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Importance of taxonomic group, life stage and circumstance of rescue upon wildlife rehabilitation in Ontario, Canada

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ABSTRACT

Wildlife rehabilitation is an increasingly important and global practice, aiming towards advancements in animal welfare and species conservation. Although there are ongoing discussions on the benefits and limitations of wildlife rehabilitation, there is a general agreement on the importance of wildlife rehabilitation on improving the welfare of wild animals and identifying threats to wildlife. Determining which factors lead to a successful outcome of rehabilitation can allow wildlife rehabilitation centres to best focus their resources to benefit animals with the greatest chance of a successful release. In this study, three factors affecting the success of rehabilitation were evaluated: taxonomic group, life stage and circumstance of rescue. We used a large database of patients' records (9561 animals from 198 species) from Sandy Pines Wildlife Centre (Ontario, Canada) over a three year study period (from 2015 to 2018). We found that reptiles had a higher rate of release (63.6 %), compared with mammals (42.1 %) and birds (48.3 %), although released reptiles spent longer in the centre than birds and mammals. Animals arriving to the centre in poor condition were less likely to be rehabilitated and spent longer in the centre than animals arriving in good condition. Overall, preadults were more likely to be released than adults, although the number of days spent at the centre did not differ by life stage. Animals suffering active damage (e.g. 'collision' and 'projectile') were less likely to be rehabilitated than animals suffering passive damage (e.g. arriving to the centre as 'orphan' or due to 'habitat destruction'); however, when only considering those animals that left the centre, the number of days spent at the centre did not differ between animals suffering passive or active damage. The analysis of patients' records can provide relevant information to rehabilitators about factors influencing rehabilitation efforts, which can be used to implement strategies that maximise release rates, given limited resources.

1. Introduction

Wildlife rehabilitation involves the treatment of injured, diseased, and displaced animals, and their release to appropriate habitats in the wild (Miller, 2012). Wildlife rehabilitation is a growing international effort, with thousands of wildlife rehabilitation centres globally working with a great diversity of species and with various management protocols, differing budgets and varying levels of specialisation (Molony, Baker, Garland, Cuthill, & Harris, 2007). These rehabilitation centres include both organisations that concentrate on the treatment of specific taxa of conservation interest and those that locally care for, and then release any wild species (Underhill et al., 1999).

There is a general agreement on the importance of wildlife rehabilitation on improving the welfare of wild animals, education and public awareness, identifying threats to wildlife populations, and monitoring the health of ecosystems (Cox-Witton et al., 2014; Sleeman, 2008). Furthermore, information recorded in wildlife rehabilitation centres can be used as an important resource for conservation, as it is evidence of the anthropogenic or natural threats to different species. This type of information is also important for understanding and improving rehabilitation efforts, e.g. in relation to morbidity on wildlife (Brown & Sleeman, 2002; Hartup, 1996; Kelly & Sleeman, 2003; Wendell, Sleeman, & Kratz, 2002); or better considering the different aspects of rehabilitation (both physical and behavioural) that determine whether an animal is ready to be released (Mullineaux, 2014). In particular, any increased understanding about the intrinsic differences across a range of taxa can lead to improved protocols for their rehabilitation. For example, the aim of wildlife rehabilitation is to release healthy animals

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into their habitat of origin, but if the prognosis of an animal arriving to a rehabilitation centre is very poor (and its succesful release is unlikely), early euthanasia may be a more appropriate *triage* decision than sustained veterinary care (Miller, 2012; Molony et al., 2007; Mullineaux, 2014); such a triage decision however may be highly dependent on the taxonomic group, e.g. an early determination of succesful release may be easier in mammals than in reptiles.

Studies reporting on a wide range of animal species and studying general patterns affecting wildlife are still limited, as the majority of previous studies are taxonomically restricted (Schenk & Souza, 2014; Tribe & Brown, 2000; Wimberger & Downs, 2010). This is problematic, especially given the fact that these taxonomically restricted studies are difficult to compare. They may differ, for example, on the measure of wildlife rehabilitation success that they use, such as release rate or post-release surveying of survival. They may use different techniques to gather and analyse data, e.g. distributing specific surveys to numerous centres, or analysing the available records of one or several wildlife rehabilitation centres (Hartup, 1996; Molony et al., 2007; Shine & Koenig, 2001; Wimberger, Downs, & Boyes, 2010). They may also focus on different variables or covariates to explain wildlife rehabilitation success, e.g. body weight or severity of injury (Haynes, Erb, & Nevis, 2013; Molony et al., 2007). The effect of other variables, such as life stage, on rehabilitation success across a range of taxa remain to be properly investigated (Kelly et al., 2011).

Here, we analysed the records of Sandy Pines Wildlife Rehabilitation Centre in Ontario, Canada, over a three year period, from 2015 to 2018. The main objective of the study was to investigate whether taxonomic group (Mammalia, Aves, and Reptilia), life stage (preadult vs adult) and circumstance of admission had any effects on the release rate of a wide range of species. Specifically, we addressed three questions. First, we determined whether the success of rehabilitation depended on taxonomic group, life stage and/or condition on arrival. Second, for those animals that were released, we evaluated whether the number of days spent at the centre was dependent on any of those same factors (taxonomic group, life stage, and condition on arrival). Third, we determined if the circumstance of admission (involving either active or passive damage to the animal) had an effect on the success of animals at the centre and/or the time of recovery for those animals that left the centre.

2. Methods

2.1. Rehabilitation centre and dataset preparation

Sandy Pines Wildlife Centre (sandypineswildlife.org) is a wildlife rehabilitation centre where injured or orphaned animals are brought to be rehabilitated and released back into the wild. The centre is located on a farm in Greater Nappanee, Ontario, Canada (44.2186 °N, 76.9821 °W). Most of the animals come from Lennox and Addington county, however the centre will take animals from an approximate 200 km radius, thus including the counties of Hastings, Deseronto, Frontenac, Loyalist, Kingston, Brighton and Ottawa. Animals predominantly come from rural environments, however as this centre admits patients from a large catchment area, many of them were found in urban environments (the level of urbanisation was not considered in the current study, however this may be a confounding effect that should be investigated in future studies). Members of the public or local authorities report injured or orphaned wildlife to Sandy Pines Wildlife Centre, and the rescuers are advised to transport the animal(s) or are collected by a volunteer driver, where upon arrival are identified and a physical examination is carried out to diagnose their health condition and deduce what injury has occurred. Appropriate behaviour for the species is also assessed by experienced staff. Injured or orphaned wildlife are held for rehabilitation or euthanised. The duration of a patient's stay at the centre is dependent on the complexity of treatment, ranging from one day to several months. In addition, orphaned wildlife may need a greater duration of care depending on the species, as they must learn skills imperative to their survival in the wild; rehabilitated animals are released back into the wild, as close to where they were originally located as possible, however, there were some exceptions, e.g. some rodents were released into suitable habitat surrounding the Centre. As the Centre had no means of monitoring the post release of animals, a 'successful release' in this case involved the release of a healthy individual without post-release monitoring as close as possible to where it was found, but always into suitable habitat. The Centre followed the Ontario Ministry of Natural Resources and Forestry protocols for release (Fish & Wildlife Conservation Act, 1997). The Centre did not operate as a sanctuary, i.e. they only kept wildlife in care that was deemed releasable, and did not keep animals permanently. If at any time during their care an animal was deemed unreleasable, such an animal was euthanized.

Animal records at Sandy Pines Wildlife Centre were obtained from WILD-ONe ("Wildlife Incident Log/Database and Online Network"; wildlifecenter.org/wild-one), an online database designed to aid wildlife rehabilitation centres and other animal care facilities in the collecting and utilising of patient-related data. The data used in this study included all the patients' records at Sandy Pines Wildlife Centre from 03 July 2015 to 28 August 2018.

We removed from our dataset any animals from species that are not established in southern Ontario (see supplementary Table S1), and any animals that we could not identify at the species level: 1 "mole shrew", 1 "shrew-mole", 1 "Allen's squirrel galago", 1 "Allen's 13-lined ground squirrel", 1 "gray ground squirrel", and 12 "black-headed garter snake". We also removed from the dataset all the animals that arrived dead to the centre (n = 189), as our goal was to determine how different groups of animals responded once at the centre (see supplementary Table S2).

Our final dataset contained data from 9561 animals: 684 reptiles (including 12 species), 4004 birds (146 species), and 4873 mammals (40 species) (Table 1). Due to low sample sizes, we disregarded invertebrate and amphibian species. Species in our dataset included mostly species with a least-concern IUCN conservation status, but it also included 5 bird species classified as near-threatened, 7 bird species and 1 mammalian species classified as vulnerable, and 3 species classified as endangered (2 turtles: *Clemmys guttata* and *Emydoidea blandingii*; and the bat *Myotis lucifugus*; IUCN, 2020; Table 1).

For each animal we used the following information: species, life stage of admission, circumstances of rescue, type of injury, disposition (e.g. died, euthanised, or released), admission date, and disposition date. We grouped species into three groups (reptiles, birds, and mammals). We used the admission dates and the disposition dates to calculate the number of days that animals spent at the centre (duration at the centre was one day if the animal died or was released the same day it was admitted). We combined the different descriptions of life stages into two levels: preadult and adult. This allowed us to make comparisons involving life stage across taxonomic groups. We used information about the circumstances of rescue and type of injury to create a binary condition variable (i.e. good or bad condition on arrival to the centre). If the animal was categorised as 'clinically healthy' we considered that animal to arrive in good condition. If the term 'generalised' or any body part were identified in the 'type of injury' field, if the circumstance of admission included any type of collision, or if the animal died before physical examination or on the day of arrival to the centre, we considered that animal to have arrived in bad condition. We also pooled the disposition information into two categories: 'died' (combining animals that died at the centre or that were euthanised); and 'left' (combining the WILD-ONe categories 'released', 'self-release' (only 4 cases) and 'transferred'). Some transferred animals were not fully rehabilitated at that time, and were transferred to other centres to insure they were raised with conspecifics, and/or got specialised care before being released. Animals were never transferred to permanent collections. We pooled 'transferred' animals with 'released' animals as we assumed that such animals must have been likely to be rehabilitated, otherwise they would have been euthanised at the centre. However, our records did not

Table 1
Species that were included in the analyses, sample sizes for the different life stages, and number of animals that left the centre or died at the centre for each species.

Order	Species (IUCN Conservation Status)	Sample size: preadults + adults (+NA)	Number of animals that left / died at the centre
Reptile orders			
Squamata	*Lampropeltis triangulum* (LC)	1 + 2	1 / 2
	Nerodia sipedon (LC)	0 + 2	0 / 2
	Pantherophis spiloides (LC)	0 + 3	1 / 2
	Storeria dekayi (LC)	1 + 1	1 / 1
	Thamnophis sauritus (LC)	1 + 0	1 / 0
	Thamnophis sirtalis (LC)	2 + 19 (+28)	41 / 8
Testudines	*Chelydra serpentina* (LC)	127 + 71 (+3)	155 / 46
	Chrysemys picta (LC)	53 + 217 (+11)	124 / 157
	Clemmys guttata (EN)	9 + 1	10 / 0
	Emydoidea blandingii (EN)	52 + 32	63 / 21
	Graptemys geographica (LC)	24 + 14	30 / 8
	Sternotherus odoratus (LC)	6 + 4	8 / 2
Bird orders			
Accipitriformes	*Accipiter cooperii* (LC)	5 + 8	3 / 10
	Accipiter gentilis (LC)	0 + 1	0 / 1
	Accipiter striatus (LC)	0 + 2	0 / 2
	Buteo jamaicensis (LC)	10 + 38	24 / 24
	Buteo lagopus (LC)	0 + 1	0 / 1
	Buteo lineatus (LC)	1 + 0	1 / 0
	Buteo platypterus (LC)	10 + 4	9 / 5
	Cathartes aura (LC)	7 + 4	5 / 6
	Circus hudsonius (LC)	3 + 3	2 / 4
	Haliaeetus leucocephalus (LC)	1 + 2	0 / 3
	Pandion haliaetus (LC)	10 + 9	2 / 17
Anseriformes	*Aix sponsa* (LC)	100 + 2	77 / 25
	Anas platyrhynchos (LC)	197 + 32 (+5)	179 / 55
	Aythya americana (LC)	0 + 1	0 / 1
	Branta canadensis (LC)	86 + 60 (+3)	70 / 79
	Bucephala albeola (LC)	0 + 1	0 / 1
	Bucephala clangula (LC)	0 + 1	1 / 0
	Clangula hyemalis (VU)	0 + 4	2 / 2
	Cygnus buccinator (LC)	2 + 1 (+1)	1 / 3
	Cygnus olor (LC)	18 + 18	17 / 19
	Lophodytes cucullatus (LC)	1 + 0	0 / 1
	Melanitta deglandi (LC)	0 + 2	0 / 2
	Mergus merganser (LC)	19 + 3	6 / 16
	Mergus serrator (LC)	3 + 0	0 / 3
Apodiformes	*Archilochus colubris* (LC)	4 + 5 (+1)	5 / 5
	Chaetura pelagica (VU)	0 + 1	0 / 1
Caprimulgiformes	*Antrostomus vociferous* (NT)	0 + 1	0 / 1
	Chordeiles minor (LC)	0 + 2	0 / 2
Charadriiformes	*Actitis macularius* (LC)	1 + 0	1 / 0
	Charadrius vociferus (LC)	5 + 1	4 / 2
	Larus argentatus (LC)	10 + 12	5 / 17
	Larus delawarensis (LC)	110 + 107 (+13)	72 / 158
	Scolopax minor (LC)	10 + 5	4 / 11
	Sterna hirundo (LC)	0 + 2	0 / 2
Columbiformes	*Columba livia* (LC)	142 + 8 (+176)	156 / 170
	Zenaida macroura (LC)	129 + 7 (+138)	118 / 156
Coraciiformes	*Megaceryle alcyon* (LC)	2 + 7 (+1)	0 / 10
Cuculiformes	*Coccyzus erythropthalmus* (LC)	0 + 1	0 / 1
Falconiformes	*Falco columbarius* (LC)	24 + 17 (+5)	23 / 23
	Falco peregrinus (LC)	1 + 1	1 / 1
	Falco sparverius (LC)	28 + 3 (+2)	25 / 8
Galliformes	*Bonasa umbellus* (LC)	8 + 16 (+1)	9 / 16
	Meleagris gallopavo (LC)	18 + 8	13 / 13
Gaviiformes	*Gavia immer* (LC)	3 + 13	6 / 10
Gruiformes	*Fulica americana* (LC)	0 + 1	0 / 1
	Rallus limicola (LC)	1 + 0	1 / 0
Passeriformes	*Agelaius phoeniceus* (LC)	5 + 11 (+1)	2 / 15
	Amphispiza bilineata (LC)	3 + 1	3 / 1
	Anthus rubescens (LC)	0 + 1	1 / 0
	Bombycilla cedrorum (LC)	35 + 13 (+1)	34 / 15
	Bombycilla garrulus (LC)	1 + 0	0 / 1
	Cardellina canadensis (LC)	0 + 1	1 / 0
	Cardinalis cardinalis (LC)	10 + 13	8 / 15
	Carpodacus purpureus (LC)	0 + 3 (+1)	3 / 1
	Catharus bicknelli (VU)	0 + 2	1 / 1
	Catharus fuscescens (LC)	1 + 0	1 / 0
	Catharus guttatus (LC)	0 + 1	1 / 0
	Catharus ustulatus (LC)	0 + 1	0 / 1
	Certhia americana (LC)	0 + 2	0 / 2
	Coccothraustes vespertinus (VU)	0 + 2	0 / 2
	Contopus virens (LC)	4 + 1	4 / 1
	Corvus brachyrhynchos (LC)	44 + 42 (+7)	21 / 72
	Corvus corax (LC)	3 + 4 (+1)	4 / 4
	Cyanocitta cristata (LC)	40 + 42 (+6)	28 / 60
	Dumetella carolinensis (LC)	5 + 6 (+1)	3 / 9
	Empidonax minimus (LC)	1 + 0	1 / 0
	Empidonax virescens (LC)	3 + 4	3 / 4
	Euphagus carolinus (VU)	0 + 0 (+1)	0 / 1
	Geothlypis trichas (LC)	0 + 3	0 / 3
	Haemorhous mexicanus (LC)	8 + 8 (+4)	11 / 9
	Hirundo rustica (LC)	29 + 5	29 / 5
	Hylocichla mustelina (NT)	1 + 2 (+1)	1 / 3
	Icterus galbula (LC)	5 + 2 (+4)	7 / 4
	Junco hyemalis (LC)	1 + 7	2 / 6

(continued on next page)

Table 1 (*continued*)

Order	Species (IUCN Conservation Status)	Sample size: preadults + adults (+NA)	Number of animals that left / died at the centre
	Lanius borealis (LC)	0 + 1	1 / 0
	Lanius ludovicianus (NT)	1 + 1	1 / 1
	Leiothlypis celata (LC)	0 + 1	0 / 1
	Melospiza georgiana (LC)	0 + 1	0 / 1
	Melospiza lincolnii (LC)	0 + 1	0 / 1
	Melospiza melodia (LC)	0 + 4	0 / 4
	Mniotilta varia (LC)	0 + 2	2 / 0
	Molothrus ater (LC)	1 + 3	0 / 4
	Myiarchus crinitus (LC)	4 + 1	4 / 1
	Passer domesticus (LC)	67 + 15 (+3)	45 / 40
	Pheucticus ludovicianus (LC)	5 + 11	4 / 12
	Pipilo erythrophthalmus (LC)	1 + 2	1 / 2
	Plectrophenax nivalis (LC)	0 + 1	1 / 0
	Poecile atricapillus (LC)	9 + 13 (+1)	12 / 11
	Progne subis (LC)	0 + 1 (+1)	0 / 2
	Quiscalus quiscula (NT)	141 + 89 (+17)	82 / 165
	Regulus calendula (LC)	0 + 1	0 / 1
	Regulus satrapa (LC)	0 + 7	0 / 7
	Riparia riparia (LC)	1 + 0	0 / 1
	Sayornis phoebe (LC)	17 + 1	15 / 3
	Setophaga americana (LC)	0 + 1	0 / 1
	Setophaga coronata (LC)	0 + 2	2 / 0
	Setophaga dominica (LC)	0 + 1	1 / 0
	Setophaga petechia (LC)	1 + 3	1 / 3
	Setophaga pinus (LC)	2 + 7	4 / 5
	Setophaga ruticilla (LC)	0 + 1	0 / 1
	Setophaga tigrina (LC)	0 + 1	1 / 0
	Setophaga virens (LC)	0 + 1	0 / 1
	Sialia sialis (LC)	1 + 0	0 / 1
	Sitta carolinensis (LC)	1 + 5	1 / 5
	Spinus tristis (LC)	41 + 23 (+1)	34 / 31
	Spizella passerina (LC)	16 + 2	14 / 4
	Spizella pusilla (LC)	1 + 2	0 / 3
	Spizelloides arborea (LC)	17 + 12 (+2)	13 / 18
	Sturnella magna (NT)	1 + 0	0 / 1
	Sturnus vulgaris (LC)	348 + 56 (+6)	264 / 146
	Tachycineta bicolor (LC)	2 + 2	2 / 2
	Thryomanes bewickii (LC)	7 + 0	7 / 0
	Thryothorus ludovicianus (LC)	1 + 2	1 / 2
	Toxostoma rufum (LC)	1 + 3	2 / 2
	Troglodytes aedon (LC)	37 + 2 (+1)	31 / 9
	Turdus migratorius (LC)	368 + 143 (+17)	279 / 249
	Tyrannus tyrannus (LC)	0 + 4	2 / 2
	Vireo gilvus (LC)	1 + 0	1 / 0
	Vireo olivaceus (LC)	5 + 1	4 / 2
		0 + 3	2 / 1
	Vireo philadelphicus (LC)		
	Vireo solitarius (LC)	0 + 1	0 / 1
	Zonotrichia albicollis (LC)	2 + 4	2 / 4
Pelecaniformes	*Ardea alba* (LC)	0 + 1	1 / 0
	Ardea herodias (LC)	3 + 16	3 / 16
	Botaurus lentiginosus (LC)	0 + 3	1 / 2
	Butorides virescens (LC)	2 + 0	2 / 0
	Ixobrychus exilis (LC)	0 + 3	0 / 3
Piciformes	*Colaptes auratus* (LC)	12 + 21 (+2)	15 / 20
	Dryobates pubescens (LC)	5 + 17 (+1)	6 / 17
	Dryocopus pileatus (LC)	3 + 7	4 / 6
	Leuconotopicus villosus (LC)	3 + 10 (+1)	5 / 9
	Melanerpes erythrocephalus (LC)	0 + 1	0 / 1
	Sphyrapicus varius (LC)	4 + 14 (+1)	9 / 10
Podicipediformes	*Podiceps auratus* (VU)	2 + 1	2 / 1
	Podiceps grisegena (LC)	0 + 1	0 / 1
	Podilymbus podiceps (LC)	0 + 1	1 / 0
Strigiformes	*Aegolius acadicus* (LC)	2 + 6	2 / 6
	Asio flammeus (LC)	0 + 2	0 / 2
	Asio otus (LC)	0 + 3	0 / 3
	Bubo scandiacus (VU)	1 + 9	1 / 9
	Bubo virginianus (LC)	4 + 16	4 / 16
	Megascops asio (LC)	5 + 5 (+1)	6 / 5
	Strix varia (LC)	7 + 40 (+1)	24 / 24
	Tyto alba (LC)	0 + 0 (+1)	0 / 1
Suliformes	*Phalacrocorax auritus* (LC)	0 + 35 (+2)	1 / 36
	Phalacrocorax carbo (LC)	0 + 7 (+1)	0 / 8
Mammal orders			
Artiodactyla	*Odocoileus virginianus* (LC)	33 + 2 (+1)	14 / 22
Carnivora	*Canis latrans* (LC)	4 + 3	3 / 4
	Lontra canadensis (LC)	0 + 2	1 / 1
	Mephitis mephitis (LC)	78 + 15 (+3)	72 / 24
	Mustela erminea (LC)	0 + 1	1 / 0
	Mustela frenata (LC)	6 + 1	5 / 2
	Mustela nivalis (LC)	8 + 2 (+1)	8 / 3
	Neovison vison (LC)	4 + 3	2 / 5
	Pekania pennanti (LC)	0 + 1	0 / 1
	Procyon lotor (LC)	941 + 199 (+20)	217 / 943
	Spilogale putorius (VU)	1 + 0	0 / 1
	Urocyon cinereoargenteus (LC)	0 + 1	1 / 0
	Ursus americanus (LC)	1 + 0	1 / 0
	Vulpes vulpes (LC)	41 + 6	38 / 9
Chiroptera	*Aeorestes cinereus* (LC)	1 + 2	0 / 3
	Eptesicus fuscus (LC)	22 + 197 (+7)	112 / 114
	Lasiurus borealis (LC)	0 + 1	0 / 1
	Myotis lucifugus (EN)	1 + 5	1 / 5
Didelphimorphia	*Didelphis virginiana* (LC)	9 + 8	10 / 7
Eulipotyphla	*Blarina brevicauda* (LC)	1 + 0	0 / 1
	Cryptotis parva (LC)	1 + 0	0 / 1
		1 + 0	0 / 1

(*continued on next page*)

Table 1 (*continued*)

Order	Species (IUCN Conservation Status)	Sample size: preadults + adults (+NA)	Number of animals that left / died at the centre
	Scalopus aquaticus (LC)		
Lagomorpha	*Lepus americanus* (LC)	3 + 0	0 / 3
	Sylvilagus floridanus (LC)	1257 + 198 (+44)	438 / 1061
Rodentia	*Castor canadensis* (LC)	2 + 7	6 / 3
	Erethizon dorsatum (LC)	17 + 28 (+1)	7 / 39
	Glaucomys sabrinus (LC)	1 + 1	2 / 0
	Glaucomys volans (LC)	6 + 24 (+1)	29 / 2
	Marmota monax (LC)	11 + 11 (+1)	8 / 15
	Microtus pennsylvanicus (LC)	7 + 1	0 / 8
	Microtus pinetorum (LC)	6 + 0	0 / 6
	Mus musculus (LC)	26 + 0 (+1)	2 / 25
	Ondatra zibethicus (LC)	5 + 9 (+1)	3 / 12
	Peromyscus maniculatus (LC)	10 + 0	2 / 8
	Phenacomys ungava (LC)	1 + 1	1 / 1
	Rattus norvegicus (LC)	12 + 1	12 / 1
	Sciurus carolinensis (LC)	966 + 146 (+12)	748 / 376
	Tamias striatus (LC)	71 + 42 (+13)	67 / 59
	Tamiasciurus hudsonicus (LC)	276 + 15 (+1)	240 / 52
	Zapus hudsonius (LC)	3 + 0	0 / 3

EN: endangered; LC: least concern; NT: near-threatened; VU, vulnerable.

contain any information about their exact destination or the status of animals once they were transferred. In our dataset, transferred animals represented only 12.18 % of animals categorised as leaving the centre, and not including them as 'released' animals did not affect our results. We also separated the circumstances of admission into two categories, those that resulted in active damage to the animal (including 'Animal interaction', 'Collision' and 'Projectile') and those that resulted in passive damage (including 'Entrapment and stranding', 'Environment', 'Nest/habitat destruction', 'Human possession' and 'Orphan'). The circumstance of admission 'Environment' included weather conditions (precipitation, temperature, and wind), smoke, or seismic events, but more details were not included in the data we obtained. 'Human possession' included confiscation of animals that were inappropriately possessed (e.g. as pets). We did not include 'Failure to thrive' nor 'Undetermined' in any of those two categories. There were no cases of 'electrocution' or 'gas flare' in our dataset.

Some animals at the centre were not released into the wild during the winter months (e.g. reptiles and amphibians), so any such animals arriving to the centre during winter may have stayed longer at the centre than during other year periods. However, the majority of animals in our dataset (92.65 %) arrived to the centre between the months of March and November, which minimised this winter effect. Consequently, including month of arrival to the centre in the relevant statistical models did not affect any of the results. The bulk of animal releases also took place between March and November (94.12 %).

2.2. Statistical analyses

We conducted our statistical analyses using R, version 3.5.3 (R Core Team, 2017). We fitted a generalised linear mixed model (GLMM) with a binomial distribution and logit link function using the glmer function in the package lme4 to determine which factors affected the success of animals at the centre. The response was the binary variable 'disposition' (animals either died at the centre or left the centre). The fixed factors in the full model were group (reptiles, birds, or mammals), life stage (preadult or adult) and condition on arrival (good or bad condition). 'Species' was used as a random factor. Similar results were obtained if the taxonomic rank 'Order' was used as a random factor instead of 'Species'.

For those animals that eventually left the centre, we determined what factors explained the number of days that they spent in the centre using a negative binomial GLMM with a log function (overdispersion precluded using a Poisson distribution). We used the glmer.nb function in the package lme4. The response was the number of days that animals spent in the centre. The fixed factors in the full model were group (reptiles, birds, or mammals), life stage (preadult or adult) and condition on arrival (good or bad condition). Species was used as a random factor.

We also used GLMMs to determine if the circumstance of admission (involving either active or passive damage) had an effect on the success of animals in the centre and/or the time of recovery for those animals that left the centre.

3. Results

Reptiles had the greatest success at rehabilitation, with 63.6 % of animals leaving the centre, compared with a 48.3 % of birds and a 42.09 % of mammals ($p < 0.05$ for both comparisons between reptiles and the other groups). Condition affected the success of animals in the centre ($p < 0.0001$): only 28.82 % of animals in bad condition left the centre compared to 84.78 % of animals that arrived in good condition. Also, 99.25 % of reptiles and 96.19 % of birds arriving in good condition left the centre, whereas for mammals this value was 71.9 %. There was a significant effect of life stage ($p < 0.0001$): only 29.26 % of adults left the centre compared to 54.26 % of preadults. There was also a significant interaction between life stage and condition ($p < 0.0001$). When animals arrived in good condition, they were more likely to recover if they were adults than if they were preadults (96.37 % vs 83 %). However, when animals arrived in bad condition, the reverse was observed (21.81 % of adults left the centre compared to 34.59 % of preadults).

For the animals that left the centre, the number of days that they spent in the centre depended on the taxonomic group ($p < 0.0001$), being highest in reptiles (median ± IQR (inner quartile range): 67 ± 73 days), intermediate in mammals (48 ± 46 days), and lowest in birds (24 ± 35 days; Fig. 1). The number of days that animals spent in the centre

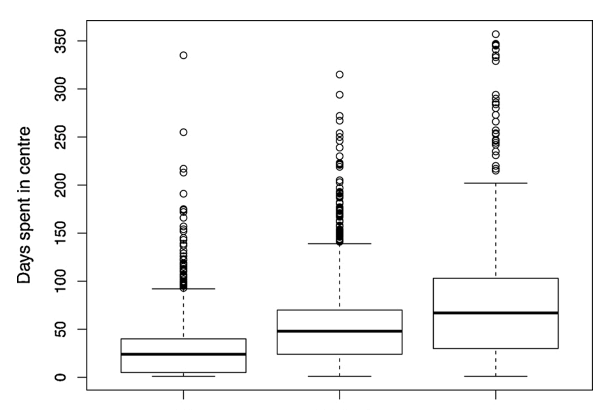

Fig. 1. Days that reptiles, birds and mammals that were successfully released spent at the centre. For each boxplot, the bar within each box represents the median, each box represents the first and third quartiles (or 25th and 75th percentiles), the two whiskers represent the maximum values that are within 1.5 * IQR of the box (where IQR or inter-quartile range is the distance between the first and third quartiles), and points beyond the whiskers represent outliers.

also depended on condition on arrival ($p < 0.0001$), being higher in animals arriving in bad condition (44 ± 40 days) than in those arriving in good condition (31 ± 51 days). However, life stage did not influence the number of days that animals spent in the centre before leaving ($p = 0.18$; preadults: 36 ± 45 days; adults: 34 ± 54.25 days).

More animals left the centre if they suffered a passive damage (62.64 %) than if they suffered active damage (31.56 %; $p < 0.0001$). There was a significant interaction between group and the type of damage ($p < 0.0001$). Active damage led to relatively similar percentages of animals leaving the centre irrespective of the group (reptiles: 38.4 %; birds: 33.89 %; and mammals: 27.02 %; Fig. 2). However, there were larger differences in the percentages of animals leaving the centre when they suffered a passive damage (reptiles: 97.35 %; birds: 72.86 %; mammals: 53.85 %; Fig. 2). Animals that left the centre spent a similar number of days in it whether they suffered active damage (median ± IQR: 27 ± 39 days) or passive damage (40 ± 47 days; $p = 0.21$).

4. Discussion

We found that rehabilitation success was higher for reptiles than for mammals and birds, and that animals arriving to the centre in good condition were more likely to be rehabilitated than if they arrived in bad condition. Overall, preadult animals were more likely to be rehabilitated than adults; this was also the case for animals arriving to the centre in bad condition, however adults fared better than preadults when they arrived to the centre in good condition. When considering only the animals that left the centre, reptiles and animals arriving to the centre in bad condition spent the longest in the centre. We also found that animals suffering active damage were less likely to be rehabilitated than those suffering passive damage.

The overall release rate for the dataset that we analysed was 46.23 %. This rate is similar to those from previous studies of generalist wildlife rehabilitation centres, e.g. 40 % in the centres of the RSPCA in the UK (Grogan & Kelly, 2013) and 38–44 % in Australian centres (Tribe & Brown, 2000). Reptiles were most successful at the centre (63.6 % release rate), when compared with mammals and birds. Although reptiles may be generally more responsive to rehabilitation, some of the differences between taxonomic groups may have been due to other

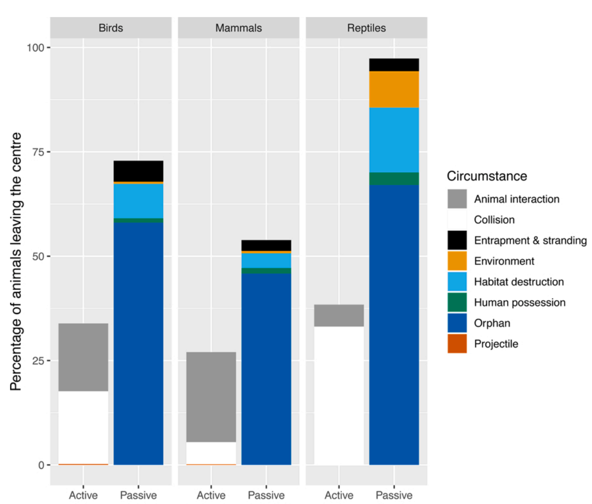

Fig. 2. Percentage of animals leaving the centre depending on the type of damage received (active or passive). Values for different circumstances of admission indicate the percentage of animals affected by a given circumstance that left the centre relative to the total number of animals that suffered active or passive damage. For example, eight out of 11 birds affected by the circumstance “Environment” left the centre (which is a 73 % of those animals); however, the shown value is small because it represents eight birds out of 1540 birds that suffered any type of passive damage.

factors, e.g. a higher number of cases where euthanasia had to be employed with birds. It must be taken into consideration that the aim of wildlife rehabilitation is to release healthy animals into their habitat of origin, and that euthanasia is employed when this is not possible due to injury, disease, a poor prognosis or unsuitable condition for release (Miller, 2012). A possible cause for the high count of euthanised birds for some species was avian disease outbreaks. For example, an outbreak of West Nile virus (a zoonotic flavivirus from the Family Flaviviridae, transmitted by mosquitos, that primarily has an effect on wild birds, but can secondarily affect other vertebrates, such as mammals (López et al., 2011)) on July and August 2018 in the study area resulted in every double-crested cormorant (*Phalacrocorax auritus)* admitted to the centre having to be euthanised to control further spread of the disease and prevent further pain to the affected animals.

Our dataset did not include behavioural aspects affecting rehabilitation effort and success, however behaviour should be considered in more detailed studies. Behavioural particularities in different taxonomic groups may determine rehabilitation approaches that ultimately will affect the rehabilitation success of each individual, e.g. mammals may be more susceptible to habituation than reptiles, and some species of mammals and birds may require substantial pre-release training for different behaviours. At the Centre, steps were taken to minimise habituation in neonates and young orphans (older juveniles and adults did not habituate or imprint on humans), e.g. keeping them in a wild setting and wearing costumes to hide the caretakers’ bodies. Before being released, animals should recognise others of the same species, and be able to interact with them appropriately. Although social and precocial animals will have a higher success when released if rehabilitated with conspecifics, sometimes animals that live communally in the wild will not do so in a captive situation due to stress (personal communication).

Our analyses indicated that life stage influenced the rate of release of animals from the centre but not the duration of an animal’s stay at the centre. Overall, preadults (including all phases of development prior to adulthood) were more likely to recover and be released back into the wild. However, this was dependent on the condition of animals on arrival to the centre. Preadults in bad condition were more likely to recover than adults in bad condition, possibly because adults normally suffered more severe damage than preadults. The opposite was however the case when animals arrived in good condition to the centre, in which case adults were more likely to recover (however, see Mullineaux, 2014). This may be the case for many species in which preadults are dependent on their parents for food and warmth; preadults arriving to the centre without any signs of damage may thus have undergone severe damage if they were separated from the parents for a significant amount of time (Haynes et al., 2013). For example, many hatchlings did not survive through the first night at the centre (personal communication). Maximising hatchling rehabilitation requires 24 -h care, which can put a lot of pressure on staff. This is an example in which the value of rehabilitation efforts towards different life stages may need to be evaluated in terms of available resources, including staff time and finances. If resources are very limited, they could be invested on juvenile birds, which have greater chances of survival, rather than investing those limited resources on hatchlings, which are less likely to survive.

Even though reptiles had the highest rate of release, successful reptiles spent more time in the centre than mammals and birds. There are at least three explanations for this finding. First, there was a higher degree of reptiles affected by collisions with vehicles, and rehabilitators may have decided that those animals required more long-term treatment or overseeing. Second, reptiles, being easier to maintain for longer, and also being more difficult to determine if they are fully recovered or not, may be maintained under rehabilitation for longer. Third, in the case of birds and mammals it may be easier to determine if animals are unlikely to recover, and thus euthanasia may be employed more and quicker in these groups, increasing the number of animals that being initially healthier recovered quickly and were released relatively earlier. In contrast, when to use euthanasia may be less clear in reptiles, and this may lead to more animals being maintained alive and staying for longer durations of time before being released.

The main leading circumstance for rescue of reptiles in this study was collisions with vehicles, as in previous studies (Beaudry, Demaynadier, & Hunter, 2010; Langen, Gunson, Scheiner, & Boulerice, 2012; Litvaitis & Tash, 2008). The second leading circumstance for rescue in this study was orphaned young, representing approximately 30 % of cases. In contrast, only 14 % of cases of orphaned young as a cause of admission were reported in wildlife rehabilitation centres in Australia (Tribe & Brown, 2000). The high number of cases of orphaned animals in this study can be explained by the location of the centre close to populated urban areas where the public finding juvenile animals and taking them to rehabilitation centres is common (Molina-López, Mañosa, Torres-Riera, Pomarol, & Darwich, 2017). Many of these *orphaned* cases are due to the public intervening when it is not necessary (e.g. fawns that being alone are thought to be abandoned when the mother is still nearby), so more public engagement and education is needed so that the interactions between the public and wildlife rehabilitation centres synergistically contribute to wildlife conservation.

Animals that arrived to the centre in poor condition, compared to animals that arrived in good physical condition, were less likely to be rehabilitated, and when they were successfully rehabilitated they spent more days at the centre. Similarly, animals that suffered active damage (e.g. vehicle collision) were less likely to be rehabilitated than animals suffering passive damage. Interestingly, the higher rates of rehabilitation of reptiles compared to those in birds and mammals, were only apparent in the case of passive damage; the negative impact of active damage on rehabilitation rates was similar across taxonomic groups. These results are in agreement with other studies showing that body condition relates to rehabilitation outcome (Drake & Fraser, 2008; Morten, Parsons, Schwitzer, Holderied, & Sherley, 2017). This knowledge is not only important in terms of strategically deploying limited resources so that to maximise rehabilitation rates while considering cost-benefit of treatments (Molina-López et al., 2017). It can also lead to optimal decisions involving animal welfare and the use of euthanasia (Molina-López, Casal, & Darwich, 2015).

In conclusion, data analysis of records from wildlife rehabilitation centres can provide useful information concerning factors, such as taxonomic group, life stage, and circumstance of admission, and their effect on the success of rehabilitation of different species. This type of information can be used to improve the effectiveness of the rehabilitation process so that rehabilitators can best invest their limited resources such as time, money and medical supplies (Molina-López et al., 2017). Such rehabilitation information should be combined with post-release monitoring. For example, if post-release monitoring indicate that released animals do not survive long in the wild, resources for rehabilitation might be better allocated. Ultimately, the goal is to maximise rehabilitation success as well as the survival and reproductive success of released individuals (particularly in the case of species of conservation concern), while improving animal welfare and educating the public on ecological matters, all of which will ultimately contribute to species conservation.

Declaration of Competing Interest

We declared that we do not have any conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jnc.2020.125897.

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