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PRESENTATION AND PROGNOSTIC INDICATORS FOR FREE-LIVING BLACK COCKATOOS (*CALYPTORHYNCHUS* SPP.) ADMITTED TO AN AUSTRALIAN ZOO VETERINARY HOSPITAL OVER 10 YEARS

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ABSTRACT: The veterinary records of three species of free-living, endangered black cockatoos (*Calyptorhynchus* spp.; $n=565$) admitted to the Perth Zoo Veterinary Hospital in Western Australia during a 10-yr period (2000–09) were analyzed to determine the effect of clinical presentation and treatment on survival to release. The most-common reason for admission was trauma (at least 76.7% of cases), and trauma was also the most-frequent finding on necropsy examination (80.1% of cases). Anemia and paralysis-paresis were significant factors determining the decreased likelihood of survival of cockatoos undergoing rehabilitation. Human activities, in particular vehicle strike, were significant causes of morbidity and mortality in free-living black cockatoo populations.

Key words: Australia, Baudin's Black-Cockatoo, black cockatoo, *Calyptorhynchus*, Carnaby's Black-Cockatoo, conservation, Red-tailed Black-Cockatoo, rehabilitation.

INTRODUCTION

The populations of all three endemic species of black cockatoo in the southwest of Western Australia (Carnaby's Black-Cockatoo [*Calyptorhynchus latirostris*], Baudin's Black-Cockatoo [*Calyptorhynchus baudinii*], and Red-tailed Black-Cockatoo [*Calyptorhynchus banksii naso*]) are in decline due to many factors including habitat loss, competition with other species, and poaching (Saunders 1990; Mawson and Johnstone 1997; Saunders and Ingram 1998). In 2000, the growing number of traumatic injuries in wild black cockatoos on the Swan Coastal Plain, an area including Perth city and an important region of black cockatoo habitat during the nonbreeding season, prompted a collaboration between the Perth Zoo Veterinary Hospital (PZVH) and the Western Australian Department of Parks and Wildlife to provide treatment and rehabilitation for these birds. Since the beginning of the program, the PZVH veterinary staff has developed an effective assessment and treatment protocol for these endangered birds. However, there is considerable expense inherent in the treatment and care of wild birds which needs to be justified, including the costs associated with labor, medication, and surgical and diagnostic equipment (Grogan and Kelly 2013). Further, the decision to hospitalize and treat a wild bird must take into account its long-term likelihood of survival in the wild, balanced against the level of potentially significant stress and pain that may be experienced by the bird during hospitalization, treatment, and subsequent release (Kirkwood and Sainsbury 1996). Therefore, it is important from both financial and welfare perspectives that rehabilitation programs establish potential predictive factors that are associated with the outcome of veterinary treatment and care. Retrospective examination of veterinary records is an important source of information and may reveal trends in life histories and demographics in terms of increased likelihood of survival. Results from such studies can be useful in directing resources toward those birds with a better chance of survival and reducing the number of cases with poor prognoses that are treated unsuccessfully. Information gathered from retrospective analyses can also be used to identify mortality and morbidity factors that can aid in species management and guide recovery efforts and, therefore, be

useful to conservation (Wimberger and Downs 2010).

Although aspects of the Perth Zoo black cockatoo program have been frequently reviewed and refined since its inception, statistical analyses of past records had not been performed until this study. Our results may also provide more relevant information for other wild psittacine rehabilitation programs, as previously published retrospective studies on rehabilitated wild birds have involved nonpsittacine species (Fix and Barrows 1990; Sweeney et al. 1997; Deem et al. 1998; Morishita et al. 1998; Punch 2001; Wendell et al. 2002; Ress and Guyer 2004; Komnenou et al. 2005; Kelly and Bland 2006; Harris and Sleeman 2007; Molony et al. 2007; Rodríguez et al. 2010). In addition, few studies published to date on other bird species examined variables associated with signalment and presenting condition relating to rehabilitation success (Ress and Guyer 2004; Molony et al. 2007) as opposed to listing the causes and characteristics of morbidity and mortality (Fix and Barrows 1990; Sweeney et al. 1997; Deem et al. 1998; Morishita et al. 1998; Punch 2001; Wendell et al. 2002; Komnenou et al. 2005; Harris and Sleeman 2007).

MATERIALS AND METHODS

On admission, all cockatoos were given a brief physical examination under manual restraint and treated with antibiotics (enrofloxacin, 15 mg/kg subcutaneously [SC], diluted in an equal volume of sterile water), anti-inflammatory medication (meloxicam, 0.2 mg/kg[a] SC), and fluids (compound sodium lactate and 5% glucose in a 1:1 solution, at 2–3% bodyweight[b] SC). If cockatoos were hospitalized, these medications, as well as an antifungal medication (terbinafine, 15 mg/kg), were continued orally twice daily as required. Biting feather lice (Phthiraptera: Mallophaga) were seen often, particularly on debilitated cockatoos, and infestations were treated with a topical pyrethrin-based spray. Ticks were seldom seen but were removed manually if present. Whole-body radiographs were performed and, if required, surgery was undertaken to repair fractures and soft tissue injuries. Blood was collected to determine packed cell volume (PCV), total plasma protein, estimated white cell count, and a differential white cell count. These parameters were compared against hematologic reference values for the species (Le Souëf et al. 2013). Cockatoos were euthanized if their presenting condition was incompatible with survival in the wild (for example, traumatically amputated limbs, limbs requiring amputation, or loss of an eye) or if unsuitable for a good quality of life in captivity as an education or breeding bird (for example, inability to fly and land safely in an aviary).

Clinical records for wild black cockatoos ($n=565$) admitted to the PZVH during a 10-yr period (January 2000–December 2009) were collated. If recorded, the following data were entered for each case: age, sex, species, body condition, when and where the bird was found, clinical presentation, hematology, medications, final outcome (euthanized, died, or survived), and findings of necropsy examination, if performed. Data on reasons for presentation were also collated, with cockatoos placed in the 'undetermined' category if they presented in any debilitated state for which the cause could not determined. The data were analyzed using SPSS Statistics 17.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were computed for variables such as species, age, sex, when the cockatoo was found in relation to presentation to PZVH, body condition, length of time in care, treatment, and outcome. Initially, associations between potential factors and the outcome were assessed using univariate analysis. 'Outcome' was used as the dependent variable, dividing cockatoos into those that had died, whether spontaneously or by euthanasia, and those that had been transferred to the rehabilitation center from the PZVH ('survived'). All factors with a P-value ≤ 0.25 on univariate analysis were selected for inclusion in the multiple regression model. Variables were not included if they were found to be associated with confounding factors (for example, cockatoos found more than 1 d before presentation had an increased chance of survival; however, it is likely that this associ-

[a] More recently, pharmacokinetic studies have indicated that this dose may be subtherapeutic in psittacine birds (Wilson et al. 2005; Cole et al. 2009).

[b] Although higher fluid rates may theoretically be recommended in dehydrated birds, this initial volume is given because higher volumes may cause discomfort if administered subcutaneously during the initial examination under manual restraint. Following this initial dose, a fluid plan is developed whereby higher volumes are administered orally to correct fluid balances and account for initial dehydration as well as to provide appropriate avian maintenance fluid volumes.

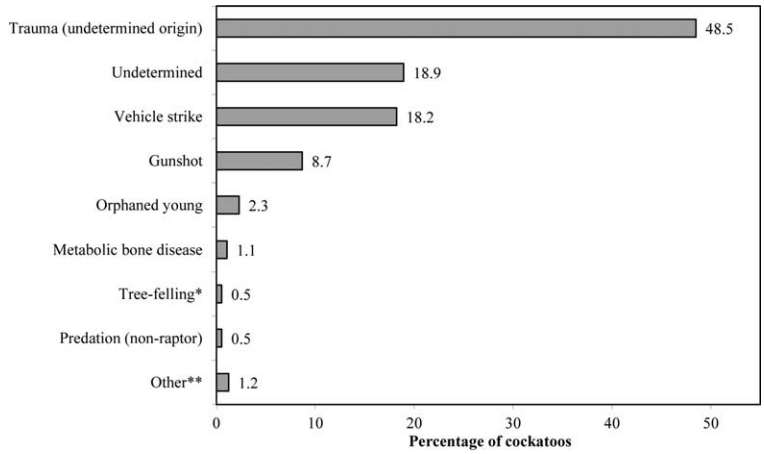

FIGURE 1. Relative frequency of reasons for admission for black cockatoos (*Calyptorhynchus* spp.) ($n=565$) treated at Perth Zoo Veterinary Hospital (Australia) 2000–09. *'Tree-felling' indicates fledglings brought down to the ground as a result of tree felling. **'Other' included predation by a raptor ($n=1$), trauma caused by being caught in a fence ($n=1$), inappropriate presentation by a member of the public of a chick that was likely to be still within the care of its parents ($n=1$), trauma caused by flying into an inanimate object ($n=1$), falling from a tree as a result of a storm ($n=2$), and congenital deformity ($n=1$).

ation was due to cockatoos with more serious injuries being presented earlier). The adequacy of the multiple regression model was assessed with Hosmer-Lemeshow statistics. Odds ratios with confidence intervals were calculated for each variable, with ratios of more than one indicating that cockatoos were more likely to survive than to die or be euthanized and ratios of less than one indicating that cockatoos were less likely to survive than to die or be euthanized. Those cockatoos that were euthanized within the first 24 h were omitted from the univariate and multivariate analyses because they created a bias towards a poor prognosis for recovery. The criteria that are currently used in the decision-making process for immediate euthanasia are also unlikely to change, meaning the practical relevance of results from such analyses would be negligible.

RESULTS

Of the black cockatoos admitted to the PZVH between 2000 and 2009 for which species was recorded, 59% were Carnaby's Black-Cockatoos, 23% were Red-tailed Black-Cockatoos, and 16% were Baudin's Black-Cockatoos. Where sex was determined via DNA testing or endoscopy ($n=183$), 53% were males and 47% were females. For cockatoos that were aged on the basis of physical appearance (e.g., plumage and bill size and color) and the presence of juvenile behavior, 39% were juveniles and 61% were adults. Of the black cockatoos admitted over the time period, 47% were euthanized (of these, 43% were euthanized during the initial examination and were thus omitted from further analysis), 10% died spontaneously, and 43% survived to rehabilitation.

The most-common reason for admission of wild black cockatoos to the PZVH was trauma, which accounted for at least 76.7% of cases (Fig. 1). Human activities (vehicle strike, gunshot, and tree felling) accounted for at least 28% of cases; however, many of the cases categorized as trauma of undetermined origin were also likely to be associated with anthropogenic factors.

In total, 43.3% of black cockatoos presented with one or more fractures. Wing fractures (i.e., distal to the shoulder) were the most-common fracture type: 73.1% of black cockatoos with fractures had one or more wing fractures while only

11% had one or more pectoral girdle fractures and 12.7% had one or more leg fractures.

Factors that were significantly associated with a reduced likelihood of survival were deep soft tissue injury ($P=0.002$), paralysis-paresis (i.e., weakness or loss of voluntary movement) ($P<0.001$), fracture ($P=0.002$), anemia (i.e., reduced red blood cell count when compared with hematologic reference values) ($P=0.026$), abnormal fecal cytology (e.g., predominantly Gram-negative bacteria or scant bacteria) ($P=0.020$), and treatment with steroid medication ($P=0.009$) (Table 1). Some presenting signs that were rare meant that sample sizes were too small for statistical analysis. These variables included metabolic bone disease ($n=10$), dyspnea ($n=17$), upper respiratory tract signs ($n=2$), regurgitation ($n=4$), and diarrhea ($n=7$).

Following multivariate analysis, the factors that remained in the model as significantly reducing the likelihood of survival were anemia ($P=0.004$) and paralysis-paresis ($P<0.001$) while superficial soft tissue injury (i.e., minor bruising and superficial skin wounds) ($P=0.008$) was associated with an increased likelihood of survival (Table 2). Hosmer-Lemeshow tests ($\chi^2=0.971$, $P=0.965$) indicated an adequate fit to the data for all steps of the multivariate regression model.

One hundred and sixty-one black cockatoos were necropsied during the 10-yr period. The most-frequent finding was traumatic injury, which was diagnosed in 80.1% of the cockatoos for which a necropsy examination was performed. Of the trauma cases, 65.9% showed only external gross signs of trauma with no significant internal (i.e., intracoelomic) changes, 2.3% showed only internal signs (such as intracoelomic hemorrhage or organ laceration), and 33.3% showed evidence of both external and internal trauma. Mycotic pneumonia ($n=13$) was the most-common nontraumatic diagnosis, while other findings included bacterial pneumonia ($n=4$), aspiration pneumonia ($n=1$), renal pathology ($n=5$), hepatopathy ($n=4$), septicemia ($n=1$), and enteric cryptosporidiosis ($n=1$). No significant findings were recorded for 9.3% of dead cockatoos examined. A *Burkholderia* sp. was cultured from an air sac swab from a Baudin's Black-Cockatoo with bacterial pneumonia.

No evidence of gastrointestinal parasites was seen in the feces of any of 79 wild black cockatoos screened or during the necropsies of 161 wild black cockatoos from 2000 to 2009. However, ascarid nematodes (*Ascaridia* sp.) were found in the feces of two black cockatoos from the Rehabilitation Centre, both of which had been in captivity for several weeks. Ectoparasites were seen often on the skin of wild black cockatoos, particularly on more-debilitated birds. The majority of ectoparasites were biting feather lice that were recorded for 56 birds. Lice taken from a Carnaby's Black-Cockatoo were identified to the genus level as *Neopsittaconirmus* and *Franciscoloa* species, both of which have been previously recorded in Carnaby's Black-Cockatoos (Stranger and Palma 1998). Five records also mentioned the presence of ticks, all found on the head (presumably because debilitated cockatoos were less able to self-preen this area).

DISCUSSION

The optimized use of limited resources is often critical to the success of endangered species programs. Conducting retrospective analyses of wildlife treatment and rehabilitation cases results in better case triage, enabling the direction of effort to cases with a better prognosis (Molony et al. 2007). There are also significant animal welfare benefits in determining the likelihood of release at an early stage of rehabilitation, as suffering will not be prolonged in cases that are unlikely to be successful (Kirkwood and Best 1998). This is the first published retrospective analysis of factors influencing rehabilitation success

TABLE 1. Univariate analysis of factors against outcome (survived versus death-euthanized) for black cockatoos (*Calyptorhynchus* spp.) presented to the Perth Zoo Veterinary Hospital (Australia) 2000–09.

	n	Survived (%)	*P*	OR[a]	CI[b] (95%)
Presenting factors					
Baudin's Black-Cockatoo	68	50	0.507	0.821	0.489–1.380
Red-tailed Black-Cockatoo	109	59.6	0.184[c]	1.352	0.869–2.103
Carnaby's Black-Cockatoo	248	52.8	0.554	0.882	0.599–1.300
Adult	175	56.6	0.473	1.217	0.762–1.945
Juvenile	118	54.6	0.473	0.822	0.514–1.313
Male	142	53.5	0.814	0.927	0.583–1.472
Female	148	55.4	0.814	1.079	0.679–1.713
Summer	112	48.2	0.154[c]	0.729	0.474–1.123
Autumn	98	51	0.565	0.855	0.545–1.342
Winter	109	57.8	0.376	1.225	0.791–1.899
Spring	114	58.8	0.231[c]	1.305	0.847–2.013
Breeding season (July–December)	218	56.9	0.248[c]	1.259	0.862–1.839
Found >24 h before	219	57.5	0.135[c]	1.514	0.887–2.585
Poor body condition	157	54.6	0.175[c]	0.746	0.495–1.124
Been in other vet clinic	110	51.8	0.471	0.832	0.519–1.334
Previously treated with fluids	33	57.6	0.853	1.099	0.524–2.304
Previously treated with antibiotics	27	55.6	1.000	0.990	0.444–2.208
Previously treated with analgesia	23	56.5	1.000	1.032	0.435–2.448
Deep soft tissue injury	161	44.7	0.002[c]	0.534	0.360–0.793
Superficial soft tissue injury	111	64.9	0.011[c]	1.789	1.144–2.798
Old fracture	17	61.1	0.808	1.194	0.446–3.196
Paralysis-paresis	54	24.1	0.000[c]	0.225	0.117–0.434
Shot	43	65.1	0.328	1.431	0.738–2.777
Fracture	180	47.8	0.003[c]	0.545	0.365–0.814
Leucocytosis	101	58.4	0.177[c]	0.687	0.405–1.168
Monocytosis	71	63.4	0.538	0.819	0.449–1.494
Anemia	127	55.9	0.026[c]	0.539	0.320–0.907
Hypoproteinemia	70	55.7	0.145[c]	0.651	0.369–1.148
Abnormal fecal cytology	50	52	0.020[d]	0.388	0.181–0.833
Treatment during hospitalization					
Treated with fluids	390	53.6	0.320	0.693	0.354–1.354
Treated with antibiotics	359	53.8	0.603	0.851	0.509–1.423
Treated with analgesia	331	52.6	0.255	0.757	0.482–1.190
Treated with antifungals	278	59.4	0.011[e]	1.693	1.133–2.529
Treated with steroids	27	29.6	0.009[e]	0.330	0.141–0.771
Given supplementary feeding	137	53.3	0.150[e]	0.717	0.465–1.107
Hospital stay >7 d	192	69.8	0.000[e]	3.220	2.155–4.814
More than one general anesthetic	241	66.4	0.000[e]	3.1	2.081–4.618
Presented after 2006 (new treatment regime)	250	55.6	0.495	1.1	0.782–1.682

[a] OR = odds ratio.

[b] CI = confidence interval.

[c] Included in multivariate analysis ($P<0.25$).

[d] Not included in multivariate analysis due to small sample size.

[e] Factor likely to be associated with confounding factors and therefore not included in multivariate analysis.

of Australian psittacine birds. Most studies on avian rehabilitation involve raptor species in North America and Europe (Ress and Guyer 2004; Komnenou et al. 2005; Harris and Sleeman 2007; Rodríguez et al. 2010).

In common with many other wild avian rehabilitation studies (Fix and Barrows

TABLE 2. Significant variables from multivariate regression analysis of black cockatoos (*Calyptorhynchus* spp.) presented to the Perth Zoo Veterinary Hospital (Australia) 2000–09, excluding birds euthanized on the first day of presentation (survival as dependent variable).

Variable	*P*	OR[a]	95% CI[b]
Superficial soft tissue injury	0.008	2.385	1.253–4.539
Anemia	0.004	0.444	0.255–0.775
Paralysis-paresis	<0.001	0.196	0.079–0.487
Constant	<0.001	—	—

[a] OR = odds ratio.

[b] CI = confidence interval.

1990; Sweeney et al. 1997; Deem et al. 1998; Morishita et al. 1998; Punch 2001; Wendell et al. 2002; Komnenou et al. 2005; Kelly and Bland 2006; Harris and Sleeman 2007), the majority of cockatoos in this study (at least 76.7%) presented with trauma. Human activities contributed to a significant number of trauma cases (28%) and were likely to have been responsible for many more due to unconfirmed vehicle strikes and shootings. Few published data on the mortality of wild psittacine species are available, but the high rates of human-caused morbidity and mortality in this study are consistent with the findings of studies on the mortality of free-ranging raptors (Wendell et al. 2002). Data can be biased due to many injured or dead birds never being found, and confirmation of the cause of injury is often not possible; therefore, the use of these data to directly analyze morbidity and mortality of wild cockatoo populations should be approached with caution. Further, as has been deduced in studies of free-living raptor morbidity and mortality (Newton 1980), the deaths of those birds that are found and admitted for treatment are likely to be highly biased toward an association with human activities or habitation. Regardless, these results confirm the significance of vehicle strike as being a likely major threatening factor for black cockatoos, as has been previously postulated (Saunders et al. 2011). Spatial clusters of cockatoos found in certain locations were also identified in this study and are consistent with areas of heavy traffic flow, such as freeways (A.L.S. unpubl. data). Black cockatoos are susceptible to vehicle strike owing to their tendency toward feeding on remnant vegetation alongside road verges and flying out into clear air space when leaving a feeding area, which often places them in the path of oncoming vehicle traffic (Saunders et al. 2011). The effect of roads on local wildlife populations can be significant if not compensated for by sufficiently high birth rates (Newton et al. 1991).

The low incidence of significant clinical and postmortem findings other than trauma suggests that most cockatoos were healthy at the time of injury and that the birds were 'unlucky' rather than 'unfit.' These results indicate that the conservation value of this rehabilitation program is likely to be high, contrary to programs that are criticized due to the reintroduction of 'unfit' individuals to wild populations (Kirkwood and Sainsbury 1996). Assuming the cockatoos can be effectively treated and rehabilitated, there is no evidence that individuals presenting with injuries are any less healthy or robust than the general population and can be considered to have a good chance of postrelease survival.

The results from the univariate analysis of risk factors for outcome during the black cockatoo rehabilitation process may help guide veterinarians in making triage decisions. Paralysis-paresis, fracture, deep soft tissue injury, anemia, and abnormal fecal cytology were factors that were

associated with a reduced chance of survival according to univariate analysis. While the former three clinical signs are often immediately obvious, anemia and abnormal fecal cytology may be useful additional indicators for clinicians assessing prognosis. In particular, anemia remained a significant risk factor following multivariate analysis, along with paralysis-paresis, and should be carefully considered by clinicians when making decisions about management of certain cases.

The predominant postmortem finding among 142 black cockatoos necropsied during the study period was traumatic injury (80.1%). Importantly, trauma was not always externally obvious, with some cockatoos showing only internal evidence of trauma on postmortem examination and many showing both external and internal signs of trauma. This finding serves as a reminder of the extensive damage that can occur as a result of vehicle strike and other causes of traumatic injury involving large forces. Clinicians should therefore not only focus on external injuries but should also assess other parameters, such as PCV, that may indicate internal blood loss and organ damage. For example, two of the cockatoos that had only internal signs of trauma also showed both anemia and hypoproteinemia, which together may indicate acute hemorrhage. These findings also lend support to the current protocol of providing analgesia and fluids to all birds even if they are not showing external signs of injury.

The diagnosis of a *Burkholderia* sp. infection in a Baudin's Black-Cockatoo represents the first report of this species from a black cockatoo. Although seen sporadically in poultry (Barnes 2003), this bacterium has only been reported once in psittacine birds when it was cultured from an African Grey Parrot (*Psittacus erithacus erithacus*) that presented with neurologic signs and respiratory distress (Akko et al. 2008).

The absence of gastrointestinal parasites in admitted wild cockatoos is unsurprising given that their most-common parasite, the ascarid nematode (*Ascaris* spp.), is transmitted via a direct life cycle (Doneley 2010). Ascaridosis is therefore seen commonly in captive cockatoos where birds are allowed access to ground foraging on substrate that is not changed regularly (Lloyd 2003). It follows that ascarid nematodes were only found in the feces of black cockatoos that had been kept in captivity with access to dirt flooring. As a result of these findings, we recommend that screening and treatment for gastrointestinal parasites (in particular ascarid nematodes) be performed prior to release of rehabilitated black cockatoos to the wild in case parasitic burdens become pathogenic following the stress of release.

Retrospective studies by their nature often have inherent limitations; given that they are limited to cases which have already received treatment, the various groups to be studied and compared are defined by past therapeutic decisions (and in the case of this study, euthanasia decisions) (Johnston 2002). For example, the standard treatment regime of replacement fluid therapy, anti-inflammatory, antibiotic, and antifungal medication has been given to all cockatoos entering the PZVH since 2005, as experience has shown that traumatic injuries and other inflammatory conditions are not always initially apparent. Dehydration is also common to wild birds entering care due to injury, shock, and stress of handling; further, the high metabolic rate of birds makes them susceptible to fluid loss after short periods of anorexia (Cousquer 2005). Because these treatments were initiated together, it was not possible to analyze their individual effect on outcome. Other challenges lay in the collection of samples within a multi-staffed institution and the subjective and nonstandardized nature of some record entries. The development of clear protocols for treatment and sample collection, as well as standardizing the way in which data are entered, are recommended for staff working within wildlife

centers. These limitations and recommendations may have relevance for other studies that aim to assess the health of wild birds by monitoring cases that are admitted to veterinary hospitals and rehabilitation centers.

In conclusion, there are growing concerns for threatened bird populations worldwide as human activities increasingly affect natural habitats, and the rehabilitation of wild birds is likely to become an increasingly important practice. Although the value of rehabilitation for conservation of endangered species may continue to be debated, there is little doubt that rehabilitation programs can at the very least greatly increase human awareness of the influence of humans on free-living wildlife populations (Fix and Barrows 1990) and contribute to wild populations if otherwise fit and healthy individuals are reintroduced. We present statistics on the morbidity and mortality of wild endemic black cockatoos in the southwest of Western Australia for the first time. The number of injuries associated with human activities (particularly vehicle strike), even if underestimated, are a direct indication of the number of black cockatoos that may be affected by anthropogenic activities. From these results it is clear that, alongside threats facing wild cockatoo populations, such as habitat destruction and fragmentation, other anthropogenic impacts such as vehicle strike and shootings should not be ignored, especially when measures may be taken to mitigate these effects.

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