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Causes of admission to a raptor rehabilitation centre and factors that can be used to predict the likelihood of release

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Running header: Raptor rehabilitation and release likelihood

ABSTRACT

Admission records of rescued birds are an important source of information for tracking the prevalence of human-related threats to wildlife. In this study, we used admission records from January 2015 to December 2016 to review the causes for raptor admissions to a raptor rehabilitation centre in Pietermaritzburg, South Africa, and to determine factors that can be used to predict the outcome of rehabilitation. During the study period, 242 raptors were admitted to the centre, representing 33 species. The major causes of admission were collision-related injuries (52%), grounded birds (12%) and orphaned chicks (10%). The most common casualties were Spotted Eagle-Owl *Bubo africanus* (23%), Yellow-billed Kite *Milvus migrans aegyptius/parasitus* (12%), Jackal Buzzard *Buteo rufofuscus* (10%) and Western Barn Owl *Tyto alba* (10%). The rehabilitation centre had a release rate of 48%. Reason for admission was a significant predictor of the outcome of rehabilitation while other variables were not. Raptors with no severe injuries such as orphaned chicks and grounded birds were more likely to have successful rehabilitation treatment than raptors suffering from collision injuries. Wildlife rehabilitators can use the results of the present study to develop triage guidelines for raptors admitted to rehabilitation centres.

Keywords: Africa, animal welfare, logistic regression, KwaZulu-Natal, Raptor Rescue, rehabilitation outcome

1 INTRODUCTION

Human-related mortality risks add to those that raptors are exposed to in the wild such as inclement weather, diseases, predation and accidents that occur when adults collide with obstacles and when fledglings are learning to fly (Dwyer et al. 2018). Globally, human landscapes are characterised by anthropogenic structures such as buildings, energy and road infrastructure that increase collision risk for birds of prey living in or near such environments (Donázar et al. 2016). For example, collisions with vehicles, windows, fences and power lines are some of the leading causes of raptor mortality in human landscapes (Hager 2009, Dwyer et al. 2018, Smith et al. 2018). One way to track the prevalence of human-related threats to raptors is via admission records at wildlife rehabilitation centres (Wendell et al. 2002, Mazaris et al. 2008, Mariacher et al. 2016, Arent et al. 2018). Animals that are injured or perceived to be in human-related danger are rescued, rehabilitated and released back to the wild (Pyke & Szabo 2018). Rehabilitation records in some cases can under-represent some threats because sick or injured birds are more likely to be brought in than dead birds (Rodríguez et al. 2010), and not all injured birds will be found or brought in. However, the information on animals that do get admitted to rehabilitation centres is important because they provide unique research opportunities that may contribute to species conservation by improving understanding of anthropogenic impacts (Pyke & Szabo 2018).

Although the goal of rehabilitation is to release animals back to the wild after successful treatment (Sarà 2014), animals that have little chance of recovery because of severe injuries should be euthanised quickly, to prevent further suffering, through a triage decision process (Molony et al. 2007, Kelly et al. 2011, Mullineaux 2014). Studies investigating factors that influence the outcome of rehabilitation are important to inform the triage process so that resources can be directed to individuals that have a high probability of recovering (Molony et al. 2007). In a study that was based on eight species of mammals and birds, admitted to

rehabilitation centres in England, Molony et al. (2007) reported that the chances of survival in care until release were predicted by the severity of the symptoms of the injury. Bone fracture injuries, for example, mostly as a result of collisions, significantly reduced the chance of release from rehabilitation for Eurasian Sparrowhawks (*Accipiter nisus*) (Kelly & Bland 2006). Reason for admission can be an important predictor for rehabilitation outcome because some animals may have been rescued with no severe injuries and therefore can be expected to fully recover (Molony et al. 2007, Wimberger & Downs 2010, Kelly et al. 2011). In some cases, the outcome of rehabilitation is influenced by the condition of the animal before the injury or rescue as some adults rescued in spring or summer, for example, maybe in poorer health immediately after breeding (Parsons et al. 2018). Therefore, adults admitted during a season when they are in poor body condition may have reduced chance of surviving rehabilitation. Headlights often dazzle nocturnal raptors as they hunt along roads, making them vulnerable to collisions with vehicles and fences, resulting in severe injuries (Anderson 2000, Bullock et al., 2011, Molina-López et al. 2011, Hernandez et al. 2018). In their study, Hernandez et al. (2018) found that nocturnal raptors were significantly more likely to be involved in vehicle collisions than diurnal raptors.

In this study, we reviewed the causes for raptor admissions to a specialist raptor rehabilitation centre in KwaZulu-Natal, South Africa, using admission records. We then determined if the outcome of rehabilitation can be predicted from information obtained from the admission records in order to inform triage decisions. A previous long term study conducted in the same rehabilitation centre by Thompson et al. (2013) used admission records from 2004-2011 to identify the most common threats to raptors and to list the species most affected. The study reported that the main causes of admission were collisions with vehicles and buildings. We examined if factors such as the reason for admission, the season of admission and raptor

activity pattern (diurnal or nocturnal) can be used to predict the outcome of rehabilitation (i.e. release back into the wild).

2 METHODS

2.1 Study area and data collection

We obtained data from admission records of birds of prey admitted to the Raptor Rescue Rehabilitation Centre in Pietermaritzburg (29°40’32”S 30°30’52”E), South Africa, from January 2015 to December 2016. The facility rehabilitates both diurnal (eagles, vultures, hawks, falcons, kites, harriers and Secretary Bird) and nocturnal (owls) birds of prey. In addition to injured birds brought in by the public or picked up by staff members, the rehabilitation centre also receives transferred raptors from other rehabilitation centres in the region such as FreeMe KZN Wildlife Rehabilitation Centre (Thompson et al. 2013). Information obtained from admission records included the date of admission, the reason for admission, species name, the area where the bird was found and outcome of rehabilitation (released, permanent captive, euthanised and died). Reasons for admission were grouped as follows: orphaned chicks (nestlings up to the age of fledglings); collisions (with motor vehicles, windows and other human infrastructure); diseased; electrocuted; found inside a house (trapped inside a building); grounded (because of inclement weather or non-visible injuries or unknown cause); poisoned (Ingested contaminated food); shot (gunshot wound); confiscated (illegally captured animals); stuck (entangled); other injuries and unknown (reason not recorded) (Table 1). Admission dates were presented as seasons: spring (September – November); summer (December – February); autumn (March – May) and winter (June – August). For this study, the outcome of rehabilitation was limited to either 1) released back to the wild; or 2) died in care (including euthanised birds).

TABLE 1 Reasons for admission of raptors to Raptor Rescue, KwaZulu-Natal from January 2015 to December 2016. Percentages indicate the proportion of raptors admitted because of the corresponding reason. Raptors are separated into nocturnal (owls) and diurnal (vultures, eagles, hawks, buzzards) species (see text for further details).

Reason	Description	Diurnal	Nocturnal	Total	%
Collision trauma	Collision with vehicles, wall, windows, fence	76	50	126	52.1
Grounded	Not able to fly, no obvious injuries	18	10	28	11.6
Chick	Orphaned, Fell from nest, grounded fledgling	2	21	23	9.5
Other injuries	Visible injuries from e.g. from dog attack, hailstorms	8	6	14	5.8
Poisoned	Ingested contaminated food	12	0	12	5.0
Found inside a house	Trapped inside building or structure	6	4	10	4.1
Diseased	Infections	3	3	6	2.5
Stuck	Entangled, stuck in dam	6	0	6	2.5
Shot	Gunshot wound	5	0	5	2.1
Confiscated	Illegally captured, seized from poachers	4	1	5	2.1
Electrocuted	Electrocuted on powerlines	4	0	4	1.7
Unknown	Admission reason not recorded	2	1	3	1.2
Total		146	96	242	100

2.2 Statistical analyses

We used the binary logistic regression function on IBM SPSS Statistics 20.0 (IBM, Armonk, USA) to determine if three variables (the reason for admission; diurnal or nocturnal activity; season of admission) were significant predictors of the outcome of rehabilitation (released or died). Multicollinearity between variables was tested using the linear regression command in IBM SPSS Statistics, with rehabilitation outcome as the response variable and reason, diurnal

and season as predictor variables. There was relatively little multicollinearity as all tolerance values were above 0.95. Only data with no missing information were used in the regression models, and variables with fewer than 10 admission cases were excluded. This eliminated from the regression data reasons like confiscated, poisoned, diseased, electrocuted, shot, found inside house and stuck which accounted for fewer than 10 cases each (Tables 1 and 2).

TABLE 2 Descriptions of all variables selected to be used in the binary logistic regression for raptors admitted to Raptor Rescue Rehabilitation Centre.

Variable	**Description**	
Outcome (categorical)		Dependent variable: Released = 1, Died = 0
Diurnal (categorical)		Diurnal raptor = 1 and Nocturnal raptor = 0
Season (categorical)		
	Spring	September - November
	Summer	December - February
	Autumn	March - May
	Winter	June - August
Reason (categorical)		
	Collision	Collision with vehicles, wall, windows, fence
	Chick	Orphaned, Fell from the nest, grounded fledgling
	Grounded	No obvious injuries
	Other Injuries	Visible injuries from, e.g. from a dog attack, hailstorms

Each of the independent variables (predictor) were tested with the dependent variable (response) to determine if, individually, they were significant predictors of rehabilitation outcome and to be consequently added to the global model if $p < 0.05$. Odds ratios (the ratio of P [released] to P [died]) were used to present effect sizes, where values greater than one indicated that a bird was more likely to be released than to die in care (Molony et al. 2007). Whereas values less than one indicated that an admitted bird was less likely to have successful treatment. In order to calculate odds ratios within a categorical variable, the first category within the variable was assigned as a reference for the other remaining categories (Molony et al. 2007). Model fit was assessed using the Hosmer-Lemeshow, Cox and Snell and Nagelkerke R square statistic. There was no significant difference between the fitted model with each of

TABLE 3 All raptor species admitted to Raptor Rescue Rehabilitation Centre, South Africa, from January 2015 to December 2016. Raptors are separated into nocturnal (owls) and diurnal (vultures, eagles, hawks, buzzards) species (see text for further details).

Common name	Row Labels	Total	%
DIURNAL			
Black Sparrowhawk	*Accipiter melanoleucus*	15	6.2
Little Sparrowhawk	*Accipiter minullus*	6	2.5
African Goshawk	*Accipiter tachiro*	6	2.5
Verreaux's Eagle	*Aquila verreauxii*	2	0.8
Common Buzzard	*Buteo buteo*	5	2.1
Jackal Buzzard	*Buteo rufofuscus*	25	10.3
Brown Snake Eagle	*Circaetus cinereus*	1	0.4
Southern Banded Snake Eagle	*Circaetus fasciolatus*	1	0.4
African Marsh Harrier	*Circus ranivorus*	1	0.4
Amur Falcon	*Falco amurensis*	6	2.5
Lanner Falcon	*Falco biarmicus*	6	2.5
Peregrine Falcon	*Falco peregrinus*	3	1.2
Eurasian Hobby	*Falco subbuteo*	1	0.4
Palm-nut Vulture	*Gypohierax angolensis*	1	0.4
White-backed Vulture	*Gyps africanus*	3	1.2
Cape Vulture	*Gyps coprotheres*	11	4.5
African Fish Eagle	*Haliaeetus vocifer*	4	1.7
Wahlberg's Eagle	*Hieraaetus wahlbergi*	2	0.8
Long-crested Eagle	*Lophaetus occipitalis*	1	0.4
Yellow-billed Kite	*Milvus migrans aegyptius/parasitus*	29	12.0
European Honey Buzzard	*Pernis apivorus*	1	0.4
Martial Eagle	*Polemaetus bellicosus*	1	0.4
African Harrier-Hawk	*Polyboroides typus*	5	2.1
Secretary Bird	*Sagittarius serpentarius*	4	1.7
Crowned Eagle	*Stephanoaetus coronatus*	5	2.1
Lappet-faced Vulture	*Torgos tracheliotus*	1	0.4
Total Nocturnal		**146**	**60.3**
NOCTURNAL			
Marsh Owl	*Asio capensis*	2	0.8
Spotted Eagle-Owl	*Bubo africanus*	55	22.7
Cape Eagle-Owl	*Bubo capensis*	4	1.7
Southern White-faced Owl	*Ptilopsis granti*	2	0.8
African Wood Owl	*Strix woodfordii*	9	3.7
Western Barn Owl	*Tyto alba*	23	9.5
African Grass-Owl	*Tyto capensis*	1	0.4
Total Nocturnal		**96**	**39.7**
Total Raptors		**242**	**100**

the variables and the data (Wald 2.537, df = 1, p = 0.111 for all models), suggesting good model fit. Names of raptors follow Hockey et al. (2005).

3 RESULTS

3.1 Species of raptors admitted and causes of admissions

From January 2015 to December 2016, 242 raptors were admitted to Raptor Rescue, representing 33 raptor species (Table 3). Admissions were evenly distributed across all four seasons and did not show any clear trends. The most commonly admitted species, with over 20 admissions each, were Spotted Eagle-Owl *Bubo africanus* (22.7%), Yellow-billed Kite *Milvus migrans aegyptius/parasitus* (12%), Jackal Buzzard *Buteo rufofuscus* (10.3%) and Western Barn Owl *Tyto alba* (9.5%) (Table 3). Forty percent (96 birds) of the admitted raptors were nocturnal, while the remaining 60% (146 birds) were diurnal species. Overall, across all species, 52.1% were admitted because of collision related injuries (i.e. collisions with vehicles, walls, windows and fences), and 60% of the total collision cases were of diurnal raptors, and the rest (40%) were nocturnal raptors (Table 1, Figure 1). Other reasons for admission across all species were: grounded birds (11.6%), orphaned chicks were 9.5% and other less frequent causes (Table 1). A majority of the orphaned chicks (62.5%) were admitted during the spring season, and 91% (21 out of 23 admitted chicks) of them were nocturnal raptors (Table 1, Figure 1).

3.2 Outcome of rehabilitation

Of the 242 raptors admitted, 116 (48%) were released back into the wild, 51 (21%) were euthanised, and 40 (17%) died from their injuries. The outcomes of the remaining birds were either unknown/unrecorded (10%) or kept as long-term captives (4%) (Figure 2). Long-term captives were kept at the African Bird of Prey Sanctuary or Predatory Bird Centre for public education purposes.

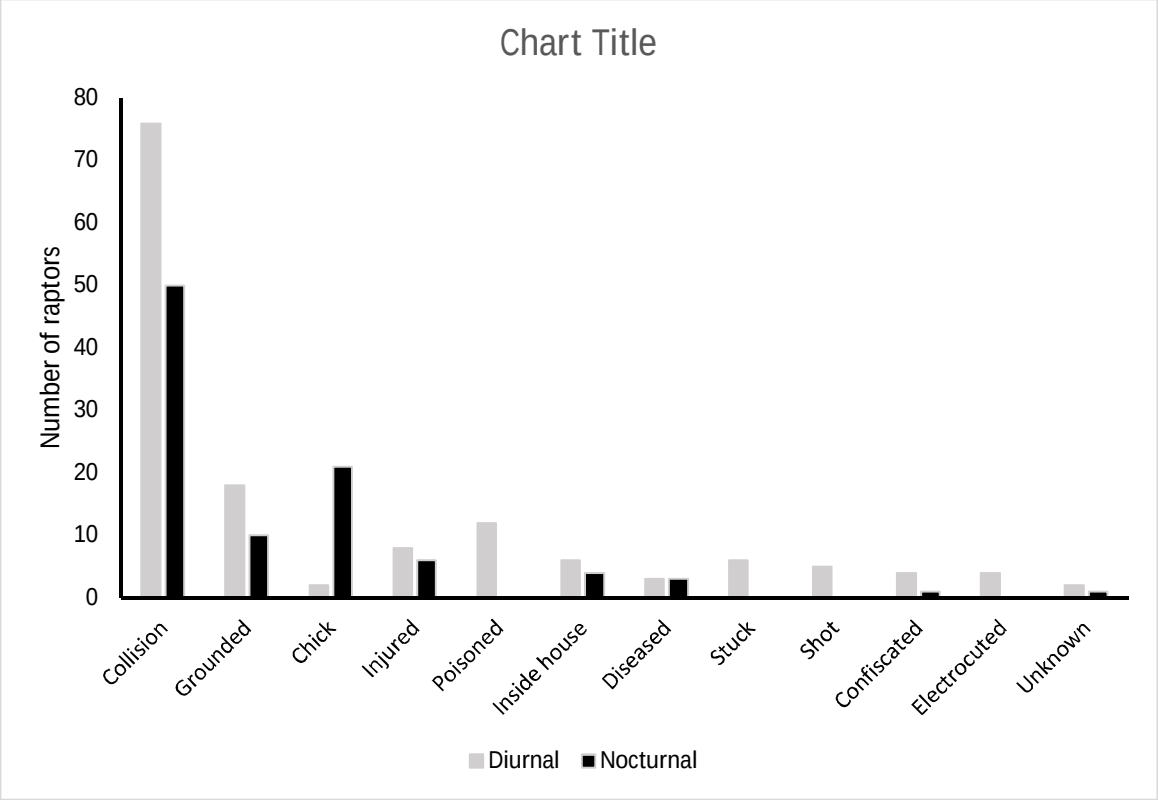

FIGURE 1 All diurnal raptors (diurnal and nocturnal) and reasons for admission to Raptor Rescue Rehabilitation Centre, South Africa.

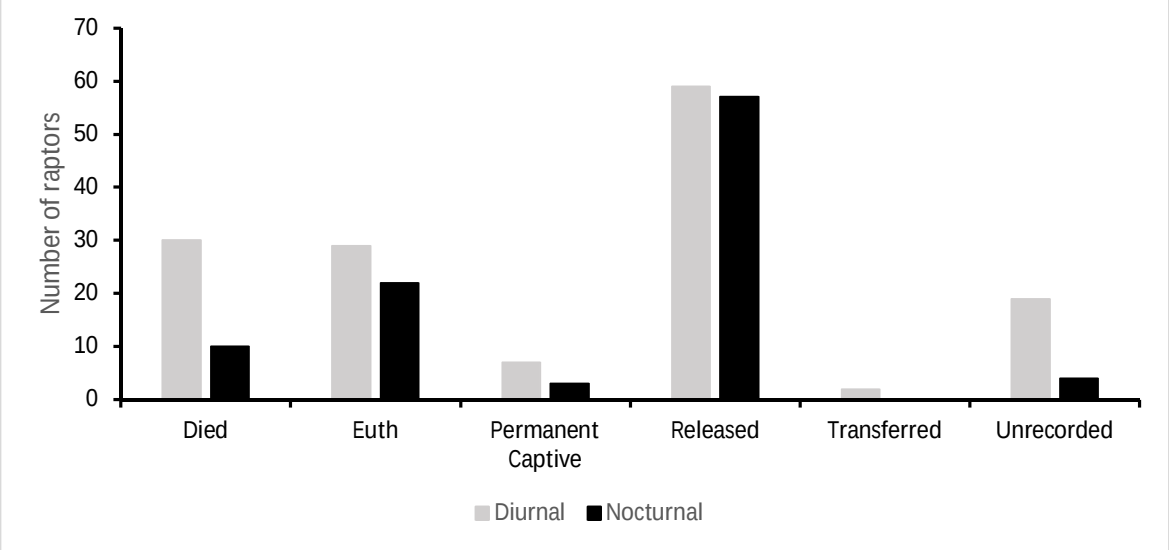

FIGURE 2 The outcome of rehabilitation of raptors admitted to Raptor Rescue Rehabilitation Centre, KwaZulu-Natal, South Africa.

3.3 Logistic regression

One hundred and seventy three records were used in the regression models, after filtering out predictor variables with fewer than 10 cases or removing records with missing information. Reason was the only significant predictor of the outcome of rehabilitation ($\chi^2 = 16.518$, df = 3, p = 0.001), while season and diurnal were not significant ($\chi^2 = 0.925$, df = 3, p = 0.925, and $\chi^2 = 2.952$, df = 1, p = 0.086), respectively. Since reason was the only significant predictor, we considered the model fitted with reason alone as the final model. The final model correctly predicted 77.6% of birds that died and 50.5% of the birds that were released back into the wild. The overall accuracy of the model was 62.4%. Orphaned chicks were 6.1 times more likely to be released than birds that were admitted because of collision related injuries. Additionally, birds admitted because they were grounded were 2.9 times more likely to be released than birds admitted because of collision injuries (Table 4 and Figure 3).

TABLE 4 Summary of significant binary logistic regression models for raptors admitted to Raptor Rescue Rehabilitation Centre. * = significant variables in the model, OR = Odds ratio.

Predictor variables	**B**	**S.E.**	**Wald**	**df**	**P Value**	**OR**	**95% C.I.for OR**	
Reason (Collision)*			14.269	3	0.003			
Reason(Chick)*	1.816	0.581	9.761	1	0.002	6.146	1.967	19.2
Reason(Grounded)*	1.054	0.443	5.649	1	0.017	2.868	1.203	6.838
Reason(Other injuries)	0.899	0.642	1.96	1	0.162	2.458	0.698	8.66
Diurnal	-0.531	0.311	2.92	1	0.087	0.588	0.32	1.081
Season (Spring)			0.471	3	0.925			
Season(Summer)	-0.074	0.424	0.03	1	0.862	0.929	0.405	2.131
Season(Autumn)	-0.031	0.456	0.005	1	0.945	0.969	0.396	2.371
Season(Winter)	0.192	0.412	0.217	1	0.641	1.212	0.541	2.715

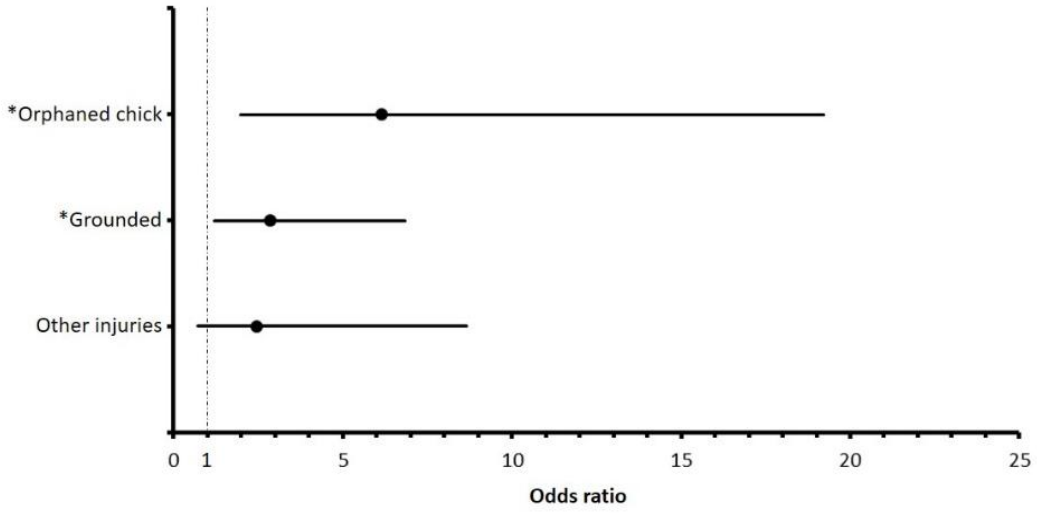

FIGURE 3 Likelihood of release from Raptor Rescue Rehabilitation Centre in KwaZulu-Natal as predicted by reason for admission. Lines on sides of each point are 95% confidence intervals. Through 1 is the line of no effect, and Reasons with points falling to the right side it predict greater likelihood of release than than the reason, collision. Note that the collision category is not shown in the graph because it was used as reference for the other categories (orphaned chick, grounded and other injuries). Asterics indicate significant predictors.

4 DISCUSSION

Our study demonstrated that collisions with human infrastructure are a leading cause for raptor morbidity in KwaZulu-Natal, accounting for more than half of all admissions. Furthermore, birds that suffered from collision injuries were significantly less likely to be released after admission to the rehabilitation than orphaned and grounded birds, suggesting that collision-related injuries pose a more serious mortality risk than any other factor (Table 4, Figure 3). This may be because fractures resulting from collisions are often severe and rehabilitators opt to euthanise birds suffering from such injuries since full recovery is less likely (Kelly & Bland 2006).

The results of the present study corroborated previous findings by Thompson et al. (2013) in the same rehabilitation centre, which indicated that collisions were the most prevalent causes of raptor admissions. Thirty nine raptor species were admitted to the centre during the Thompson et al. (2013) study period, the three most commonly admitted species being Spotted

Eagle-Owls (*Bubo africanus*), Western Barn Owls (*Tyto alba*) and Yellow-billed Kites (*Milvus migrans aegyptius/parasitus*); a result corroborated by our study. Our results are also consistent with findings from other rehabilitation centres from elsewhere in the world. For example, in England, collision with windows and vehicles represented over 70% of Eurasian Sparrowhawk (*Accipiter nisus*) admissions (Kelly & Bland 2006), while in Tenerife, where both diurnal and nocturnal raptors were admitted, over 40% of the total admissions were because of collisions related injuries (Rodríguez et al. 2010). Features of human-modified landscapes such as roads, traffic, power lines and windows increase the chances of collisions for birds of prey in such environments (Rodríguez *et al*. 2010). However, the collision risk of some raptors can also be increased by their feeding habits (Wendell et al. 2002); raptors that hunt for garden birds, for example, are more likely to collide with buildings or windows as they pursue their prey (Hager 2009, Dwyer et al. 2018). Motor vehicle collisions are typically expected to affect raptors that hunt on the side of the road or feed on roadkill. Such casualties in the present study included Jackal Buzzards and Yellow-billed Kites, which may scavenge carcasses of animals dead on the road (Dean & Milton 2003).

A total of 242 raptors were admitted to Raptor Rescue Rehabilitation Centre during the study period, of which 60% were diurnal raptors, and 40% were nocturnal raptors. Collision trauma was the leading reason for admission of both diurnal and nocturnal raptors and accounted for over 50% of the admission cases in each group. In terms of prevalence, collision trauma was followed by grounded birds for diurnal raptors. Amongst nocturnal raptors however, orphaned chicks was the second most common reason for admission (Table 1). Other less important causes of admission in this study were: poisoned, birds stuck inside a house or other structures, electrocuted, gunshot wounds, other injuries and unrecorded reasons (Table 1). Since admissions depend on people finding the affected animals and their willingness to take them to the nearest rehabilitation centre, many potential cases remain unreported. Other

threats like poisoning can be underestimated because they can be easily mistaken for others. For example, amongst scavenging raptors, signs of weakness may not always indicate injury or dehydration but can also be an indication of ingested poison in low doses (Naidoo et al. 2011).

Overall, the centre's release rate of 48% was comparable to Molina-López et al. (2013), where a release rate of 47% was reported. However, it was lower than other studies such as Komnenou et al. (2005), Knight et al. (2009) and Montesdeoca et al. (2017) where 57%, 57%, and 58% of the admitted raptors were released back to the wild, respectively. The release rate reported in this study was higher than that of the previous study by Thompson et al. (2013), which was 38%. Kelly and Bland (2006) reported a much lower release rate of 24% for Eurasian Sparrowhawks in England.

Our study has demonstrated that the reason for admission to a rehabilitation centre can be a significant predictor of the outcome of rehabilitation. Contrary to this study, Kelly and Bland (2006) found that clinical diagnosis was a significant predictor of rehabilitation outcome, not the reason for admission. Ideally, it would have been best to test both predictors (reason for admission and clinical diagnosis), however, it was not possible to use both predictors in this study because they were either not clearly differentiated from each other in the medical records or information on clinical diagnosis was missing. We also investigated if the likelihood of release of raptors from the rehabilitation centre was associated with activity pattern of raptors (i.e. diurnal vs nocturnal) and the season of admission. The results of the study indicate that neither activity nor season was a significant predictor of the outcome of rehabilitation of raptors at the Raptor Rescue Rehabilitation Centre. Further investigation into possible predictors for raptor rehabilitation outcome such as measures of body condition is needed, see Molina-López et al. (2015). Knowing the factors that can be used to predict rehabilitation outcomes can help

the triage decision process and thus ensuring the prioritisation of animals that have a better chance of recovering and to be subsequently released back into the wild.

5 CONCLUSIONS

Diligent keeping of admission records is crucial for developing an evidence-based triage protocol (Grogan & Kelly 2013). Since the results of the present study show that reason for admission was a good predictor of the outcome of rehabilitation, rehabilitators should prioritise birds that are admitted because of non-collision related reasons over those with severe injuries. Other studies have highlighted the poor prognosis of raptors admitted to rehabilitation centres with collision trauma or bone fractures (Kelly & Bland 2006, Molony et al. 2007).

Successful rehabilitation does not end at the release of rehabilitated birds; therefore, post-release monitoring is critical to truly evaluate the contribution of rehabilitation centres to the welfare and conservation of animals. Where funds are available radio-tracking, and ring recovery data can yield detailed short to long term information on the survival rates of rehabilitated raptors. The improved release rate at Raptor Rescue may be indicative of improved treatment protocols possibly as the centre is a specialist centre for birds of prey. We, therefore, recommend the opening of more specialised rehabilitation centres for efficient rehabilitation of injured animals.

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7 DATA AVAILABILITY STATEMENT

Data used in this study are available on request from the corresponding author.

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