scats collected multiplied by the percentage of the park area in each of the three activity levels. We used ArcMap 10.136 to map scat locations, raccoon locations, and percent of *B. procyonis*-contaminated area compared to area of the park.

Contamination reduction methods

In an effort to reduce current and additional contamination of the park with *B. procyonis*, we attempted four reduction methods, which consisted of lethal raccoon removal (previously described), soaking *B. procyonis*-contaminated soil with 20% bleach solution, soaking *B. procyonis*-contaminated soil with boiling water, or by flaming the contaminated area. Contamination reduction methods were conducted during a 2-day period in July 2018. We took the known *B. procyonis*-positive scats and concentrated the eggs according to the methods of Ogdee et al.[37] We made one hundred 1-ml aliquots of water that each contained approximately 1000 live *B. procyonis* eggs. We randomly selected six aliquots and quantified each aliquot (= 1015 ± 12.7; range = 976–1056 eggs) with a Beckman Coulter® cell counter (Z series, Beckman Coulter, Indianapolis, Indiana), and checked for larval motility of 200 eggs (= 199 ± 0.01). We then established and marked the location of 40 circular plots with 30-cm diameters. Plots were arranged in an 8 by 5 grid pattern and were separated by 5 m. We pipetted two 1-ml aliquots of *B. procyonis* eggs into the central area of each

TABLE 1. Demographics of *Baylisascaris procyonis*-positive raccoons and raccoon scat collected every three months from the Wildlife Research Park of Texas A&M University–Kingsville from July 2017 through June 2018.

	RACCOONS				*B. PROCYONIS* NEMATODES			SCAT		
		SEX RATIO	AGE CLASS				SEX RATIO	*B. procyonis* OVA		
SEASON	N	M:F	ADULT:JUV	PREVALENCE[1]	N	INTENSITY[1]	M:F	N	POSITIVE	PREVALENCE[1]
Summer '17	20	8:12	10:10	11/20 (55%)	138	12.5±0.7	64:74	46	8	17.4
Autumn '17	9	3:6	5:4	4/9 (44%)	93	23.2±0.6	46:47	25	4	16.0
Winter '17	11	5:6	5:6	6/11 (54%)	44	7.3±0.2	21:23	24	5	20.8
Spring '18	10	6:4	4:6	2/10 (20%)	20	10.0±0.3	8:12	25	1	4.0
Total	**50**	**22:28**	**24:26**	**23/50 (46%)**	**295**	**12.8±1.1**	**139:156**	**120**	**18**	**15.0**

[1]Definitions of prevalence and intensity follow those of Bush et al. (1997).

plot, one aliquot at a depth of 2.5 cm and the other aliquot on the soil surface and 10 cm to the right of the first aliquot. Due to soil compaction of the clay loam soils of the park, a nail was driven into the ground to a depth of 2.5 cm, the 1-ml aliquot of eggs was pipetted into the nail hole, and a clay soil plug was pressed into the hole to return soil back to its original state. Plots randomly received one of eight treatments: 1) 3.8 L of 20% bleach solution (1 part 8.25% sodium hypochlorite to 4 parts water), 2) 3.8 L of boiling water, 3) flaming the plot with a propane burner (Lincoln Electric Inferno Propane Torch kit, Lowe's, Kingsville, Texas, USA) for 15 seconds, 4) flaming the plot with a propane burner for 30 seconds, 5) flaming the plot for 15 seconds, followed by tilling the plot, and then reflaming for an additional 15 seconds, and 6–8) conducting treatments 3–5 but first soaking the plot 3 times/day for 3 days with 3.8 L of water prior to placing *B. procyonis* eggs into the plot. This experiment design created five replications of each treatment. Solutions were slowly poured onto plots to avoid splashing and displacing the eggs and soil from their marked locations. Water was boiled on site with a propane gas camp stove and then immediately poured onto the plot. Doing so reduced the time from removing the boiling water from the stove and the initiation of pouring the water onto the plot so water had little time to cool. Tilling was conducted using a 15-cm front tine rototiller (Craftsman® Model 29934, Lowe's, Kingsville, Texas USA). A soil moisture probe (Extech Digital Soil Moisture Meter Model MO750, Forestry Supplier, Jackson, Mississippi, USA) was used to verify that the ground moisture was > 90% for plots of treatments 6–8 and < 40% for the other treatment plots.

We then collected soil samples from each plot at the locations of the 2.5 cm deep aliquot and from the soil surface aliquot with a 2 cm diameter AMS soil probe (AMS Hammer Head Soil Probe, Forestry Suppliers, Jackson, Mississippi, USA). Because tilling the plot of treatments 5 and 8 disrupted egg placement, multiple soil probe samples were required to ensure adequate egg recovery. Soil samples were analyzed for *B. procyonis* eggs according to the methods of Ogdee et al.[37] Soil samples, except those from the 20% bleach solution treatment, were treated with 20% bleach to remove the outer adhesive protein coat.[25] Eggs were concentrated by centrifugation, and 200 eggs were quantified with a hemocytometer to determine the fraction of motile larvae in eggs, using motility as a proxy for viability.[38]

Two separate statistical analyses were used to address the third study objective, to evaluate *B. procyonis* environmental contamination reduction methods. For the first analysis, we assessed egg viability as affected by three treatments (bleach, boiling water, and dry flame) and two soil depths (0 cm at the soil surface and 2.5 cm below the soil surface) with a generalized linear mixed model that considered treatment, soil depth, and their interaction as fixed effects and replication nested within treatments as a random effect; soil depth was modeled as a repeated measures factor.[39] For the second analysis, we assessed egg viability as affected by flame application (flame for 15 sec, flame for 20 sec, and flame/till/flame), soil water status, and soil depth with a generalized linear mixed model that considered these effects and their interactions as fixed effects; replication nested within moisture conditions and the interaction between replication and flame treatment nested within moisture conditions as random effects.[39] Because of convergence problems in the second analysis, data were analyzed for each soil depth separately. For both analyses, a logit link was used to accommodate the binomial nature of the response variable (number of viable eggs out of 200 eggs in each experimental unit). For both analyses, significant interactions were followed by simple main effect and simple effect tests.[40] All analyses were completed with SAS v 9.4.[41]

Results

Baylisascaris procyonis in raccoons

We captured 20, 9, 11, and 10 raccoons, respectively, during each collection period for a total of 50 raccoons. Age class (adult:juvenile) and sex ratio (male:female) of raccoons did not deviate ($\chi 2 = 0.54$, 3 df, $P = 0.91$ and $\chi 2 = 1.66$, 3 df, $P = 0.65$, respectively) from a 1:1 relationship during the year. Prevalence of *B. procyonis* in raccoons within the park was 46% (Table 1) with a mean intensity of 12.8 ± 1.1 nematodes/infected raccoon. Prevalence of *B. procyonis* in raccoons fluctuated from a high of 55% during summer 2017 to a low of 20% during spring 2018,

but did not significantly differ ($\chi 2$ = 3.84, 3 df, P = 0.28) throughout the year (Table 1). Mean intensity fluctuated from a high of 23.2 nematodes/infected raccoon during autumn 2017 to a low of 7.3 nematodes/infected raccoon during winter 2017 (Table 1). However, mean intensity of *B. procyonis* differed ($\chi 2$ = 11.0, 3 df, P = 0.012) throughout the year with 92% of the chi-square value being due to the range extremes (Table 1). Abundance of *B. procyonis* was proportional ($\chi 2$ = 0.98, 3 df, P = 0.81) between adult and juvenile raccoons during the four collection periods. However, overall abundance of *B. procyonis* was greater ($\chi 2$ = 25.7, 1 df, P < 0.0001) in juvenile raccoons than adult raccoons. This pattern was consistent ($\chi 2$ > 4.3, 1 df, P = 0.04) for each collection period except for spring 2018 when no difference in abundance of *B. procyonis* was detected ($\chi 2$ = 0.45, 1 df, P = 0.50) between adult and juvenile raccoons. Sex ratio of *B. procyonis* nematodes during the year did not deviate ($\chi 2$ = 0.64, 3 df, P = 0.89) from an even ratio (Table 1).

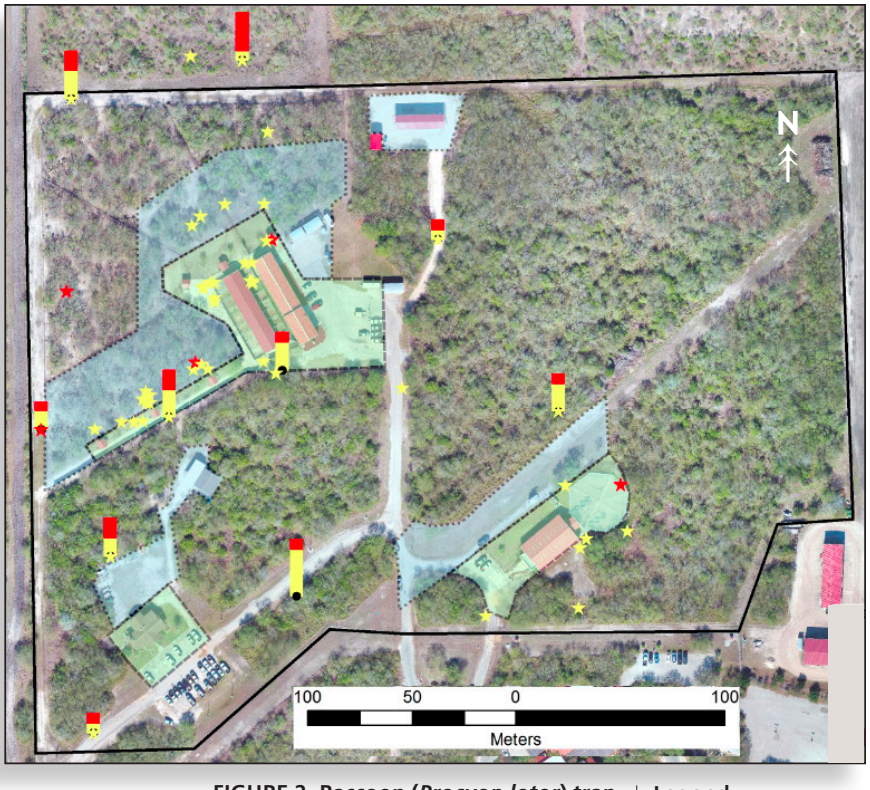


FIGURE 2. Raccoon (*Procyon lotor*) trap and scat locations found in the Tio and Janell Kleberg Wildlife Park from July 2017 through June 2018 in Kingsville, Texas, USA. Trap locations are indicated by black dots, accompanied by a bar indicating the proportion of raccoons that were positive (red) to negative (yellow) for *Baylisascaris procyonis*. Scat collection locations are indicated as positive (red star) and negative (yellow star) for *B. procyonis* ova. Boundaries for daily (green), weekly (blue), and monthly (black outline) human activity indicate proximity and frequency of interaction with *B. procyonis*-contaminated locations.

Baylisascaris procyonis in scats

Eighteen of 120 raccoon scats (15%) were positive for *B. procyonis* eggs (Table 1). Prevalence of *B. procyonis*-positive raccoon scat did not differ ($\chi 2$ = 3.33, 3 df, P = 0.34) during the year. From the locations of *B. procyonis*-positive raccoon scats, we estimated that approximately 20% of the total enclosure areas that contain animals potentially were contaminated with *B. procyonis* eggs. In addition, we determined that *B. procyonis*-positive scats were not proportionally distributed ($\chi 2$ = 9.6, 2 df, P = 0.008) throughout the park. A disproportionally greater number of positive scats were located in areas of high and medium human activity (45% and 12.5% of the chi-square value, respectively) (Fig. 2).

Contamination reduction methods

The initial raccoon population of the park was estimated to be 20.1 ± 0.7 raccoons. However, due to near-immediate raccoon immigration to fill the void created by raccoon removal, the seasonal estimate of the raccoon population was reduced to 9.8 ± 0.1, 11.2 ± 0.4, and 10.5 ± 0.3 raccoons, respectively, during each capture period. Population estimates for raccoons did not differ ($\chi 2$ = 5.4, 3 df, P = 0.14) between capture periods.

In the first analysis of contamination reduction treatments (bleach, boiling water, and dry flame for 15 sec), the number of viable *B. procyonis* eggs that remained in the soil plot interacted between treatment method and soil depth ($F_{2,\ 15.42}$ = 84.69, P < 0.0001) (Table 2). Treatment effects differed between the soil surface ($F_{2,\ 21.53}$ = 91.93, P < 0.0001) (Fig. 3a) and the 2.5-cm depth ($F_{2,\ 9.307}$ = 22.60, P = 0.0003). At the surface, flaming the plot was most effective, followed by boiling water, and then 20% bleach solution (Fig. 3a; Table 2). Depth did not have an impact on the efficacy of 20% bleach solution ($F_{2,\ 24}$ = 0.80, P = 0.3795), but did for boiling water ($F_{1,5.145}$ = 138.18, P < 0.0001) and dry flame ($F_{2,\ 16.21}$ = 146.19, P < 0.0001) (Fig. 3a; Table 2). All three treatments at the 2.5-cm depth were less than 80% effective at reducing egg viability (Table 2). Boiling water and 20% bleach solution were ineffective in killing B. procyonis eggs at the 2.5 cm depth (Table 2).

In the second analysis of contamination reduction treatments (flame for 15 sec, flame for 30 sec, and flame/till/flame for 15 sec) at two depths, *B. procyonis* egg survival was minimal at the surface (0 ± 0% – 1 ± 0.3%) (Table 3), so comparisons were made at the 2.5-cm depth (Fig. 3b; Table 3). Soil water status and treatment interacted ($F_{2,\ 24}$ = 447.03, P < 0.0001) in their effects on egg

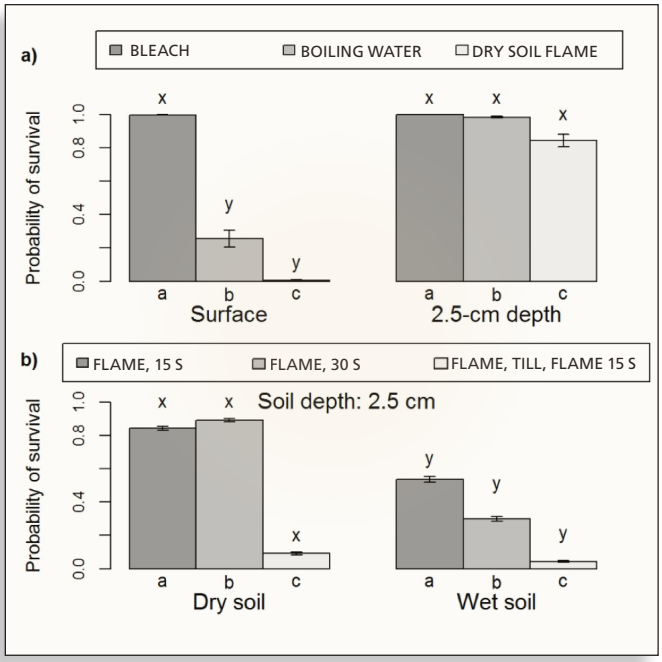


FIGURE 3. *Baylisascaris procyonis* egg viability after a) receiving one of three treatments at two soil depths and b) one of three treatments at 2.5-cm depth in wet and dry soil in southern Texas, 2018. The lower case letters a, b, and c compare treatments within a (a) soil depth and (b) soil water content. The lower case letters x and y compare (a) soil depths and (b) soil moisture content within a treatment. The error bars represent standard error of the mean.

TABLE 2. *Baylisascaris procyonis* egg viability (%) (±SE) within a 30-cm diameter dirt plot (n=40) at two soil depths after receiving one of three treatments to reduce the potential exposure and transmission to managed wildlife and their human caregivers in southern Texas, 2018.

	TREATMENT		
SOIL DEPTH	BLEACH	BOILING WATER	DRY FLAME (15 S)
0 cm	99.7 ± 0.2A[1]c[2]	25.6 ± 5.2Ab	0.05±0.2Aa
2.5 cm	99.9 ± 0.1Ac	98.4 ± 0.6Bb	84.4 ± 3.6Ba

[1]Viability means within a treatment followed by the same upper case letter are not significantly different ($P > 0.05$, protected LSD test). [2]Viability means at a soil depth followed by the same lower case letter are not significantly different ($P > 0.05$, protected LSD test).

TABLE 3. *Baylisascaris procyonis* egg viability (%) (±SE) within a 30-cm diameter dirt plot (n = 40) at two soil depths and water content levels after receiving one of three treatments to reduce the potential exposure and transmission to managed wildlife and their human caregivers in southern Texas, 2018.

		TREATMENT		
SOIL DEPTH	SOIL WATER	FLAME 15 S	FLAME 30 S	FLAME/TILL/ FLAME
0 cm	<40%	0.5 ± 0.2	0.1 ± 0.1	0.5 ± 0.2
	>90%	0.3 ± 0.2	0 ± 0	1.0 ± 0.3
2.5 cm	<40%	84.3 ± 1.2B[1]b[2]	89.2 ± 0.98Bc	9.2 ± 0.91Ba
	>90%	53.6 ± 1.6Ac	30 ± 1.4Ab	4.4 ± 0.65Aa

[1]For a given soil depth, viability means within a treatment followed by the same upper case letter are not significantly different ($P > 0.05$, protected LSD test). [2]For a given soil depth, viability means within a soil water content followed by the same lower case letter are not significantly different ($P > 0.05$, protected LSD test).

viability (Fig. 3b; Table 3). Treatments differed between the <40% soil moisture, dry plots ($F_{2,24} = 532.46$, $P < 0.0001$) and the >90% soil moisture, wet plots ($F_{2,24} = 203.67$, $P < 0.0001$) (Table 3). Soil water content affected the efficacy of all three treatments: application of flame for 15 sec ($F_{1,24} = 203.93$, $P < 0.0001$), application of flame for 30 sec ($F_{1,24} = 578.09$, $P < 0.0001$), and application of flame for 15 sec, tilling, and flaming for an additional 15 sec ($F_{1,24} = 17.42$, $P < 0.0001$) (Table 3). At the surface, all three treatments, regardless of soil moisture content, were greater than 98% effective at reducing egg viability (Table 3). For dry plots at the 2.5-cm depth, flaming-tilling-reflaming had the best kill rate of *B. procyonis* eggs, followed by flaming the plot for 15 seconds, then flaming the plot for 30 seconds (Fig. 3b; Table 3). For wet plots at the 2.5-cm depth, flaming-tilling-reflaming had the best kill rate of *B. procyonis* eggs, followed by flaming the plot for 30 seconds, then flaming the plot for 15 seconds (Fig. 3b; Table 3). In general, more *B. procyonis* eggs were rendered unviable on the surface by each method than at the 2.5-cm depth (Table 3).

Discussion

The raccoons at the Tio and Janell Kleberg Wildlife Research Park of Texas A&M University–Kingsville were found to be infected with *B. procyonis*, and the abundance and prevalence of infected raccoons within the park and surrounding area was apparently sufficient to maintain the parasite. Therefore, wildlife held in this outdoor facility and their human caregivers were potentially exposed to this debilitating parasite. It is worthy to note that a greater proportion of *B. procyonis*-infected raccoons were observed in areas of the park with the greatest human activity, which were areas where food was either stored or fed to the research animals of the park. Such areas that offered communal food sources perhaps were prime areas for the establishment of territories by raccoons. We noted more adult raccoons were caught within the commensal food areas than juvenile raccoons, which offers circumstantial evidence that perhaps such areas were located within raccoon territories. Adult raccoons exhibit strong spatial fidelity, and home range sizes reflect the distribution and quality of available resources.[42] It also is noteworthy that the commensal food areas contained a greater number of latrine sites rather than single scats. It is possible that such areas contained soil that was highly contaminated with *B. procyonis* eggs, thus creating greater exposure of territorial adult raccoons to the parasite via ingestion of infective eggs or infected paratenic hosts. A greater number of latrine sites within commensal areas has been documented previously.[16] This is a possible scenario as to why more *B. procyonis*-infected, adult raccoons were caught within the areas of high human activity.

The observed prevalence, abundance, and mean intensity of *B. procyonis* in our study, in general, followed the expected pattern for age classes of raccoons. Juvenile raccoons are hypothesized to have greater levels of *B. procyonis* infections than adult raccoons due to acquiring eggs via nursing on females and their naivety to the parasite.[5] In addition, as raccoons get older they develop resistance and/or an immune response that can lead to self-cure of *B. procyonis* infections.[2]

A short-term raccoon removal program was not successful in reducing the prevalence and abundance of *B. procyonis* from the park. Raccoon abundance was reduced by 50% from its initial level, at best, but due to probable immigration, abundance stabilized even with continued removal efforts. Such results are commonly incurred with removal efforts.[43] Raccoons either immigrated into the park from surrounding areas and brought their parasite loads with them, which included *B. procyonis*, or they quickly became infected with *B. procyonis* once they became established within the park. A single infected raccoon can contaminate 0.03 ha/year with *B. procyonis* eggs.[16] However, this estimate assumes every square meter within a contaminated area becomes infested, which is unlikely. Therefore, a population of infected raccoons could contaminate a larger area with *B. procyonis* eggs; thus, increasing the likelihood for potential exposure to the parasite.

In addition, a statewide survey conducted in Texas to detect *B. procyonis* in relationship to habitat characteristics found that prevalence of *B. procyonis* infection in raccoons was highest in clayey soils of central Texas.[14] It was posited that *B. procyonis* occurrence would be higher in clayey textured soils because of slow egg percolation rates and high moisture retention properties of clayey soils; thus promoting the viability of *B. procyonis* eggs and increasing the likelihood of transmission.[14] Most *B. procyonis* eggs remain on the soil surface of all soil particle sizes even after 2 years, although egg percolation improves in wet environments.[37] In addition, infected raccoon scats completely decay after 20 cm of precipitation and eggs are found up to 49 cm from the scat decay site.[16]

Of the remaining treatments other than raccoon removal to reduce contamination by *B. procyonis* eggs, 20% bleach solution was completely ineffective in killing the eggs. Bleach does remove the outer adhesive protein coat,[25] which could potentially cause eggs to be susceptible to desiccation. However, ground temperatures, even in semi-arid southern Texas, do not exceed the lethal limit for *B. procyonis*.[15] In addition, *B. procyonis* eggs remain within the top 10 cm of the soil surface and can survive for at least 2 years in soils.[37] Also, because soil has insulating properties against extreme high temperatures,[44] pouring boiling water onto contaminated soil can kill most *B. procyonis* eggs on the surface, but water apparently cools too quickly on dry soil to percolate deeper and be effective in killing eggs at lower depths. In addition, one must be careful to avoid pouring water too quickly onto the soil surface, which can cause splashing and dissipate eggs even further from its origin, thus creating an even greater contamination area. Flaming the ground for as little as 15 seconds was sufficient to kill the eggs on the surface, but insulating properties of soil kept eggs deeper in the soil column from being rendered unviable. Soaking the ground with water prior to flaming the surface allowed for greater heat transfer to occur deeper into the soil column, which improved the kill rate of *B. procyonis* eggs, but did not render all eggs unviable. Although no attempted method resulted in a 100% kill rate, the combination of flaming, tilling, and reflaming was the best method for reducing live *B. procyonis* eggs from a contaminated site.

Caregivers of managed wild animals need to be made aware of the potential risks to which they, and the animals for which they provide care, are exposed. *Baylisascaris procyonis* is effective at infecting a wide variety of species, especially in areas with high exposure risk. It would be prudent to monitor wild raccoons near outdoor managed animal facilities, including zoos, to determine the potential exposure risk to the animals and human workers within the facility. Human workers should always wear disposable gloves within a wildlife facility and thoroughly wash their hands often to reduce their risk of infection with this parasite.

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Euthanasia as a benchmark for animal welfare and wild bird rescue protocols and facilities in Japan

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Handfeeding a rehabilitating osprey *(Pandion haliaetus).*

Introduction

In Japan, the term "wildlife rescue" is used to describe the process of treating and rehabilitating injured, orphaned, sick, or displaced wild animals incapable of surviving in the wild on their own, analogous to the term "wildlife rehabilitation" in other countries. Whenever possible, rescued animals are released so they can live in their original wild habitat. The main purposes of wildlife rehabilitation or rescue are to promote the welfare of the individual animal through humane care and to provide public education.[1-3] "Wildlife rescue" and "wildlife rehabilitation" can be considered interchangeable terms for the purposes of this paper.

The practice of wildlife rehabilitation and wildlife rescue internationally

Wildlife rescue has been performed in various countries including Canada,[2] Australia,[4,5] China,[6] the United States,[7] and Europe.[8] Wildlife rescue is a common activity worldwide; however, regulations and legislation pertaining to wildlife rescue vary between countries and regions. In Canada, citizens and several companies working in cooperation contribute to wildlife rescue activities,[9] and rehabilitators with expertise and skills work independently of the government. In Western Australia, New South Wales, and

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ABSTRACT: Animal welfare is an important element of wildlife rehabilitation, and some countries use standardized protocols to ensure animal welfare is addressed during the rehabilitation process. In Japan (where the term "wildlife rescue" is preferred), no common management procedures prioritize animal welfare, especially for wild bird rescue. Approximately 90% of wildlife rescue cases in Japan are wild birds. To provide an overview of wild bird rescue and rehabilitation in Japan, and to collect data on rescue groups, a web-based survey and in-person questionnaire were developed and administered to 26 wild bird rescue groups operating between September 2014 and April 2018. The survey revealed substantial variation between rescue groups in terms of management protocols, feeding, medical treatment, and criteria for euthanasia. Only 26.9% of the groups consider euthanasia as an option. The more recently a rescue group was established, the more likely it is to have a euthanasia protocol. To meet the stated goals of wildlife rehabilitation, and improve the physical and mental health of rescued animals, it is important for standards of care to be established, ideally using criteria on par with international standards, to be implemented by each rescue group in Japan.

KEYWORDS: animal welfare; care standards; euthanasia; Japan; wild bird; wildlife rehabilitation; wildlife rescue.

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the United States, all rehabilitators are registered or licensed and perform wildlife rescue activities according to established guidelines.[7,10] In South Africa, even though wildlife rehabilitation is regarded as necessary and each rehabilitation center must obtain a permit from the provincial government, obstacles exist. Inadequate funding, inconsistent methods of care, variable rehabilitator expertise, poor post-release monitoring, and contentious relationships between rehabilitators and wildlife officials threaten the welfare of the individual animal. In order to implement wildlife rescue that respects animal welfare, it is necessary to have supportive governmental (national, state, provincial) management, as well as focused education of rehabilitators by experts trained in animal welfare.[11]

The practice of wildlife rehabilitation and wildlife rescue in Japan

In Japan there are no guidelines and very few trained rehabilitators. It is difficult for trained rehabilitators in Japan to fully utilize and share their training because wildlife rescue facilities suffer from poor funding and inadequate space for managing each individual animal's successful rehabilitation and restoration of full physical function. Although wildlife rescue is considered a public service in Japan, there is public indifference toward supporting wildlife rescue facilities and activities.

Japan's national animal welfare law, the Act on Welfare and Management of Animals, does not cover wild animals. There is no general animal welfare legislation for rescued wildlife in Japan.[12] No investigation prior to this study has examined the content of wildlife rescue work at each wildlife rescue facility, and in particular, how that work addresses animal welfare. Based on previous reports, certain parameters affecting the welfare of rescued wildlife include initial treatments (starting with triage, and occurring with or without veterinary involvement in Japan), the floor environment (size of the floor and flooring material), release criteria, and the use of euthanasia when appropriate.

Animal welfare considerations in wildlife rehabilitation and rescue

It is imperative that wildlife rescue meets the individual animal's social and physical needs, and that animal welfare principles form the foundation of all wildlife rescue work,[13] but there are various common welfare problems that can occur during the wildlife rescue process. Wildlife rescue involves the capture of individual animals, transport, and subsequent confinement in a closed environment, all of which may cause the animals physical and psychological stress.[14-17]

Husbandry and enclosures

Poor husbandry may create overcrowding, which may cause both physiological and psychological stress. Inappropriate floor material may result in abrasions and foot injuries,[18] such as bumble foot.[19] In a captive enclosure, abnormal behavior is related to an inadequate or noxious environment, and as such, is an indicator of stress and low quality of life.[20] In the case of group enclosures, stressed captive animals may be prone to causing and sustaining injuries because of conflict with other individuals.[4,21] Stressed individuals may display stereotypic behaviors, such as repetitive pacing and feather-plucking.[22] Animals exhibiting frequent and severe stereotypic behavior have little conservation value and might not survive if released into the wild.[23]

Handling protocols

Handling of captive wild birds has been associated with changes in their body weights and adrenal cortices, indicating chronic stress.[14,17,24-25] Stressed animals in rehabilitation centers are likely at an increased risk of infections from fungal organisms such as *Candida* spp.,[26] bacteria such as *Chlamydia* spp.,[27] and parasites such as *Plasmodium* spp.[28] Animals with infections or injuries should not be released back into the wild, and they may need a prolonged stay at the center, creating additional or prolonged stress. Thus, it is important to recognize species-specific signs of stress in rescued animals and try to assure them the best quality of life possible, in order to avoid detrimental sequelae to welfare problems experienced during confinement.

Euthanasia

The application of good animal welfare principles requires that euthanasia be an available option for consideration. Providing a death free of pain and distress may be the most humane choice when an animal is suffering. Euthanasia is an important measure to help ensure the welfare of ill or injured animals, such as livestock,[29] domestic animals,[30] experimental animals,[31-32] zoo animals,[33-34] and wildlife.[10]

Especially in cases when the medical prognosis is extremely poor and/or the animal is unsuitable for release, euthanasia in wildlife rescue is recognized as necessary.[35] Tomlinson[36] proposes that, from an animal welfare viewpoint, rescued wildlife that cannot be released back into nature in a short period of time, or that are in untreatable pain or distress, should be euthanized. The guidelines of the American Veterinary Medical Association (AVMA) state that the most important duty of the veterinarian in performing euthanasia is to ensure the use of humane techniques that lead to a rapid death without pain and distress.[37] The National Wildlife Rehabilitators Association (NWRA) and the Department of Parks and Wildlife in Western Australia define the conditions under which euthanasia should be recommended or pursued.[10,38] Yeates[39] advocates that if an animal is experiencing constant pain currently, or can be expected to endure it in the future without relief, euthanasia may be in the animal's best interests in terms of welfare.

Captivity creates a threat to the welfare of wildlife, some species more than others, at all phases of the rescue process, from initial capture to life after release. Therefore, it is important that animals are triaged according to an established protocol soon after arrival at the rescue center. A final decision on euthanasia should be made either immediately or within the first 24–48 hours of captivity.[40]

Animal welfare considerations for wildlife rescue in Japan

Although proper triage, and the ability to perform euthanasia if necessary, respect the welfare of rescued animals; Japanese culture, which values an avoidance of human intervention in the lives of wildlife whenever possible, may influence rehabilitators' decision-making during triage. In Japan, the credentials of a person who performs euthanasia are not rigorously enforced and do not stipulate veterinary qualifications. Moreover, the methods of euthanasia are not strictly regulated, so various methods—such as carbon dioxide gas, cervical dislocation, and exsanguination—are performed in wild birds, sometimes without prior administration of anesthesia. The lack of established guidelines governing euthanasia in rescued wildlife, perhaps coupled with Japanese culture, make it difficult to obtain appropriate euthanasia drugs and skilled personnel.

To confirm whether animal welfare is secured in wild bird rescue in Japan, it is necessary to evaluate how consistently animal welfare, triage, enclosure, husbandry, and euthanasia protocols are followed in wildlife rescue facilities. To effectively determine the issues to be addressed, an overview of wildlife rescue activities in the country has been undertaken. In this study, providing proper euthanasia when indicated is used as the benchmark to assess animal welfare. In many other countries, euthanasia is included in the minimum standards as a means of ensuring respect for animal welfare and the quality of life for rescued wildlife.[41]

Study Objectives

Approximately 90% of the wildlife rescued in Japan are birds.[42,43] Wild bird rescue has been conducted for about half a century in this country, but it is not known whether wild bird rescue is practiced following internationally accepted standards of animal welfare.

This study has three objectives: 1) to determine whether wild bird rescue practiced in Japan is performed with regard for animal welfare; 2) to identify and prioritize which protocols should be addressed in wild bird rescue, as practiced in Japan, from the perspective of animal welfare; and 3) to compare Japan's wild bird rescue and welfare standards with those of other countries.

Materials and Methods

First, we identified as many Japanese wild bird rescue facilities as possible, and determined how best to contact each. Next, we interviewed staff and/or volunteers to obtain a general overview of protocols within each facility. Finally, we identified specific parameters related to the welfare of rescued wildlife, such as initial treatments and housing environments.

Survey population

We included wild bird rescue groups that met three criteria: 1) had a website, 2) operated during the time between September 2014 and March 2018, and 3) agreed to participate in the survey.

Data collection

General information on wild bird rescue groups was initially collected from 72 websites that disseminated information about the 55 wild bird rescue groups in Japan. All websites from facilities that admitted injured or diseased wild birds in Japan between September 2014 and March 2018 were searched, and each facility's operational structure (government, private, or zoo) was recorded. In Japan, all wildlife rescue work is under the jurisdiction of the local government, and wildlife rescue group data, such as operational structure, address of facilities, and contact information, are published on the website of the local government. Because each local government has a website, the activities of identifying all wildlife rescue groups, collecting basic information about them, and requesting an interview survey were easily accomplished. If the local government outsourced wildlife rescue work to a private organization, such as a nonprofit organization, private party, or zoo, the local government website contained that information. Some of these private rescue organizations, as well as the Wild Bird Society of Japan and the prefecture branches of the Japan Veterinary Medical Association, also had websites containing overlapping information about each wild bird rescue group in Japan; this explains why 55 wildlife rescue groups existed but 72 websites were examined.

Interview surveys were conducted for the 26 rescue groups (47% of total wild bird rescue groups) that agreed to participate in this study. The investigators visited the rescue groups and interviewed representatives at each facility who performed wild bird rescue duties on a daily basis. Interviewers collected data on facility management, the rescue process from intake to release or final disposition, and organizational affiliation. The following nine items were selected as questionnaire items based on previous reports: 1) the main management body of a rescue group (i.e. government, private, or zoo); 2) the rescue group's use of intake criteria (whether there were species or age restrictions); 3) year the facility was established (hereinafter referred to as year of opening); 4) presence of a full-time veterinarian; 5) annual intake number; 6) initial treatment options and criteria (wound treatment, provision of heat, tube feeding, rehydration via provision of water); 7) housing (enclosure floor size, indoor floor material, outdoor floor material); 8) criteria for release; and 9) use of euthanasia.

Statistical analysis

A logistic regression analysis was performed to identify factors associated with the practice of euthanasia that directly related to animal welfare. The continuous variable was calculated using a Shapiro-Wilk test to confirm a normal distribution. Of the nine questions, euthanasia (whether or not to perform) was the objective variable, and the other eight items were explanatory variables. We evaluated which items were related to euthanasia. Explanatory variables included management group (government, private, and zoo), year of opening, presence of a full-time veterinarian, annual intake number, initial treatment (frequency of each of the following: wound treatment, provision of heat, tube feeding, rehydration via provision of water), floor size based on size (length) of the bird (large bird >55 cm, medium-sized bird 35–55 cm, small

TABLE 1. Data collected from the 26 wild bird rescue groups that participated in the study from September 2014 to March 2018 in Japan.

VARIABLE	N	(%)
(1) TYPE OF FACILITY		
Government	9	(34.6)
Private	13	(50.0)
Zoo (managed by local government)	4	(15.4)
(2) ESTABLISHED INTAKE CRITERIA	26	(100.0)
(3) YEAR OF OPENING		
Year from 1969 to 1979	11	(42.3)
Year from 1980 to 1990	4	(15.4)
Year from 1991 to 2001	7	(26.9)
Year from 2002 to 2012	4	(15.4)
(4) FULL-TIME VETERINARIAN	15	(57.7)
(5) ANNUAL INTAKE NUMBER		
1 to 150 birds	15	(57.7)
151 to 300 birds	5	(19.2)
301 to 450 birds	5	(19.2)
451 to 600 birds	1	(3.8)
(6) CRITERIA OF EACH INITIAL TREATMENT		
(6A) WOUND TREATMENT		
not performed	7	(26.9)
no specific criteria	0	(0.0)
depending on initial examination	11	(42.3)
always treat when it was injured	8	(30.8)
(6B) PROVISION OF HEAT		
not performed	1	(3.8)
no specific criteria	1	(3.8)
depending on initial examination	4	(15.4)
always	20	(76.9)
(6C) FEEDING-TUBE		
not performed	6	(23.1)
no specific criteria	6	(23.1)
depending on initial examination	4	(15.4)
always	10	(38.5)
(6D) REHYDRATION, PROVISION OF WATER		
not performed	7	(26.9)
no specific criteria	4	(15.4)
depending on initial examination	6	(23.1)
always	9	(34.6)

VARIABLE	N	(%)
(7) FLOOR SIZE CRITERIA		
(7A) FLOOR SIZE FOR SMALL-SIZE BIRD (LENGTH < 35 CM)		
0.1 to 1.9 m^2	16	(61.5)
2.0 to 3.9 m^2	4	(15.4)
4.0 to 5.9 m^2	4	(15.4)
6.0 to 7.9 m^2	2	(7.7)
(7B) FLOOR SIZE FOR MEDIUM-SIZE BIRD (LENGTH 35-55 CM)		
0.1 to 4.9 m^2	15	(57.7)
5.0 to 9.9 m^2	9	(34.6)
10.0 to 14.9 m^2	1	(3.8)
15.0 to 19.9 m^2	1	(3.8)
(7C) FLOOR SIZE FOR LARGE-SIZE BIRD (LENGTH > 55 CM)		
0.1 to 9.9 m^2	11	(42.3)
10.0 to 29.9 m^2	13	(50.0)
30.0 to 59.9 m^2	1	(3.8)
60.0 to 99.9 m^2	1	(3.8)
(7D) INDOOR FLOOR MATERIAL		
sand	2	(7.7)
concrete	6	(23.1)
straw	3	(11.5)
tatami	1	(3.8)
bird enclosure and cardboard	13	(50.0)
not housed indoors	1	(3.8)
(7E) OUTDOOR FLOOR MATERIAL		
soil	14	(53.8)
concrete	5	(19.2)
sand and gravel	3	(11.5)
not housing outdoors	4	(15.4)
(8) RELEASE CRITERIA	15	(57.7)
(9) EUTHANASIA CRITERIA	7	(26.9)

bird <35 cm), indoor flooring material for rescued birds (concrete, straw, tatami, bird enclosure and cardboard, sand, or birds not housed indoors), and outdoor flooring material for rescued birds (soil, concrete, sand and gravel, or birds not housed outdoors). The results are presented as odds ratios (OR), and a 95% confidence interval (CI). Hosmer-Lemeshow goodness-of-fit tests was performed for each univariate analysis. Brant tests were performed to check the proportional OR assumptions. Stata/IC 14 (Stata Corp LP, College Station, Texas, USA) was employed for all analyses. For statistical estimations and inferences, two-sided hypothesis tests were conducted with a significance level of 5%.

Results

From our investigation of website data, it was revealed that in a total 55 wild bird rescue groups were located in 33 prefectures Japan. Of these 55 groups, 26 (47%) agreed to participate in the study. Table 1 provides data collected from the groups taking part in this study.

According to the results of our logistic regression analysis, having established intake criteria (OR = 0.37, 95% CI = 0.15–0.88, p = 0.024), year of opening (OR = 1.15, 95% CI = 1.03–1.30, p = 0.016), and having criteria for housing floor size based on the size of the bird (OR = 9.38, 95% CI = 1.30–67.64, p = 0.026) were significantly related to performing euthanasia (Table 2), and the other items (management group, presence of a veterinarian, annual intake number, treatment protocols, actual floor size, floor material, release criteria) were not significantly related to performing euthanasia (p > 0.05).

Discussion

Wildlife rescue groups should aim to treat and rehabilitate injured wildlife in a way that prioritizes the quality of life and welfare of housed animals. Elements that support welfare include rapid

TABLE 2. Logistic regression analysis of euthanasia as an objective variable at each wild birdrescue group (n=26) in Japan from September 2014 to March 2018.

EXPLANATORY VARIABLES	N	OR	95% CI	P-VALUE
(1) TYPE OF FACILITY	26			
Government	9	REFERENCE	—	—
Private	13	3.55	0.33 - 38.78	0.298
Zoo (managed by local government)	4	8.00	0.45 - 139.29	0.154
(2) ESTABLISHED INTAKE CRITERIA	26			
NO	0	REFERENCE	—	—
YES	26	0.37	0.15 - 0.88	0.024
(3) YEAR OF OPENING				
CONTINUOUS VARIABLE: 1969 - 2012	26	1.15	1.03 - 1.30	0.016
(4) FULL-TIME VETERINARIAN	26			
NO	11	REFERENCE	—	—
YES	15	6.66	0.67 - 66.53	0.106
(5) ANNUAL INTAKE NUMBER				
CONTINUOUS VARIABLE: 1–500	26	0.99	0.99 - 1.01	0.957
(6) INITIAL TREATMENT				
(6A) WOUND TREATMENT	26			
not performed	7	REFERENCE	—	—
no specific criteria	0	N/A	N/A	N/A
depending on initial examination	11	2.5	0.34 - 18.33	0.367
always treat when it was injured	8	N/A	N/A	N/A
(6B) PROVISION OF HEAT	26			
not performed	1	REFERENCE	—	—
no specific criteria	1	N/A	N/A	N/A
depending on initial examination	4	12.0	0.97 - 148.32	0.053
always	20	N/A	N/A	N/A
(6C) FEEDING-TUBE	26			
not performed	6	REFERENCE	—	—
no specific criteria	6	2.0	0.19 - 20.61	0.560
depending on initial examination	4	N/A	N/A	N/A
always	10	0.5	0.50 - 4.98	0.554
(6D) REHYDRATION, PROVISION OF WATER	26			
not performed	7	REFERENCE	—	—
no specific criteria	4	0.27	0.02 - 3.65	0.322
depending on initial examination	6	0.16	0.01 - 1.98	0.154
always	9	N/A	N/A	N/A
(7) FLOOR SIZE CRITERIA	26			
NO	9	REFERENCE	—	—
YES	17	9.38	1.30 - 67.64	0.026
(7A) FLOOR SIZE: SMALL-SIZE BIRD (length < 35 cm)				
Continuous variable	26	0.71	0.41–1.21	0.206
(7B) FLOOR SIZE FOR MEDIUM-SIZE BIRD (length 35-55 cm)				
Continuous variable	26	0.92	0.69–1.22	0.561
(7C) FLOOR SIZE FOR LARGE-SIZE BIRD (length > 55 cm)				
Continuous variable	26	1.00	0.99 - 1.02	0.311
(7D) INDOOR FLOOR MATERIAL	26			
not housed indoors	1	REFERENCE	—	—
sand	2	0.50	0.02 - 12.90	0.676
concrete	6	0.50	0.01 - 19.56	0.711
straw	3	N/A	N/A	N/A
tatami	1	0.20	N/A	N/A
bird enclosure and cardboard	13	N/A	N/A	N/A

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TABLE 2, continued

EXPLANATORY VARIABLES	N	OR	95% CI	P-VALUE
(7E) OUTDOOR FLOOR MATERIAL	26			
not housed outdoors	4	REFERENCE	—	—
soil	13	0.29	0.03 - 3.37	0.324
concrete	5	N/A	N/A	N/A
sand and gravel	3	N/A	N/A	N/A
(8) ESTABLISHED RELEASE CRITERIA	26			
NO	11	REFERENCE	—	—
YES	15	2.89	0.49 - 17.17	0.243

triage, proper first aid and initial treatments, suitable captive husbandry and housing, and adherence to release criteria that promote a successful return to the wild. If wild birds are suffering from pain, trauma, or disease that cannot be alleviated, or if they would not survive without extensive surgery, performing euthanasia is an important measure to preserve animal welfare at wildlife rescue centers. If suitable release sites are unavailable, or if birds are unable to return to the wild for any reason, euthanasia should be chosen.[44] In this study, only seven of the 26 participating groups (26.9%) performed euthanasia for rescued birds; however, it is not known what percentage of the other 29 nonparticipating groups perform euthanasia.

Relationship between euthanasia and intake criteria

All 26 groups in this study answered that they had established criteria for intake, and there was a positive correlation of intake criteria with euthanasia (Table 2). There was, however, no consistency in intake criteria (species and age restrictions) between groups. Non-native species and harmful species were not to be admitted into rescue facilities. The Ministry of the Environment announced that all wildlife rescue groups and citizens were to prevent the erroneous rescue of chicks; however, there were no clear guidelines specifying that chicks were not accepted.[45] Furthermore, 20 rescue groups in this study indicated that when chicks were brought directly to their facilities, they were difficult to refuse and consequently admitted, thus underscoring the lack of consistency in intake criteria between rescue groups.

Relationship between euthanasia and year of opening

Newer facilities tended to perform euthanasia more than did older facilities. One reason for this tendency is that the new public wildlife rescue facilities, which were built through taxes, were designed like animal hospitals and allowed to be individually managed and provide better care for animals. In contrast, the older facilities tended to be designed for temporary mass production of poultry.

Relationship between enclosure size and animal welfare

Some facilities housed grey herons (*Ardea cinerea*) and northern goshawks (*Accipiter gentilis*) in unacceptably small enclosures measuring 0.5 m^2 and 0.4 m^2, respectively. The birds were not able to fully expand their wings or stretch their necks. There is no law in Japan that regulates against this poor welfare situation.

Inadequate space will create stress that can be manifested in abnormal behaviors. The stress response in wild birds (compared with captive-bred birds) is prolonged, as was shown in an experiment with parrots.[46] In Victoria, Australia, the enclosure dimensions for various sizes and species of rescued wild birds are specified as part of the Code of Practice for the Welfare of Wildlife During Rehabilitation.[44]

The International Wildlife Rehabilitation Council (IWRC) and the National Wildlife Rehabilitators Association (NWRA) have established housing requirements for avian patients based on species, natural history, and construction materials.[47] Thus, providing an adequate and appropriately-sized enclosure is important for the welfare of birds.

Relationship between floor materials and animal welfare

No consistent criteria existed among rescue groups for the choice of floor materials. Some used concrete because it was easy to clean and thus convenient for staff. Others prioritized the comfort needs of the rescued birds by using materials such as sawdust and straw that provided good cushioning and absorption, and would therefore be expected to prevent disease in the soles of the feet; however, depending on the bird species, the risk of aspergillosis and other respiratory diseases could be significantly increased.[48] One group frequently changed the perches, made mainly from Japanese beech (*Fagus crenata*) trees, to keep them fresh. The resulting variety in perch size and shape would promote normal foot health. In addition, the frequent changes could enhance the effects of the tree's natural phytoncidal (antimicrobial) properties,[49] conceivably promoting foot and overall health.

When investigating floor materials, it was observed that injuries to the soles of rescued birds in six groups were attributed to the flooring material and perches. Water birds were provided pools in their enclosures. Waterfowl with webbed feet are vulnerable to bumble foot if they are confined to an area with packed

ground or weed stubble because they do not naturally burden their sensitive feet.[50] Although it is also important to consider the potential increase in effort on the part of the rehabilitator, wildlife rescue that respects animal welfare should be prioritized.[51]

Relationship between euthanasia and the presence of a full-time veterinarian

A major concern identified in this study that might heavily affect animal welfare is the presence of a veterinarian. In this survey, surprisingly, the presence of a full-time veterinarian was not significantly related to the use of euthanasia, and criteria for performing euthanasia did not involve a veterinarian's decision. In contrast, the wildlife rescue guidelines of the Japan Veterinary Medical Association (JVMA) state that a veterinarian should determine the judgment for or against euthanasia, although there is no stipulation about who can perform the euthanasia in these guidelines or in animal welfare laws.[12,52] Also, regarding the method to be used for euthanasia, the guidelines recommend using drugs, but the appropriate drug name and method are not specified.[52-53]

Although, in this survey, there was no direct connection between the performance of euthanasia and the presence of a veterinarian, veterinarians are in a unique position to perceive an animal's well-being and should be involved. They will quickly notice the signs of stress in animals through their specialized skills and expertise, and they can preserve the welfare of rescued animals through informed triage and euthanasia decisions.[26,40,54]

In Japan, the quality of life of rescued animals is given little attention by most veterinarians or rehabilitators. This may be due to a lack of guidance and education from the authorities who mandate wildlife rescue and to the perception that jobs in wildlife rescue are simply poorly-regarded tasks ordered by the municipality.

Importance of wild bird rescue standards

In Japan, with the exception of the JVMA's recommendations for veterinarians, no guidelines exist for rescuing wildlife or for regulating or managing the people who engage in wildlife rescue; and the ethics surrounding rescue are unclear and inconsistent between rescue groups. In this study, it was revealed that the lack of a consistent management protocol and standard operating procedures for wildlife rescue groups resulted in rescue activities that were not evidence-based and that did not address animal welfare. For example, if a facility is underfunded or lacks sufficient space for the number of animals needing help and being admitted, it is entirely possible that an animal with a wound that is still healing could be released prematurely. Prioritizing animal welfare should be a common philosophy for all wildlife rescue.

It is important to have common standard operating procedures in the wildlife rescue centers of a country to enforce and improve networking and cooperation. The United States, Australia, and Spain each have a system of permits or licenses for people involved in wildlife rescue, as well as minimum standards guiding wildlife rescue practices to ensure best possible outcomes for each animal.[10,13,47,55-59] In the United Kingdom (UK), as in Japan, there is no formal system for training rehabilitators, but in the UK both the British Wildlife Rehabilitation Council and the British Veterinary Zoological Society have issued voluntary guidelines for wildlife rehabilitation.[18,60]

Wildlife rehabilitation can only be effective if conducted with clear objectives.[11] It was found that rehabilitation-specific guidelines[61] that outlined effective practices for reintroduction improved the reintroduction process. It is necessary to establish standards that are adapted to locally native wildlife and that reference scientific reports based on animal welfare or successful release. Examples include providing a rescue environment similar to the natural habitat,[62] minimizing human contact,[63] and employing group rescue for animals with a flock ecology.[64]

Limitations of the study

The primary limitation of this study was the small sample size, which included only 26 facilities. There are 55 facilities in total, meaning a participation rate of 47%. The groups were operated by various organizations, including the government and NGOs, both for-profit and non-profit, leading to considerable variety in management, quality of housing, intake number, and treatment procedures. Logistic regression analyses were performed to avoid variety in rescue procedures by categorizing the questions as much as possible.

Conclusion

This study revealed that the practice of wild bird rescue in Japan is inconsistent and raises many concerns about poor animal welfare. Although regional differences should be considered, in principle, wildlife rescue should be consistent regardless of rescue group, based on the ecology of the bird species and focused on the welfare of wildlife.

According to this survey, the wildlife rescue system in Japan varies greatly between local governments. To create appropriate standards for animal welfare, it would be important to first conduct a survey to understand the issues in each rescue group and wildlife rescue system in the area. The results could then be incorporated into a set of national standards, based on scientific evidence and international guidlines, to maximize care for rescued birds.

Author contributions

NU contributed to creating the concept and design of this study, researching websites for literature and field survey, writing the initial draft, and editing the final paper. SH contributed to the review and preparation of the manuscript for editing. AT contributed to the idea and design of this research, supervision, statistical analysis, organization of data, writing the draft of introduction and discussion, and editing.

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CONTINUED FROM PAGE 6

Collaboration Prevents Human–Wildlife Conflict

NAMIBIA *(December 7, 2020)*—Namibian cattle farmers and scientists at the Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW) have seen the fruit of their collaboration.

Using data from the tracking of over 250 cheetahs, researchers were able to map their territories and, more critically, their movements within the territories. They found that there are core areas within the territories that function as communication hubs for the local cheetah population and are effectively hotspots of cheetah activity.

Researchers identified these communication hubs and worked with local farmers to keep livestock out of the hubs. This reduced livestock losses by over 80 percent.

Dr. Jörg Melzheimer and Dr. Bettina Wachter of Leibniz IZW Cheetah Research Project explain. "We demonstrated that cheetahs did not follow the breeding herds, but maintained their spatial system of communication hubs and instead preyed on wildlife occurring naturally on the farms in the hotspot locations. This implies that there are no problem cheetahs, but problem areas with high predation risk." Melzheimer adds, "The future of the cheetah does not lie in the hands of scientists or conservationists, it depends on all stakeholders working together on viable solutions."



PHOTO ©MARIUSZ KLUZNIAK. CC BY-NC-ND 2.0.

Cheetah (*Acinonyx jubatus*).

Tracking Tags Able to Transmit Large Amounts of Data to Satellites

MIAMI, USA *(December 4, 2020)*—Scientists at the University of Miami, in partnership with Wildlife Computers, Inc., created a new activity data product application for marine animal tracking. A study of the technology was published in November in the journal *Animal Biotelemetry*. The technology is designed to remotely track and transmit data gathered on an individual animal's activity levels over several months, along with the temperatures and depths they experienced.

Wide-ranging ocean species, such as sharks, tunas, and billfish, lead complex lives hidden under the ocean surface. This makes studying activity levels in these species very challenging for scientists. While some tags have integrated accelerometers capable of measuring animal activity levels, the amount of raw data generated is generally too large to transmit via satellite, which required scientists to somehow retrieve the tags and download the accelerometer data. This has been a major limitation for gathering key data on how these species use their environment.

"Along with changes in activity level, the tag also collects and transmits data on the animal's swimming depth and the temperatures they encounter with a user-programmable resolution," said Kenady Wilson, Ph.D. research scientist, Wildlife Computers and a co-author of the study. "These data are transmitted via our MiniPAT (pop-up archival transmitting news tag) with a tracking period of up to three months."



MiniPAT® wildlife tracking tag for satellite data transmission. *Image ©Wildlife Computers, Inc.*

To see how well the tag performed in the wild, the team attached MiniPAT tags enabled with the ATS data product to sandbar sharks. After one month, the tags popped off as programmed and successfully transmitted the sharks' activity data along with their environmental conditions and locations.

"The ability to now remotely track how animals are behaviorally responding to changes in environmental conditions over several months and across vast expanses of open ocean really opens up a lot of new research opportunities" said Neil Hammerschlag, research associate professor at the UM Rosenstiel School of Marine & Atmospheric Science and UM Abess Center for Ecosystem Science & Policy. "This is especially important for understanding if and how these species respond to climate change."

EU Bans Lead Shot in Wetlands

BONN, *(November 27, 2020)*—A September meeting has led to draft entry 63 in Annex XVII of the European Parliament's regulation 1907/2006 - Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH). This will ban lead shot in and around wetlands.

The Agreement on the Conservation of African–Eurasian Migratory Waterbirds (AEWA) organization notes that not only

will this legislation prevent primary poisoning of waterbirds that mistake lead shot for food or grit, but that "Additional wider positive effects will include a decrease in the secondary poisoning of predatory and scavenging birds, which are regularly poisoned by either consuming contaminated birds or eating the pellets of lead shot embedded in their prey." The ban will also improve ecosystem and human health; a fine improvement for the global One Health initiative.

Speaking with AEWA, Technical Committee Chair Dr. Ruth Cromie notes, "Removing toxic lead exposures from waterbirds isn't just about stopping them dying, it will lead to better breeding potential, better immune systems, better ability to thrive, and that's what we all need—healthy birds in healthy wetlands."

Budget-Friendly Autoclaves in Our Future?

CAMBRIDGE, USA *(November 18, 2020)*—A team of researchers at MIT and the Indian Institute of Technology has come up with a way to generate an autoclave's pressurized steam passively, using just the power of sunlight, with no need for fuel or electricity. The device, which would require a solar collector of about 2 square meters to power a typical small-clinic autoclave, could maintain safe, sterile equipment at low cost in remote locations. A prototype was successfully tested in Mumbai, India.

The system is described in the journal Joule, in a paper by MIT graduate student Lin Zhao, MIT Professor Evelyn Wang, MIT Professor Gang Chen, and 10 others at MIT and IIT Bombay.

The key to the new system is the use of optically transparent aerogel, a material developed over the last few years by Wang and her collaborators. The material is essentially a lightweight foam made of silica, the material of beach sand, and consists mostly of air. Light as it is, the material provides effective thermal insulation, reducing the rate of heat loss by tenfold.

Much of the developing world faces limited availability of reliable electricity or affordable fuel. "We saw this as an opportunity to think about how we can potentially create a low-cost, passive, solar-driven system to generate steam at the conditions that are necessary for autoclaving or for medical sterilization," explains Wang, who is the Gail E. Kendall Professor of Mechanical Engineering and head of the mechanical engineering department.

In the Mumbai tests, even though the sky was hazy and cloudy, providing only 70 percent insolation compared to a sunny day, the device succeeded in producing the saturated steam needed for sterilization for the required half hour period.

The test was carried out with a small-scale unit, only about a quarter of a square meter, about the size of a hand towel, but it showed that the steam production rate was sufficient that a similar unit of somewhere between 1 and 3 square meters would be sufficient to power a benchtop autoclave of the kind typically used in a doctor's office, Zhao says.

The main limiting factor for practical deployment of such devices is the availability of the aerogel material. One company, founded by Elise Strobach PhD '20, who is a co-author of this paper, is already attempting to scale up the production of transparent aerogel, for use in high thermal efficiency windows. But so far the material is only produced in small amounts using relatively expensive laboratory-grade supercritical drying equipment, so widespread adoption of such a sterilization system is likely still a few years off, the researchers say.

Since the other components, except for the aerogel itself, are already widely available at low cost throughout the developing world, fabrication and maintenance of such systems may ultimately be practical in the areas where they would be used. The parts needed for the quarter-square-meter prototype came to less than $40, Zhao says, so a system sufficient for a typical small autoclave would be likely to cost $160 or so, once the necessary aerogel material becomes commercialized. "If we can get the supply of aerogel, the whole thing can be built locally, with local suppliers," he says. *Images available at news.mit.edu/2020/autoclave-sterilize-medical-solar-1118*



PHOTO © AVELINO ZEPEDA MARTINEZ. CC BY-NC 2.0.

Sandbar shark (*Carcharhinus plumbeus* [Nardo 1827]).

California Agencies Create Wildlife Disaster Network

DAVIS, CALIFORNIA, USA *(October 5, 2020)*—UC Davis and the California Dept. of Fish & Wildlife (CDFW) have created the Wildlife Disaster Network (WDN), a new partnership to respond to disasters, such as wildfires, that affect wildlife. Modeled after the Oiled Wildlife Care Network (OWCN), this new initiative will allow a strategic response to the increasingly severe disasters that plague the state.

"Through OWCN, we've seen how effective a mobilized and coordinated response can be to help aid wildlife, and I'm excited to see how the Wildlife Disaster Network can bring that same level of care to wildlife affected by wildfire," said

Michael Ziccardi, director of OWCN and the One Health Institute at UC Davis, via a University news post.

Wildlife Disaster Networks's UC Davis lead is Dr. Jamie Peyton, who worked on the tilapia burn bandage technique. Speaking with The Aggie, UC Davis's newspaper, Dr. Peyton notes, "One of the most challenging issues for wildlife in disasters is finding the best habitat to release them, since large areas are often destroyed in wildfires. Together as a team with veterinarians, biologists, wildlife carers, and the public, we can help ensure that our wildlife has a chance to survive these disasters."

The Network includes a hotline, 1-800-WHC-OIL-9 (1-800-942-6459), for reporting injured wildlife. They'll be able to use the hotline to coordinate between wildlife rehabilitation centers and share information. Dr. Deana Clifford, CDFW's lead, explains, "The idea is to create a collaborative process which works within any existing emergency incident command structure, that brings experts together to respond to injured animals and prevent suffering."

A CDFW news report sums up the initiative, "In addition to easing the suffering of animals that are trapped by wildfires in California's changing climate, the vets hope that the Wildlife Disaster Network will allow for California's wildlife veterinarians and disaster response professionals to add to their knowledge, and promote further collaboration with others to share this knowledge. The long-term impacts on wildlife from these massive disasters are also largely unknown and in critical need of further investigation and intervention, especially in areas with threatened species. All of the data collected by the participants of the Wildlife Disaster Network—such as necropsy reports on the animals who do not survive their injuries—will help build a framework of scientific knowledge that didn't previously exist."

January Bushfires Cause Wildlife Center Evacuation

ADELAIDE, AUSTRALIA *(January 24, 2021)*—The Cherry Gardens fire caused the evacuation of 15 critical care wombats from the Wombat Awareness Organization in late January. An additional 72 wombats sheltered in their burrows, much as free roaming wombats do during bushfires. Reports are that the center escaped direct fire damage and that all wombats are back at the center.

Speaking with Australian Broadcast Company News, center director Brigitte Stevens notes, "We thought we were kind of prepared, but we didn't think about when we evacuate, where do we go, and how do we transport the volume of wombats we have?"

Center staff have proposed a government-supported wildlife fire shelter that would be an evacuation center both for animals currently in care at wildlife centers within the council and for wildlife injured or displaced during a fire, assuming space was not available at existing centers.

Funding for Native Wildlife

SYDNEY, AUSTRALIA *(February 1, 2021)*—WIRES is funding research at University of Sydney School of Veterinary Science to better understand and manage wildlife diseases. The $200,000 grant over two years will support initiatives to improve disease diagnosis in native wildlife and ultimately improve long-term outcomes.

Disease outbreaks and resurgence in native wildlife are becoming more common due to the combination of climate change, unprecedented bushfires, and long-term drought conditions.

"Wildlife carers often rescue animals suffering with diseases and rely on veterinarian advice to best treat and manage affected animals while in care," said Leanne Taylor, WIRES' CEO. "More research into wildlife diseases is greatly needed, particularly now with so many species moving to endangered status. We look forward to working with the University of Sydney School of Veterinary Science team to gain better insights into diagnosis and treatment for our native animals."

The first phase of this project will be to survey wildlife carers and veterinarians about the most common diseases impacting wildlife in care that require better treatments or have indeterminate causes.



PHOTO © CALIFORNIA DEPT OF FISH & WILDLIFE.

Jamie Peyton of UC Davis and colleagues from the California Dept. of Fish & Wildlife examine paws of a mountain lion with burn injuries from the September 2020 Bobcat Fire.

University of Sydney research lead, Professor David Phalen from the School of Veterinary Science said, "The funding from WIRES will ultimately result in a marked reduction in illness and improved chances for a successful release and long-term post release survival for any species of birds, mammals, and reptiles that are brought into care." Lorikeet paralysis syndrome and wombat road deaths are among the subjects of native animal research that funding will go towards.

Professor Phalen and his team previously uncovered and prevented further poisoning in both eastern grey kangaroos (iron poisoning through feeding on limited vegetation) and barn owls (poisoning due to eating mice and rats that had consumed rodent bait). Professor Phalen was also part of a committee organised by Wildlife Health Australia that helped develop evidence-based wildlife feeding guidelines for the public, following the 2019–20 bushfire season. ■

Clinical and pathologic findings of an outbreak of vitamin D3–responsive metabolic bone disease in heron and egret (family Ardeidae) chicks fed capelin (*Mallotus villosus*)

M Horgan, R Duerr, and B Murphy. *Journal of Zoo and Wildlife Medicine*, 12 January 2021;51(4):958–969. doi.org/10.1638/2019-0238.

An increase in cases of metabolic bone disease (MBD) in chicks of six species of heron and egret (family Ardeidae) was identified at a wildlife rehabilitation center in the spring and summer of 2018. The outbreak affected 34.3% of birds in care for four or more days during the first 3 months of the study and was the most common reason for euthanasia during that time. Cases were characterized by lameness, increased flexibility of multiple long bones, angular deformities, and bone fractures. Gross postmortem examinations were conducted on 145 nestlings and fledglings that died or were euthanatized either because of MBD or for unrelated conditions. Histology was performed in four cases and three controls. Histologic findings were characterized by multiple lesions in the appendicular long bones, including variable elongation of the physis, retention of cartilage cores in the metaphyseal primary spongiosa, poorly mineralized osteoid seams within the primary spongiosa, thinning or lack of diaphyseal cortical bone compaction, and folding fractures typically propagating through the physis–metaphyseal interface. Folding fractures were often associated with focal metaphyseal fibroplasia. The parathyroid gland diameter of birds diagnosed postmortem with MBD in care was significantly larger than that of unaffected birds. The authors hypothesized that a dietary deficiency of vitamin D_3 because of low levels in the bird's captive diet of capelin (*Mallotus villosus*) was the cause of the MBD. Starting in mid-July, every chick's diet was supplemented with 714 IU oral vitamin D_3/kg body weight per day, after which the number of birds developing MBD declined to a rate of 4.3%. This study characterizes the clinical, gross, radiographic, and histologic features of vitamin D_3-responsive MBD in young herons and egrets and provides evidence to support the recommendation that captive birds on a diet of capelin be supplemented with vitamin D_3, especially during growth.

MRSA and enterobacteria one health concern in wild animals undergoing rehabilitation

DR Silveira, TP de Moraes, K Kaefer, LG Bach, A de O Barbosa, VD Moretti, PQ de Menezes, US de Medeiros, TT da Silva, PM Bandarra, et al. *RSD* [Internet], 17 Jan 2021 [cited 26 Jan 2021];10(1):e34810111809. www.rsdjournal.org/index.php/rsd/article/view/11809.

The presence of contaminated animals in wildlife rehabilitation centers poses a threat for both animals and humans that come into contact with them or the contaminated environment. The aim of this study was to assess the presence of *Staphylococcus aureus*, including methicillin-resistant *S. aureus* (MRSA), as well as studying the biofilm formation capacity of these isolates, *Yersinia enterocolitica*, *Salmonella enterica,* and *Campylobacter* spp., in wild animals from a rehabilitation center. During a two-year period, feces were collected from animals that were admitted to a wildlife rehabilitation center (n=324 samples). The pathogens were isolated from 51 (15.7%) animals of different species of mammals, birds, and reptiles. Forty isolates (12.3%) were identified as *S. aureus*; of these, 32 (9.9%) were identified as MRSA and 72.5% were able to form biofilm. *Y. enterocolitica* was found in five mammals (5.1%), three reptiles (21.43%), and two birds (0.94%). *Salmonella* and *Campylobacter* were isolated from one bird each (0.67% and 0.67%, respectively). A wide diversity of animal species in rehabilitation centers, including birds, mammals, and reptiles, can carry MRSA and enterobacteria of health concern and eliminate in the feces. The presence of these pathogens in the gastrointestinal tract of wild animals admitted to a wildlife rehabilitation center shows the importance of microbiological monitoring of animals at the time of their admission and reinforces the need for specific hygienic-sanitary care.

Detection and control of dermatophytosis in wild European hedgehogs (*Erinaceus europaeus*) admitted to a French wildlife rehabilitation center

C Le Barzic, A Cmokova, C Denaes, P Arné, V Hubka, J Guillot, and V Risco-Castillo. *Journal of Fungi*, 2021;7(2):74. doi.org/10.3390/jof7020074.

The rising number of European hedgehogs (*Erinaceus europaeus*) admitted every year to wildlife rehabilitation centers might be a source of concern to animal and public health, since transmissible diseases, such as dermatophytosis, can be easily disseminated. This study seeks to evaluate the frequency of dermatophyte detection in hedgehogs admitted to a wildlife rehabilitation centre located near Paris, France, and to assess the risk of contamination in the center in order to adapt prevention measures. A longitudinal cohort study was performed on 412 hedgehogs hosted at the Wildlife Animal Hospital of the Veterinary College of Alfort from January to December 2016. Animals were sampled once a month for fungal culture. Dermatophyte colonies were obtained from 174 out of 686 skin samples (25.4%). Besides *Trichophyton erinacei*, *Trichophyton mentagrophytes* and *Nannizzia gypsea* were also found. Dermatophyte detection seemed to be associated with the presence of skin lesions, while more than one-third of *T. erinacei*-positive animals were asymptomatic carriers. Healing required several months of treatment with topical and systemic azoles, but dermatophytosis did not seem to reduce the probability of release. Daily disinfection procedures and early detection and treatment of infected and asymptomatic carriers succeeded in limiting dermatophyte transmission between hedgehogs and humans.

The use of Cydectin® by wildlife carers to treat sarcoptic mange in free-ranging bare-nosed wombats (*Vombatus ursinus*)

JM Old, CJA Skelton, and HJ Stannard. *Parasitology Research*, 2021;120:1077-1090. doi.org/10.1007/s00436-020-07012-8.

Wombats suffer from sarcoptic mange, a mite infection that ultimately leads to

their death from secondary infections. In 2017, wildlife carers were granted legal approval to treat bare-nosed wombats (*Vombatus ursinus*) for sarcoptic mange in the field using 4 mL of topical Cydectin® per adult wombat. However, (limited) scientific field trials suggest approved protocols are inadequate, which has been supported anecdotally by wildlife carers. Elucidating carer experience is key to holistically advancing understandings of sarcoptic mange treatment. We interviewed 18 wildlife carers regarding the use of Cydectin® to treat free-ranging adult wombats infected with sarcoptic mange, which uncovered 43 detailed case studies for examination. Case studies revealed that wildlife carers have used 10–200-mL doses of topical Cydectin® to treat wombats to recovery. These results suggest there is no best-fit for treating wombats in the field, due to individual differences in observed levels of sarcoptic mange severity and differences in wombat behavior. Furthermore, wildlife carers suggested pour-on Cydectin® appeared non-toxic to wombats at rates as high as 200 mL per treatment. We recommend scientific trials should be undertaken to determine the impact and efficacy of the varying treatment regimens, including low and high doses of topical Cydectin® on bare-nosed wombats. This information is required for regulating authorities, and subsequently wildlife carers, and managers, to make fully informed decisions about wombat sarcoptic mange treatment.

And just for fun.

"Wombats use rock-hard butts to fight, flirt, and frolic"

Anatomic interactive atlas of the loggerhead sea turtle (*Caretta caretta*) head

A Arencibia, A Melián, and J Orós. *Animals*, 2021;11(1):198. doi.org/10.3390/ani11010198.

Because several diseases have been reported affecting the head of sea turtles, accurate anatomic knowledge of this body part is necessary. We provide an open access, anatomic, interactive atlas of the head of the loggerhead sea turtle (*Caretta caretta*), to facilitate anatomic learning using osteology, gross dissection, and computed tomography (CT) images. Using segmentation and visualization software, relevant anatomic structures were identified and colored in all images, and a computer atlas was developed. This atlas, composed of 55 images, provides an interactive anatomic resource for veterinarians, biologists, researchers, and students involved in loggerhead sea turtle conservation.

The head of the sea turtle is susceptible to congenital, developmental, traumatic, and infectious disorders. An accurate interpretation and thorough understanding of the anatomy of this region could be useful for veterinary practice on sea turtles. The purpose of this study was to develop an interactive two-dimensional (2D) atlas viewing software of the head of the loggerhead sea turtle (*Caretta caretta*) using images obtained via osteology, gross dissections, and computed tomography (CT). The atlas is composed of 10 osteology, 13 gross dissection, 10 sagittal multiplanar reconstructed CT (bone and soft tissue kernels), and 22 transverse CT (bone and soft tissue windows) images. All images were segmented and colored using ITK-SNAP software. The visualization and image assessment were performed using the Unity 3D platform to facilitate the development of interactive content in 2D. This atlas can be useful as an interactive anatomic resource for assessment of the head of loggerhead sea turtles. *View full text.*

Cellular autofluorescence is magnetic field sensitive

N Ikeya and JR Woodward. *PNAS*, 2021; 118(3):e2018043118. doi.org/10.1073/pnas.2018043118.

The radical pair mechanism is the favored hypothesis for explaining biological effects of weak magnetic fields, such as animal magnetoreception and possible adverse health effects. To date, however, there is no direct experimental evidence for magnetic effects on radical pair reactions in cells, the fundamental building blocks of living systems. In this paper, using a custom-built microscope, we demonstrate that flavin-based autofluorescence in native, untreated HeLa cells is magnetic field sensitive, due to the formation and electron spin-selective recombination of spin-correlated radical pairs. This work thus provides a direct link between magnetic field effects on chemical reactions measured in solution and chemical reactions taking place in living cells.

We demonstrate, by direct, single-cell imaging kinetic measurements, that endogenous autofluorescence in HeLa cells is sensitive to the application of external magnetic fields of 25 mT and less. We provide spectroscopic and mechanistic evidence that our findings can be explained in terms of magnetic field effects on photoinduced electron transfer reactions to flavins, through the radical pair mechanism. The observed magnetic field dependence is consistent with a triplet-born radical pair and a $B_{1/2}$ value of 18.0 mT with a saturation value of 3.7%.

Associated article:

Birds have a mysterious 'quantum sense.' For the first time, scientists saw it in action.

A new dichromatic species of Myotis (Chiroptera: *Vespertilionidae*) from the Nimba Mountains, Guinea

NB Simmons, J Flanders, EM Bakwo Fils, G Parker, JD Suter, S Bamba, M Douno, MK Keita, AE Morales, and WF Frick. *American Museum Novitates*, 2021;2020(3963):1–40. doi.org/10.1206/3963.1.

The genus *Myotis* is a diverse group of vespertilionid bats found on nearly every continent. One clade in this group, the subgenus *Chrysopteron*, is characterized by reddish to yellowish fur and, in some cases, visually striking dichromatic wing pigmentation. Here, we describe a new dichromatic species of *Myotis* (*Chrysopteron*) from the Nimba Mountains in Guinea. The new species is superficially similar to *Myotis welwitschii*, but phylogenetic analyses based on cytochrome *b* data indicated that it is actually more closely related to *M. tricolor*. Discovery of this new taxon increases the number of *Myotis* species known from mainland

Africa to 11 species, although patterns of molecular divergence suggest that cryptic species in the *Chrysopteron* clade remain to be described. This discovery also highlights the critical importance of the Nimba Mountains as a center of bat diversity and endemism in sub-Saharan Africa.

Ravens parallel great apes in physical and social cognitive skills

S Pika, MJ Sima, CR Blum, E Herrmann, and R Mundry. *Scientific Reports,* 2020;10**:**20617. doi.org/10.1038/s41598-020-77060-8.

Human children show unique cognitive skills for dealing with the social world, but their cognitive performance is paralleled by great apes in many tasks dealing with the physical world. Recent studies suggested that members of a songbird family—corvids—also evolved complex cognitive skills, but a detailed understanding of the full scope of their cognition was, until now, not existent. Furthermore, relatively little is known about their cognitive development. Here, we conducted the first systematic, quantitative large-scale assessment of physical and social cognitive performance of common ravens with a special focus on development. To do so, we fine-tuned one of the most comprehensive experimental test-batteries, the Primate Cognition Test Battery (PCTB), to raven features, enabling also a direct, quantitative comparison with the cognitive performance of two great ape species. Full-blown cognitive skills were already present at the age of four months with subadult ravens' cognitive performance appearing very similar to that of adult apes in tasks of physical (quantities, and causality) and social (social learning, communication, and theory of mind) cognition. These unprecedented findings strengthen recent assessments of ravens' general intelligence, and add to the growing evidence that the lack of a specific cortical architecture does not hinder advanced cognitive skills. Difficulties in certain cognitive scales further emphasize the quest to develop comparative test batteries that tap into true species, rather than human-specific, cognitive skills, and suggest that socialization of test individuals may play a crucial role. We conclude to pay more attention to the impact of personality on cognitive output, and a currently neglected topic in Animal Cognition—the linkage between ontogeny and cognitive performance.

Dire wolves were the last of an ancient New World canid lineage

AR Perri, KJ Mitchell, A Mouton, S Álvarez-Carretero, A Hulme-Beaman, J Haile, A Jamieson, J Meachen, AT Lin, BW Schubert, et al. *Nature,* 2021. doi.org/10.1038/s41586-020-03082-x.

Dire wolves are considered to be one of the most common and widespread large carnivores in Pleistocene America, yet relatively little is known about their evolution or extinction. Here, to reconstruct the evolutionary history of dire wolves, we sequenced five genomes from sub-fossil remains dating from 13,000 to more than 50,000 years ago. Our results indicate that although they were similar morphologically to the extant grey wolf, dire wolves were a highly divergent lineage that split from living canids around 5.7 million years ago. In contrast to numerous examples of hybridization across Canidae, there is no evidence for gene flow between dire wolves and either North American grey wolves or coyotes. This suggests that dire wolves evolved in isolation from the Pleistocene ancestors of these species. Our results also support an early New World origin of dire wolves, while the ancestors of grey wolves, coyotes, and dholes evolved in Eurasia and colonized North America only relatively recently.

Bacteria and antibiotic resistance detection in fractures of wild birds from wildlife rehabilitation centers in Spain

A Tardón, E Bataller, L Llobat, and E Jiménez-Trigos. *Comparative Immunology, Microbiology and Infectious Diseases*, 2021;74:101575. https://doi.org/10.1016/j.cimid.2020.101575.

Anatomic adaptations make birds more prone to open fractures with exposed bone parts losing vascularization. As a result of this exposure, fractures are colonized by different microorganisms, including different types of bacteria, both aerobic and anaerobic, causing osteomyelitis in many cases. For this reason, antibiotic treatment is common. However, carrying out antibiotic treatment without carrying out a previous antibiogram may contribute to increased resistance against antibiotics, especially in migratory wild birds. In this paper, bacterial counts regarding fracture type, bacterial identification, and antibiotic resistance have been analyzed in wild birds from wildlife rehabilitation centers in Spain. The results obtained showed that open fractures had higher bacterial counts (CFU/mL) than closed ones. Bacteria in family Enterobacteriaceae identified were *Escherichia* spp., *Enterobacter* spp., *Shigella* spp., *Hafnia alvei*, *Proteus mirabilis*, *Leclercia adecarboxylata,* and *Pantoea agglomerans*. Other bacteria present in wild birds' fractures were *Aeromonas* spp., *Enterococcus* spp., *Bacillus wiedmannii,* and *Staphylococcus sciuri*. All species found presented resistance to at least one of the antibiotics used. Wild birds can be implicated in the introduction, maintenance, and global spreading of antibiotic resistant bacteria, and represent an emerging public health concern. Results obtained in this paper support the idea that it is necessary to take this fact into account before antibiotic administration to wild animals, since it could increase the number of bacteria resistant to antibiotics.

Transcontinental 2200 km migration of a Nathusius' pipistrelle (*Pipistrellus nathusii*) across Europe

JT Alcalde, M Jiménez, I Brila, V Vintulis, CC Voigt, and G Pētersons. *Mammalia*. Ahead of print: 20 October 2020. doi.org/10.1515/mammalia-2020-0069.

A male *Pipistrellus nathusii* ringed in Pape Natural Park (S. Latvia) in August 2015 was recovered recently dead in Pitillas' Lagoon Natural Reserve (N. Spain) in March 2017. At 2224 km in SSW direction, this is the first documented bat migration between these countries and, worldwide, the longest migration record of a bat. We also report other observations of this species in autumn in Northern Spain, suggesting that the Iberian Peninsula may



be an important wintering area for Nathusius' pipistrelles. Conservation measures should be agreed on by countries along the migration routes to improve the protection of this species.

Behavior change in urban mammals: A systematic review

K Ritzel and T Gallo. *Frontiers in Ecology and Evolution.* 2020;8:576665. https://doi.org/10.3389/fevo.2020.576665.

As cities expand to accommodate a growing human population, their impacts to natural ecosystems and the wildlife residing within them increase. Some animals that persist in urban environments demonstrate behaviors distinct from their non-urban counterparts. These potential behavioral changes are the subject of a growing body of research in the areas of wildlife ecology, biology, and conservation. In spite of increasing urban wildlife research, studies focused specifically on changing behavior in urban mammals is limited. We conducted a systematic literature review to synthesize current research on behavior changes in wild urban mammals. We included 83 papers published between 1987 and March 2020. Omnivores were the leading subject of study, closely followed by carnivores, and the specific behaviors most widely studied were home range and vigilance. Among the reviewed studies, there were 166 observations of 44 distinct behaviors, with 155 occurrences of behavior change relative to conspecifics in non-urban areas. The most commonly studied and observed type of behavior change was alert behavior. Results indicate urban environments drive adaptive responses in behavior, including changes in home range and diet preference, shifts in activity budget and vigilance, decreased flight initiation distance, and increased nocturnal activity. Some urban mammal species even demonstrated the ability to modulate behaviors based on environmental cues. Our results highlight the need for long-term wildlife behavior studies across a variety of urban settings to promote successful urban wildlife management and conservation.

Cranial morphology of captive mammals: a meta-analysis

L Siciliano-Martina, JE Light, and AM Lawing. *Frontiers in Zoology,* 2021;18(4). doi.org/10.1186/s12983-021-00386-0.

Captive facilities such as zoos are uniquely instrumental in conservation efforts. To fulfill their potential as bastions for conservation, zoos must preserve captive populations as appropriate proxies for their wild conspecifics; doing so will help to promote successful reintroduction efforts. Morphological changes within captive populations may be detrimental to the fitness of individual animals because these changes can influence functionality; thus, it is imperative to understand the breadth and depth of morphological changes occurring in captive populations. Here, we conduct a meta-analysis of scientific literature reporting comparisons of cranial measures between captive and wild populations of mammals. We investigate the pervasiveness of cranial differences and whether cranial morphological changes are associated with ecological covariates specific

to individual species, such as trophic level, dietary breadth, and home range size.

Cranial measures of skull length, skull width, and the ratio of skull length-to-width differed significantly between many captive and wild populations of mammals reported in the literature. Roughly half of captive populations differed from wild populations in at least one cranial measure, although the degree of changes varied. Carnivorous species with a limited dietary breadth displayed the most consistent changes associated with skull widening. Species with a more generalized diet displayed less morphological changes in captivity.

Wild and captive populations of mammals differed in cranial morphology, but the nature and magnitude of their cranial differences varied considerably across taxa. Although changes in cranial morphology occur in captivity, specific changes cannot be generalized for all captive mammal populations. The nature of cranial changes in captivity may be specific to particular taxonomic groups; thus, it may be possible to establish expectations across smaller taxonomic units, or even disparate groups that utilize their cranial morphology in a similar way. Given that morphological changes occurring in captive environments like zoos have the potential to limit reintroduction success, our results call for a critical evaluation of current captive husbandry practices to prevent unnecessary morphological changes.

Microbes linked to cancer in threatened California foxes

Princeton University. *Science Daily*, 4 February 2020. sciencedaily.com/releases/2020/02/200204163654.htm.

Microbes are known to affect digestion, mood, and overall health, but cancer? Researchers lay out a multi-step process: First, Santa Catalina foxes become infested with ear mites, which change the foxes' microbiome and allow a staph infection to take hold. The antibiotic-resistant *Staphylococcus pseudintermedius* infection leads to chronic inflammation of the foxes' ears—and in that inflamed tissue, tumors can flourish.

Individual dietary specialization in a generalist predator: A stable isotope analysis of urban and rural red foxes

C Scholz, J Firozpoor, S Kramer-Schadt, P Gras, C Schulze, SE Kimmig, CC Voigt, and S Ortmann. *Ecology and Evolution,* 2020;10(16):8855–8870. https://doi.org/10.1002/ece3.6584.

Some carnivores are known to survive well in urban habitats, yet the underlying behavioral tactics are poorly understood. One likely explanation for the success in urban habitats might be that carnivores are generalist consumers. However, urban populations of carnivores could as well consist of specialist feeders. Here, we compared the isotopic specialization of red foxes in urban and rural environments, using both a population and an individual level perspective. We measured stable isotope ratios in increments of red fox whiskers and potential food sources. Our results reveal that red foxes have a broad isotopic dietary niche and a large variation in resource use. Despite this large variation, we found significant differences between the variance of the urban and rural population for $\delta^{13}C$ as well as $\delta^{15}N$ values, suggesting a habitat-specific foraging behavior. Although urban regions are more heterogeneous regarding land cover (based on the Shannon index) than rural regions, the dietary range of urban foxes was smaller compared with that of rural conspecifics. Moreover, the higher $\delta^{13}C$ values and lower $\delta^{15}N$ values of urban foxes suggest a relatively high input of anthropogenic food sources. The diet of most individuals remained largely constant over a longer period. The low intraindividual variability of urban and rural red foxes suggests a relatively constant proportion of food items consumed by individuals. Urban and rural foxes utilized a small proportion of the potentially available isotopic dietary niche as indicated by the low within-individual variation compared to the between-individual variation. We conclude that generalist fox populations consist of individual food specialists in urban and rural populations, at least over those periods covered by our study.

SARS-CoV-2 spike protein predicted to form complexes with host receptor protein orthologues from a broad range of mammals

SD Lam, N Bordin, VP Waman, HM Scholes, P Ashford, N Sen, L van Dorp, C Rauer, NL Dawson, and CSM Pang, et al. *Scientific Reports,* 5 October 2020;10:16471. https://doi.org/10.1038/s41598-020-71936-5

SARS-CoV-2 has a zoonotic origin and was transmitted to humans via an undetermined intermediate host, leading to infections in humans and other mammals. To enter host cells, the viral spike protein (S-protein) binds to its receptor, ACE2, and is then processed by TMPRSS2. Whilst receptor binding contributes to the viral host range, S-protein:ACE2 complexes from other animals have not been investigated widely. To predict infection risks, we modelled S-protein:ACE2 complexes from 215 vertebrate species, calculated changes in the energy of the complex caused by mutations in each species relative to human ACE2, and correlated these changes with COVID-19 infection data. We also analyzed structural interactions to better understand the key residues contributing to affinity. We predict that mutations are more detrimental in ACE2 than TMPRSS2. Finally, we demonstrate phylogenetically that human SARS-CoV-2 strains have been isolated in animals. Our results suggest that SARS-CoV-2 can infect a broad range of mammals, but few fish, birds, or reptiles. Susceptible animals could serve as reservoirs of the virus, necessitating careful ongoing animal management and surveillance.

Susceptibility of raccoon dogs for experimental SARS-CoV-2 infection

CM Freuling, A Breithaupt, T Müller, J Sehl, A Balkema-Buschmann, M Rissmann, A Klein, C Wylezich, D Höper, K Wernike, et al. *Emerging Infectious Diseases,* 2020;26(12):2982–2985. dx.doi.org/10.3201/eid2612.203733.

Raccoon dogs might have been intermediate hosts for severe acute respiratory syndrome-associated coronavirus in 2002–2004. We demonstrated susceptibility of raccoon dogs to severe acute

respiratory syndrome coronavirus 2 infection and transmission to in-contact animals. Infected animals had no signs of illness. Virus replication and tissue lesions occurred in the nasal conchae.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) emerged in Wuhan, China, at the end of 2019. Researchers have identified close relatives to SARS-CoV-2 in bats and pangolins (order Pholidota). Whether the pandemic was initiated by direct transmission from bats or through an intermediate mammalian host is still under debate. During the 2002–2004 severe acute respiratory syndrome pandemic, researchers documented the causative virus in raccoon dogs (*Nyctereutes procyonoides*) in China, indicating that these animals might have been intermediate hosts for the virus. Fur producers in China own >14 million captive raccoon dogs, accounting for >99% of the global share of raccoon dogs. However, whether these animals are susceptible to SARS-CoV-2 is unknown. Using our established study design, we characterized susceptibility, viral shedding, transmission potential, serologic reactions, and pathologic lesions of raccoon dogs after experimental SARS-CoV-2 infection.

Relatives of rubella virus in diverse mammals

AJ Bennett, AC Paskey, A Ebinger, F Pfaff, G Priemer, D Höper, A Breithaupt, E Heuser, RG Ulrich, JH Kuhn, et al. *Nature*, 7 October 2020;586:424–428. https://doi.org/10.1038/s41586-020-2812-9.

Since 1814, when rubella was first described, the origins of the disease and its causative agent, rubella virus (Matonaviridae: *Rubivirus*), have remained unclear. Here we describe ruhugu virus and rustrela virus in Africa and Europe, respectively, which are, to our knowledge, the first known relatives of rubella virus. Ruhugu virus, which is the closest relative of rubella virus, was found in apparently healthy cyclops leaf-nosed bats (*Hipposideros cyclops*) in Uganda. Rustrela virus, which is an outgroup to the clade that comprises rubella and ruhugu viruses, was found in acutely encephalitic placental and marsupial animals at a zoo in Germany and in wild yellow-necked field mice (*Apodemus flavicollis*) at and near the zoo. Ruhugu and rustrela viruses share an identical genomic architecture with rubella virus. The amino acid sequences of four putative B cell epitopes in the fusion (E1) protein of the rubella, ruhugu, and rustrela viruses and two putative T cell epitopes in the capsid protein of the rubella and ruhugu viruses are moderately to highly conserved. Modelling of E1 homotrimers in the post-fusion state predicts that ruhugu and rubella viruses have a similar capacity for fusion with the host-cell membrane. Together, these findings show that some members of the family *Matonaviridae* can cross substantial barriers between host species and that rubella virus probably has a zoonotic origin. Our findings raise concerns about future zoonotic transmission of rubella-like viruses, but will facilitate comparative studies and animal models of rubella and congenital rubella syndrome.

Quantity–quality trade-offs in the acquisition of token preference by capuchin monkeys (*Sapajus* spp.)

E Quintiero, S Gastaldi, F De Petrillo, E Addessi, and S Bourgeois-Gironde. *Philosophical Transactions of the Royal Society*, 2021;376(1819):B37620190662. doi.org/10.1098/rstb.2019.0662

Money represents a cornerstone of human modern economies, and how money emerged as a medium of exchange is a crucial question for social sciences. Although non-human primates have not developed monetary systems, they can estimate, combine, and exchange tokens. Here, we evaluated quantity–quality trade-offs in token choices in tufted capuchin monkeys as a first step in the investigation of the generalizability of tokens as reinforcers, which is a potentially relevant factor underlying the emergence of money in humans. We measured capuchins' exchange preferences when they were repeatedly provided with 10 units of three token types yielding food combinations varying in quantity and quality. Overall, capuchins maximized their quantitative payoff, preferring tokens associated with a higher food amount, rather than showing violations of rationality. However, some individuals did not maximize their qualitative payoff, possibly because of conditional valuation effects or owing to the choice overload phenomenon, according to which too many options reduce the accuracy of choice. Our study supports the importance of comparative research to finely analyze the multiple components shaping the economic behaviours of other species, possibly to achieve a more comprehensive, evolutionary- and ecologically-based understanding of human economic behavior.

This article is part of the theme issue "Existence and prevalence of economic behaviors among non-human primates." **(*Associated article here.*)** ■

Webinar report:

Animals in Crises. From "Animals, Climate Change and Global Health" series by Animalsclimatehealth.com. Originally held November 11, 2020. *Video here.*

The ongoing climate crisis, in combination with the coronavirus crisis, has made it patently clear that disasters are here to stay going forward. Whilst we have been able to pay little attention to the regulation of disasters in the past, our future and the future of non-human animals will critically depend on whether, and to what extent, human and animal interests are being considered in disaster regulation. Here, we're interested in gaining a better understanding of how crises are defined and regulated, and what their relation is to emergency laws and the regulation of climate.

Speakers: Clemens Driessen (Wageningen University), Leslie Irvine (University of Colorado), Jo-Anne McArthur (We Animals Media), Crystal Heath (Veterinarians Against Ventilation Shutdown); Moderator: Steven White (Griffith University).

For more information, visit animalsclimatehealth.com/session-3/.

TAIL ENDS



Oops, I really need to get some control into that right swing.

Reddish egret (*Egretta rufescens*)
J. N. "Ding" Darling National Wildlife Refuge
PHOTO ©DIANA ROBINSON. CC BY-NC-ND 2.0.

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Yellow-necked field mouse (*Apodemus flavicollis* Melchior 1834).



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