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Surviving the Urban Jungle: Anthropogenic Threats, Wildlife-Conflicts, and Management Recommendations for African Crowned Eagles

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Larger carnivores often trigger human-wildlife conflicts that arise from perceived threats to humans and domestic animals' safety, which generate the need for management and removal strategies. These issues become especially challenging when humans and wildlife coexist close to one another, for example, in urban landscapes. African Crowned Eagles (*Stephanoaetus coronatus*) are powerful forest raptors that breed within the metropolitan green-space system of Durban and Pietermaritzburg, South Africa. Negative human-wildlife interactions can occur because eagles occasionally predate on pets, such as cats (*Felis catus*) and small dogs (*Canis lupus familiaris*), and provisioning domestic stock to nest sites has previously been quantified. Here, wildlife management becomes critical, usually aimed at reducing or eliminating causes of economic or social harm, but have to be balanced against conservation goals regarding threatened species. In this study, we (i) identified causes of harm or loss of Crowned Eagles because of injuries (n = 53 incidents; 31 mortalities); and (ii) describe interactions with negative perceptions to human livelihoods, particularly concerning predation on pets and livestock. Anthropogenic causes of mortality were more likely to be reported than remote natural deaths, which provides important opportunities for mitigation measures. Most avoidable are electrocution on utility poles, persecution via gunshot wounds and poisoning (targeted or secondary), while collisions with anthropogenic structures, such as glass panes, vehicles and fence wires, are more challenging to mitigate. Out of 44 verified Crowned Eagle vs. pets and livestock conflicts, we documented 19 dog attacks (2012–2020), with detrimental impacts on social perception and acceptance of urban eagles. Pet and livestock conflicts were primarily associated with juveniles and immature eagles (83%). Of these, 19% occurred during September alone, which marks the end of the post-fledging dependency period; 70% occurred outside the breeding season. We provide management recommendations regarding various categories of Crowned Eagle human-wildlife interactions. For example, activities such as rehabilitation and falconry

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can coordinate to achieve a high standard of public support and conservation outcomes for Crowned Eagles. Finally, we discuss using different management intervention strategies, including rehabilitation, falconry, re-wildling processes, and lethal control of specific "problem" individuals toward achieving the goal of sustainable, healthy Crowned Eagle populations that coexist with humans in urban landscapes.

Keywords: apex predator, avian mortality, biodiversity conservation, birds of prey, falconry, illegal persecution, raptor rehabilitation, wildlife management

INTRODUCTION

Wildlife management is primarily a human response to reduce or eliminate causes of economic or social damage caused by wildlife (Treves et al., 2006). As humans transform landscapes on a global scale, interactions between wildlife and human livelihood and economic systems increase (Distefano, 2005). Conservation goals are becoming an important part of wildlife management, and negative interactions (hereafter termed conflicts) with stakeholders often arise (Redpath et al., 2013). Damage to food crops, livestock, and managed game are widespread causes of economic and social impact in ex-urban landscapes, involving farmers, game managers, and other interest groups (Redpath et al., 2004).

In urban landscapes, the public stakeholders have a strong bearing on perceptions of wildlife species that pose a perceived or real threat to human safety, and children in particular (Treves et al., 2006; Gehrt et al., 2010). This perception is extended to pets and companion animals (Gehrt et al., 2010; Poessel et al., 2012). While traditional responses were to hunt or otherwise target harmful species, in the case of large carnivores, this is often illegal through conservation regulations, or socially unacceptable on animal welfare grounds (Treves et al., 2006). In some cases, lethal control or removal of specific individuals can help to alleviate public fear and drive artificial selection in the population (Treves and Nauton-Treves, 2005). Increasingly in urban mosaic landscapes where wildlife persists, there are human–wildlife interactions and the need to turning conflict into coexistence (Patterson et al., 2018; Widdows and Downs, 2018; Frank et al., 2019; Streicher et al., 2021).

It is not just humans *per se*, but also anthropogenic structures that can pose threats to urban wildlife: vehicles, electrical networks, fences, windows, and mirroring surfaces, are some of the novel elements that can cause injuries or death, which can have severe impacts not only on individuals but also at the population level (Chace and Walsh, 2006; Sumasgutner et al., 2021). Most birds of prey rely on agility and fitness to actively hunt prey. Injuries that incapacitate hunting aptitude often result in starvation, illness, infection, and death. Typical injuries include trauma-associated cuts and abrasions, burns from electrocution, barbed wire and leghold trap ensnarement, broken bones, and puncture and gunshot wounds (Burke et al., 2002; Thompson et al., 2013; Maphalala et al., 2021). Individuals with these types of injuries could heal and recover if able to safely rest and obtain food without stress. However, rehabilitation and release procedures (e.g., hard-release of long-term admissions) of raptors may be met with poor post-release survival (Holz et al., 2006; Monadjem et al., 2014). Falconry, a centuries-old cultural heritage (UNESCO, 2012), is "taking quarry in its natural state using trained birds of prey" (IAF, 2015). The use of falconry techniques in rehabilitation and release has been successfully demonstrated (Holz et al., 2006; IAF, 2013), and rehabilitated raptors have a significant influence on the benefit of that individuals' life, and endangered species populations. Furthermore, many birds of prey conservation, education, and research programs have been initiated or led by falconers (Hartley, 1991; Cade and Temple, 1995; Kenward, 2009; Lombard, 2010; Dixon et al., 2011; IAF, 2015), and raptor display centers became important for conservation education and outreach in many parts of the world.

African Crowned Eagles (*Stephanoaetus coronatus,* hereafter Crowned Eagles) are a threatened forest species distributed across sub-Saharan Africa (IUCN, 2014). These large raptors uniquely persist in southern KwaZulu-Natal (KZN), South Africa, within residential green space mosaic landscapes in relatively high nesting densities compared with forest (Malan et al., 2001; McPherson et al., 2016a,b; Muller et al., 2020). This is an unusual phenomenon, the occurrence of a large raptor in an urban landscape (Amar et al., 2018), leading to several challenges for these eagles. One challenge for breeding pairs is the removal of alien trees, such as eucalyptus trees (*Eucalyptus saligna, E. camaldulensis*), by ring-barking/ girdling. In the course of a nationwide management scheme called "Working for Water," the government aims primarily to provide poverty-relief by employing task forces to control invasive vegetation and restore indigenous hydrological systems (Forsyth et al., 2004; Turpie et al., 2008). These dead trees stand defoliated and decaying for many years, resulting in a less sheltered nest site that will ultimately disappear (Reynolds et al., 2019). Another challenge is the likely increase in human-eagle interactions in the region regarding harm to livelihoods via pet and livestock attacks and eagles because of anthropogenic mortality. Crowned Eagles have occasionally been documented as a conflict species preying on livestock and pets (Boshoff, 1990; Boshoff et al., 1994; McPherson et al., 2016b; Reynolds et al., 2021) and, in rare circumstances, predatory attacks on children (Steyn, 1983; Thomsett, 2011).

Our objective was to identify and classify threats to breeding eagles and causes of nest failures, as well as the livelihood threats and harmful incidents regarding negative human-Crowned Eagle interactions (conflicts). Although the numbers and density of urban Crowned Eagles are relatively high compared with the rest of Africa (McPherson et al., 2016a,b; Muller et al., 2020), we hypothesized that their persistence in urban areas is dependent on nest site protection and reduced human-eagle conflict. Our

results formed the foundation for a series of discussions with local wildlife officials and stakeholders. These discussions resulted in a management strategy that is presented to improve future human-wildlife interactions and facilitate Crowned Eagle conservation in an increasingly urbanized world.

MATERIALS AND METHODS

We used two different data sets. Our breeding data were systematically collected and used to infer causes of nest failure were collected from April 2012 to April 2017 in southern KZN, South Africa (**Figure 1**), while our incident reports on livelihood threats and harm to Crowned Eagles spanned April 2012 until December 2020. The urban areas are described in detail in McPherson et al. (2016a; 2016b) and covers a range of a total of 92 different breeding territories (Muller et al., 2020). The long-term data collection included an annual breeding monitoring between August and December, whereby territories were visited regularly, at least twice per month, to assess nest progress (see Muller et al., 2020 for details). Breeding attempts were monitored until conclusion to provide information on breeding success, and eaglets were fitted with a G-ring and an alpha-numeric color ring when 70 ± 5 days old) in accordance with the SAFRING user manual (de Beer et al., 2001). Additionally, in 2012 and 2013, 11 nest camera-traps were installed at territories with high urban cover and historical reports of pet predation (see McPherson et al., 2016b for details). Another trail camera-trap was installed in 2014 to monitor the first Crowned Eagle nest located on anthropogenic infrastructure (**Supplementary Figure 1**).

Our data on human-eagle interactions were categorized into three groups: (1) nest site threats, (2) harm to Crowned Eagles from injury and mortality, and (3) negative interactions with pets (**Table 1**). While nest success was monitored systematically (as described above), other interactions were incidental reports. Regional awareness of the research and community science involvement was developed via outreach to existing formal and informal conservation networks, public seminars (n = 52; conservancies, bird clubs, eco-estates), a Facebook community page with 5,291 followers ([30.09.2021]),[1] articles in local newspapers (**Supplementary List 1**), and field activities in residential areas. Most incidents were recorded via feedback from concerned citizens, the public, rehabilitation organizations, Natal Falconry Club (NFC), Ezemvelo KZN Wildlife officers (EKZNW), eThekwini municipality, and the Durban Natural Science Museum. Incident reports were responded to personally (by SCM; and assisted by TPC, BHH, BDLP) or with the aid of Raptor Rescue Rehabilitation Centre (RR), Centre for the Rehabilitation of Wildlife (CROW), Free-Me, Monkey Helpline, NFC members, and EKZNW officers. Where possible, age classes of Crowned Eagles involved were identified by plumage characteristics and defined as; juvenile (fledge—12 months), immature (1–2 years), sub-adult (2–5 years), and adult (5+ years). Consequently the P.I. (SCM) verified reported cases with follow up site visits, carcass autopsies, and some cases, photographs, and a detailed interview report by telephone were sufficient to validate the information. Pet incidents reported here only include verifiable ones. For example, many pets, especially domestic cats (*Felis catus*) and small dogs (*Canis lupus familiaris*), go missing and are attributed to a local crowned eagle without further evidence. But missing pets cannot be verified and were not included in this summary analysis.

[1] www.facebook.com/CrownedEagleResearch

RESULTS

Nest Site Threats

Of the 239 Crowned Eagle breeding attempts recorded, 162 produced a nestling (67.8%; annual mean (±SE) = 68.7 ± 13.3%; lowest breeding success in 2015: 48.7%; highest breeding success in 2014: 81.6%; these breeding data are published in Muller et al., 2020). Of the 11 nest camera-traps installed for a diet study in 2012 and 2013, all recorded breeding attempts successfully fledged a nestling. Approximately half of the known nest failures over 5 years (n = 77) occurred during incubation and half during nestling rearing. If possible, causes of nest failures were identified on-site, and classified in the following three categories.

Alien Tree Management

To date, 104 used (current and historical) individual nests of Crowned Eagles were documented in the southern KZN study area and located in 92 different territories (**Figure 1**). Of these nests, 55 (52.9%) were built in non-indigenous trees (blue gum *E. saligna* n = 45; red river gum *E. camaldulensis* n = 4; *Pinus* spp. n = 4, syringa *Melia azedarach* n = 1; camphor *Cinnamomum camphora* n = 1). Some invasive tree management practices have been detrimental to Crowned Eagle nest sites. From 2011 to 2015, eight nest trees were subject to girdling (five have now collapsed). The resultant defoliating and decaying usually last for 5–15 years (pers. obs. SCM). A further two nest trees were killed because of fire. Crowned Eagles frequently reused traditional nest sites, and some continued to nest in defoliated

TABLE 1 | Categories of threats and areas of management opportunity for African Crowned Eagles in southern KwaZulu-Natal, South Africa.

Threats	Description
Nest site threats	
Exotic tree removal	Felling patch or tree with active nest
Ring-barking exotic trees	Defoliating nest tree, reduced cover
Proximity disturbance	Recreational activities, construction work near nest
Nest collapse	Natural occurrence easily countered
Injury and mortality	
Electrocution	Phase-phase/phase—ground
Poisoning	Targeted or secondary
Persecution	Shot, snared
Collision	Vehicles, walls, windows, wires/fences
Natural death	Starvation, intraspecific conflict (mortal combat), Injured while hunting
Other	e.g., Traditional medicine or '*muthi*'
Pet and livestock attacks	
Types of incidents	Identify breeds, locations, frequency
Biological context	Dispersal ecology, prey imprinting
Social context	Perceptions/supplementary feeding

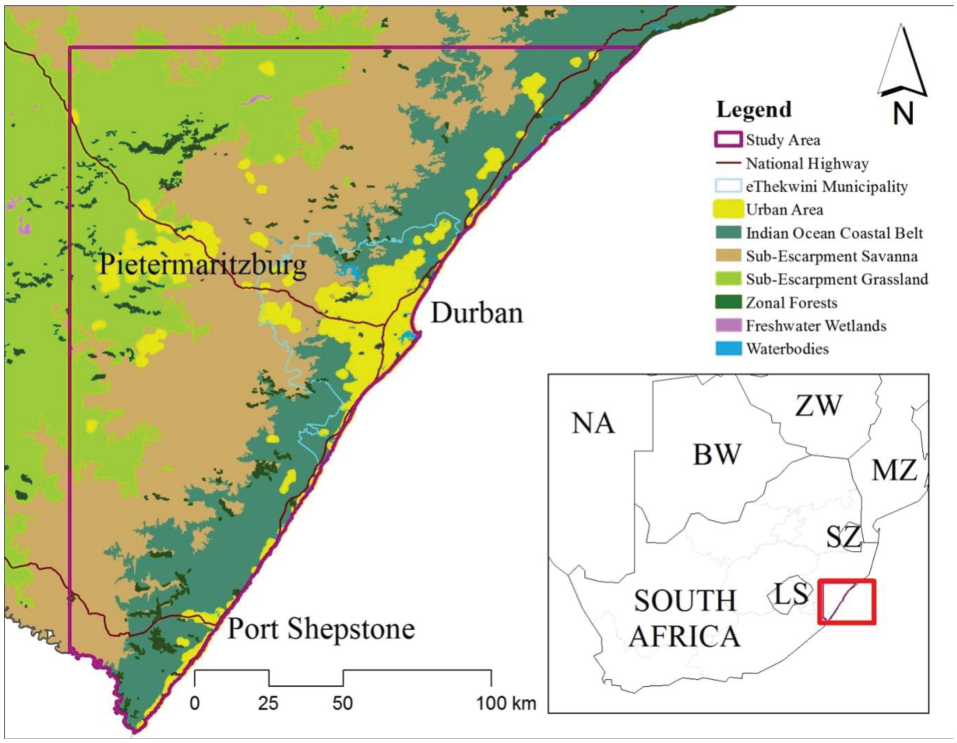

FIGURE 1 | The study site area within southern KwaZulu-Natal, South Africa.

trees. It is implied but not exactly known if the eagle's site fidelity on a tree that has been defoliated leads to higher breeding failure because of higher exposure to the elements (extreme summer heat and sunlight, and wind, rain, hail and lightning). On 14 Feb 2017, a gum tree, girdled many (unknown) years ago, was extensively decaying, collapsed with an eagle nestling near fledging age which survived the incident and could flap short distances to avoid capture. The parent birds continued to drop food to the nestling over the following days, and one week later, the nestling was seen perched high in a nearby tree (pers. obs. SCM). Another six nest trees of Crowned Eagle in the study stand fully foliaged, but isolated and exposed after the other large trees in the patch were felled and removed. Most nest trees have thus far been protected from felling; however, one in a more remote non-urban location was felled between breeding seasons.

Nest Disturbance

Crowned Eagle nest site disturbance is likely site-specific and could be based on local human activity, habitat, topology, and possibly also individual variation in sensitivity of the breeding pair. While most individuals showed signs of disturbance at 100–150 m, some pairs were habituated to daily residential and recreational activity within 30 m of the nest tree. Recently fledged Crowned Eagle offspring at these sites are generally inquisitive and habituate readily to benign human activities (pers. obs.).

One Crowned Eagle nest in Durban was positioned on a wastewater pipeline bridge (**Supplementary Figure 1**). The setting is reasonably remote and occasionally accessed by maintenance staff and contractors via a gated footbridge. The bridge's single pylon resembles a large tree trunk supporting the structure, and the nest is placed directly above this pillar on the maintenance footpath. This nest was first identified in 1989, with incomplete breeding records, including a failed attempt in 2008 when human disturbances were suspected (pers. comm. N. Leidenberg 2012). This nest site was not used for several subsequent years until we recorded the sporadic presence of sub-adults and adults between 2012 and 2015. In 2014, while being monitored by a trail camera-trap, this nest successfully fledged an eaglet. While many raptor species are known to nest on artificial structures (Cade et al., 1994; Machange et al., 2005; Sumasgutner et al., 2020), this is the only Crowned Eagle nest to date known to occur naturally on an artificial structure.

Nest Site Collapses and Collapse Mitigation

Crowned Eagles show high site fidelity, and fresh nesting material is added annually to rebuilding size and shape as old strata decay. This process sometimes leads to imbalance and eventually partial or complete collapse of the nest structure. This is particularly likely to occur during the violence of summer thunderstorms, affecting nestlings and recently fledged juveniles. In an emergency situation, a wooden pallet frame attached within 5 m of the fallen nest (**Supplementary Figure 2**) can serve as a platform to return a fallen eaglet (Hoffman and Hoffman, 2009). With foresight, a longer-term solution can be prepared

for unstable nests in advance of the nesting season. Platforms constructed of treated timber beams and interwoven branches, placed in the immediate vicinity of a previously collapsed nest, can be used as solid nest foundations for some eagles. At Victoria Country Club Estate nest site, Pietermaritzburg, such a platform was installed, and the pair immediately started building a nest on top (**Supplementary Figure 3**). This platform was used to successfully fledge a nestling in 2012. It remained unoccupied for the following season, where it was re-fitted with more concealed and natural-looking timber. The platform supported a larger nest in 2014, which also saw an eaglet successfully fledge, and again in 2016 without interim maintenance. At another site, a platform was installed 1 m lower than the collapsed nest's original position. This platform was ignored as the pair built a new nest from scratch in the original position on a natural fork.

Injury and Mortality of Crowned Eagles

Fifty-three separate incidents of harm to Crowned Eagles were documented during this study (**Figure 2**). Of these, 41 (77.4%) occurred from 2012 to the end of 2018, while six were reliable historical accounts before 2012 [pers. comm.; D. Brighton, M. Neethling, E. Rasmussen, and (Anonymous Reporter, 1997)]. Five were from 2019 to January 2021, where Covid-19 related travel restrictions have limited the P.I.

Of all documented Crowned Eagle deaths, electrocutions accounted for 21%, gunshot 15%, and vehicle collisions 13%. All forms of collisions accounted for 31% of all incidents (**Table 2**). It is unknown what fraction of Crowned Eagle mortality is reported, and we suspect relatively high numbers of electrocutions and gunshot deaths are not found nor reported. This is why post-fledging Crowned Eagle telemetry studies to gain quantitative knowledge of mortality are urgently needed. Furthermore, reported electrocution cases were 100% fatal, and it is unknown to what extent minor electrocutions can influence avoidance behaviour of electrical infrastructure.

Crowned Eagle juveniles can become habituated relatively easily in the first three months post-fledging if given positive close encounters with humans—especially regarding food. This makes them trusting and susceptible to harmful persecution in surrounding areas. For example, in a historical incident of supplementary feeding of a fledged juvenile (pers. comm. D. Brighton 2012), the individual was frequently provided portions of red meat over several weeks. It habituated to a point where it could be fed from a gloved hand. At eight months of age, it was also spending time close to other houses in the neighborhood and thereafter was shot in a resident's yard.

The 2012 Crowned Eagle juvenile from Zimbali Coastal Resort (ID: N2) also became habituated by being forced by natural events to feed on prey dropped to the forest floor below the nest. This location was 15 m from the footpath to a lodge restaurant. This eagle eventually allowed humans to approach within 1 m, calmly perched on a footpath handrail (**Supplementary Figure 4**). This eagle injured people walking or jogging on the footpath on two documented occasions by grasping at the head or shoulders during a daring flyby (**Table 3**). Although considered "play" or practice rather than hunting attempts, the ∼60 mm long talons and great grip strength make these potentially serious incidents. *In situ* human-aversion training was given to increase the eagles' flight-distance. No other human-attacks (except toward researchers climbing to nests where one individual female made contact with the climber and several others performed close fly-byes) were recorded during our study period.

Pet and Livestock Attacks

A total of 66% of verified attacks (n = 29/44) on pets reported during our study were by juvenile and immature Crowned Eagles. Awareness of the research and reports of verified incidents appeared to be high in some neighborhoods, seemingly facilitated by a few key contacts and active neighborhood watch or social media groups.

The first significant "problem eagle" during the research occurred in winter 2012. A juvenile Crowned Eagle was identified in three dog attacks and implicated in more than 12 domestic cat disappearances within one neighborhood from May to November 2012. Postscript information came to light that recently vacated tenants in the neighborhood had been offering processed sausages to the juvenile eagle on their property. This likely resulted in the individuals' food search patterns being directed toward human habitations. Various threats on the eagle's life were received, and intervention (translocation) was intended; however, capture attempts failed and shortly thereafter, in October 2012, the last sighting was recorded.

Domestic dog attacks by Crowned Eagles appeared much more likely to be reported than domestic cat attacks. Perhaps this is because of predatory tactics (rapid removal of a cat from the attack location), socio-demographic factors, and differing perceptions of conflict issues. For example, five individual eagles could potentially be attributed to the non-validated reported disappearance of 35 cats from 2012 to 2015, whereas 13 dogs were injured or killed. Dog breeds included in this sample are Jack Russell, Chihuahua, Daschund, miniature Doberman Pincher, Yorkshire Terrier and unattended puppies of various breeds. These breeds, especially brown-coated types, are superficially similar in size and shape to one of their preferred prey, rock hyrax *Procavia capensis* (McPherson et al., 2016b).

Non-mortal attacks on pets were typically addressed by local veterinary clinics. The range of injuries observed could be caused by Crowned Eagles, as well as dogs and vervet monkeys (*Chlorocebus pygerythrus*). Therefore, reliable identification of taphonomic signs is required for accurate documentation. Seasonal differences in pet and livestock conflicts, along with the demographics of juvenile and immature birds, revealed that 19% occurred during September alone (**Table 3B**), which marks the end of the post-fledging dependency period. Overall, 70% occurred outside the breeding season and were primarily associated with juveniles and immature eagles (83%; **Table 3C**).

DISCUSSION

Globally, the growth of urban environments is one of the most significant factors affecting wildlife and human-wildlife

FIGURE 2 | Typical injuries of African Crowned Eagles. Print of feather dust after a collision with a mirrored window by an adult male Crowned Eagle (©Jacques Sellshop). Immature Crowned Eagle "V4" electrocuted while alighting on an electricity pole while carrying prey (©Ben Hoffman). Adult colliding with wire fence while in pursuit of domestic chicken (©Adeline McCarter). X-Ray of Crowned Eagle "H9" admitted with a fractured ulna; also apparent is a calcification on tibiotarsus and a.177 airgun pellet in throat/crop area (©Oliver Tatham).

interactions (Soulsbury and White, 2016; Frank et al., 2019). Despite the many challenges of urban environments, there has been an increasing tendency for some herp, avian and mammalian species to persist in the urban habitats of KwaZulu-Natal (Downs et al., 2021). In our study area, the maintenance of green spaces (especially natural habitats and human-managed green spaces) and connectivity within an urban matrix increase biodiversity and provide conservation value (Roberts, 1994; Downs et al., 2021). The Crowned Eagle is one of these species persisting in this urban mosaic landscape, but it faces anthropogenic threats.

Urban Crowned Eagles' main threats are nest failures because of nest disturbance and extreme weather, incidents with anthropogenic infrastructure, or direct human-eagle interactions that cause injuries and death (McPherson et al., 2016a,b; Muller et al., 2020; Downs et al., 2021). Approx. 30% of the observed annual breeding failure rate (Muller et al., 2020) could be allocated to nest disturbance and heavy rainfall events, specifically affecting girdled eucalyptus trees. More difficult to quantify are injury and death after fledging, which often appear to be human-related. As humans are directly and indirectly responsible for large scale ecosystem disruption and animal mortality, we become increasingly aware of compensating for such negative impacts. Mitigation measures should make quantifiable offsets to enhance the conservation of target species and habitats. The most direct mitigated threat is

TABLE 2 | Categories and outcome of incident types harming African Crowned Eagles in southern KwaZulu-Natal ("at risk" = confirmed report but no recorded injury/death; "non-fatal" injuries with unknown long-term outcome and confirmed "mortalities").

	Collisions													
	Vehicle	Airstrike	Wall	Window	Wire/Fence	Natural obstacle	Electrocution	Poison	Snare	Trapped/entangled	Gunshot	Threat of persecution	Injured while hunting	Intraspecific combat
At risk	1									1		5		1
Non-fatal	2			2	3	1		1		3	1		1	
Mortality	4	1	1	1	1	1	11	1	1		7			2
Total	**7**	**1**	**1**	**3**	**4**	**2**	**11**	**2**	**1**	**4**	**8**	**5**	**1**	**3**

eagle persecution, which generally can be best influenced by awareness campaigns and stakeholder empowerment via engaging management plans (Distefano, 2005). Presently various urban conservancies make a valuable contribution to awareness and increasing wildlife persistence in the study area[2] (e.g., Kloof Conservancy etc.).[3]

Threats to Urban Crowned Eagles

Nest Site Threats

Nest site protection is important for urban Crowned Eagles. They prefer to nest in tall trees, usually located in green belts in the urban mosaic (McPherson et al., 2016b), and frequently reuse traditional nest sites. Eucalyptus trees are included in the government funded "Working for Water" management scheme (Working for Water, 2012). Through this practice, the traditional nest site experiences increased exposure to weather extremes, which potentially reduces nest success. These eucalyptus trees provide not only nesting sites for Crowned Eagles (McPherson et al., 2016a, 2021), but also Black Sparrowhawks (*Accipiter melanoleucus*; Malan and Robinson, 2001; Malan and Shultz, 2002; Sumasgutner et al., 2016; Wreford et al., 2017), African Fish Eagles (*Haliaeetus vocifer*; Welz and Jenkins, 2005), and Woolly-necked Storks (*Ciconia episcopus* Thabethe et al., 2021). Considering our results about the successful protection of nest trees and the multi-year nest-site fidelity in Crowned Eagles, identified nest trees should remain protected for at least 3 years after a breeding event. Protection should extend to the immediate trees around the nest tree (4–10 trees with DBH > 500 mm) to provide shelter and seclusion. In addition, if preferred Crowned Eagle nest sites are limiting, nest-site collapse mitigation should be implemented or artificial platforms provided.

Injury and Mortality of Crowned Eagles

We documented numerous intentional human harm incidents to Crowned Eagles during our study, with most involving juvenile and immature Crowned Eagles, especially in autumn (post-fledgling). Learned tolerance and the founder effect may increase Crowned Eagles' ability to persist locally and expand into urban forests elsewhere. Crowned eagle collisions with anthropogenic structures, and gunshot wounds, accounted for most Crowned Eagle deaths in our study.

There is growing international and national awareness of the impact of electricity networks on raptor electrocution and collision with wires (Lehman et al., 2007; Jenkins et al., 2010). The South African national electricity provider ESKOM has partnered with the Endangered Wildlife Trust and developed reactive mitigation responses for raptor electrocutions (Van Rooyen, 1999; Hoogstad and Chetty, 2015). Crowned Eagle electrocutions were documented and reported, and follow up visits confirmed insulation strips were fitted within the three months of reporting. Electrocution can have significant population-level effects (Harness et al., 2008; Fox and Wynn, 2010). The issue is a legacy of a nationwide systemic design in South Africa, and we urge the inception of statutory requirements for the rapid, proactive replacement of unsafe designs.

Pet and Livestock Attacks

Most verified Crowned Eagle attacks (n = 29) on pets were by juveniles or immatures in our study. Generally, domestic pets contribute less than 1% of their breeding diet (McPherson et al., 2016b). However, the isolated cases of juvenile Crowned Eagles taking pets cause negative perceptions about these raptors (McPherson unpubl. data). Developing awareness in veterinary clinics with an easy reporting scheme would provide reliable data on the quantity and distribution of pet-eagle interactions and improve awareness and management efficacy.

Negative experiences (e.g., frightened during a hunting attempt or kill, lack of food reward from hunting attempt) provide an opportunity for an individual eagle to modify behavior and reduce interest and intent on domestic animals, which would otherwise generate negative public attitudes. Where an individual eagle becomes habitual in foraging for pets or stock, removing the individual could prevent a wider public reaction toward the Crowned Eagle population. Exercising non-lethal measures by removing or translocation of specific individuals could protect both the individual and the species reputation (Treves and Nauton-Treves, 2005), and allows for low impact and sustainable use of these individuals.

[2]https://conservancieskzn.org.za

[3]https://www.kloofconservancy.org.za

TABLE 3 | Pet and livestock attacks by African Crowned Eagles in southern KwaZulu-Natal by (A) prey type; (B) seasonal occurrence; and, (C) age structure.

Conflict category	Habituated, threatening, suspected	Non-fatal attack on pet	Pet/stock depredation	Description
(A) Incidents by prey-type				
Dog		11	8	Dog numbers are fairly reliable to total individuals reported
Cat		6	5	Often a single confirmed kill is accompanied by accusations of several missing cats in neighborhood
Chickens			5	Fowl incidents nearly always involve multiple casualties
Ducks			3	Many kills from each report, one bird killed 2 ducks per day for a month
Captive duiker		1	2	Top-threatened and protected species and of high value for hunting industry
Guineafowl			2	Multiple kills in a flock
Rabbits piglets			1	Many taken from one incident as an eagle took up residence at a petting zoo
Death threat to eagle	4			These threats are not linked to confirmed attacks but are very likely attributed to the suspicions from pets lost in area
Habituated human threat	5			Overly habituated individuals sometime injuring visitors to lodge and residents jogging trails
Total	**9**	**18**	**26**	
(B) Incidents by month (2012-2020)				
Jan	1	1	2	Nestling of the year fledged, still completely dependant on food provisions by parents. Biennial nests, the immature is often dispersed.
Feb		1	4	
Mar				
Apr	2	3	1	The juvenile is still largely reliant on provisioning and will start self-hunting. Biennial or failed previous year nests, pair are active nest building and courtship.
May	3	1	2	
Jun		2	2	
Jul		1	4	Incubation period. At biennial nests, the juvenile is more independent but when unsuccessful, its presence and begging suppress the pairs breeding. At annual breeding pairs the juvenile may be forced into early independence.
Aug	1	2	3	
Sept	2	3	5	
Oct			1	Active nests, nestling in nest. At biennial nests the immature becomes much more independent, many Food resources more available (hadeda ibis nestlings, etc.) and makes dispersal movements.
Nov		2		
Dec		2	2	
(C) Incidents by Crowned Eagle age structure				
Adult		1	3	
Subadult		2	2	
Immature	3	4	8	
Juvenile	6	8	9	
Unknown		3	4	
Total	**9**	**18**	**26**	

Bold text denotes total numbers.

Management Implications

Mortality, Mitigation, and Rehabilitation

Despite our qualitative summary of Crowned Eagle mortality, there remains a gap in our knowledge about this mortality's quantitative, population-level effects. Ongoing research of breeding success and mark re-sighting data will be used to model the population dynamics to inform recruitment, dispersal, and population stability. Future research should focus on the quantitative identification of sub-adult mortality. To better understand the post-release behavior, and outcomes of

management intervention, the use of modern telemetry is affordable and scientifically valuable. A suggested voluntary requirement of the sustainable use of "problem" Crowned Eagles for falconry and falconry-based re-wilding efforts is the sponsorship and fitting of post-release telemetry—preferably multi-year lifespan, mortality alert system, and PTT or GPS with CTT, GSM, or Argos transmission in the southern KZN region.

Incidents of Crowned Eagle persecution should be investigated further. Wildlife crimes investigations should be pursued to raise awareness and reservations for further illegal persecution. In particular, surveys into the local "*muthi*" markets were not included during our research. Raptor trade for such belief-based use (and also for bushmeat) is concentrated in West and Central Africa (Buij et al., 2016), and hunting pressure linked to the trade is currently on the rise (Bates et al., 2021; Sumasgutner et al., 2021). To quantify such practices in other parts of Africa would be a valuable addition to understand potential population impacts on Crowned Eagles in peri-urban and rural areas. The impacts of electrocution and collisions should be a primary focus of this further research as these could be readily mitigated (Dwyer and Mannan, 2007; Dwyer et al., 2014; Jenkins and Benn, 1998).

Presently there is good engagement and collective effort for Crowned Eagle conservation in the study area. This is demonstrated with the involvement of various Non-Government Organizations (RR, SAFA, NFC, CROW, Free-me, Birdlife South Africa's affiliated regional clubs), conservancies and EKZNW. These collaborations are valuable foundations for the success of a management strategy, but also rely heavily on the awareness, reporting networks, and goodwill of the local communities.

Reducing Pet-Wildlife Interactions

The first step in reducing threat and harm to domestic pets from urban Crowned Eagles is to encourage pet owners to have an outdoor enclosure for their pets. Catio (wordplay on patio) enclosures are becoming popular and commercially available (CatioSpaces, 2015). We highly recommend the development of the pet enclosure ethos in Durban and Pietermaritzburg. This type of enclosure benefits the health of the pet and of the indigenous fauna: the enclosure isolates the cat or dog from wild animals and zoonosis such as rabies, toxoplasmosis, mange, and disease vectors such as fleas (Garrett, 1994; Bradley and Altizer, 2007; Lepczyk et al., 2015). It protects the garden wildlife from recreational hunting by domestic cats, which has a vast impact on wildlife (Loss et al., 2013; Seymour et al., 2020), and an enclosure protects the cat or small dog from being attacked by large wild animals, including Crowned Eagle and wandering dogs. Without an enclosure, dogs over 10 kg as pack companions to small dogs reduce opportunities for Crowned Eagles to attack.

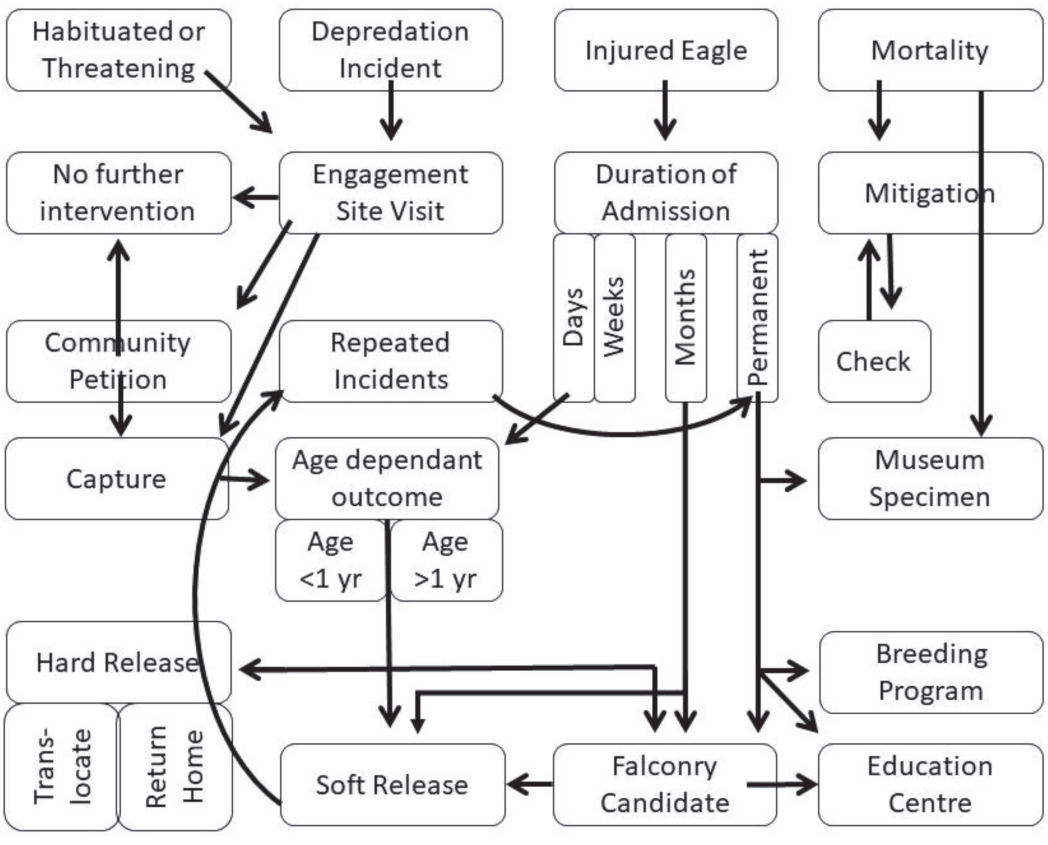

FIGURE 3 | Decision flow chart of management actions regarding human-wildlife conflicts with the African Crowned Eagle in southern KwaZulu-Natal, South Africa.

Procedural Management

Actively managing Crowned Eagle wildlife conflict will benefit the community and the urban breeding population's persistence. A decision flow chart (**Figure 3**) provides procedural information for documentation, site evaluation, and management actions to implement this. This was developed over successive meetings and correspondence with EKZNW, eThekwini Municipality, RR, and NFC.

Through the course of our study, proactive awareness mainly included the development of public awareness of Crowned Eagles has developed through social media, seminar series, posters, newsletter articles, and especially, site visits. These methods have empowered citizens to be involved in the research. An annual press release in local newspapers and interest club magazines would aid in the better reporting and data collection of incidents and attacks. Attacks on pets by Crowned Eagles most frequently occurred in autumn and winter; therefore, the information is best distributed in April.

In contrast, reactive responses were undertaken following incidents when a pet was killed or seriously injured, or an eagle was threatening and confiding to humans, and management action then helped mitigate the social and ecological impact of the identified culprit. A site visit from an individual from the collaborating organizations can inform of the management options available. Necessary ID, location and report information is documented on the EKZNW/University of KwaZulu-Natal (UKZN) research database. If a further conflict occurs or there is strong community support for management action, actions might include a direct translocation (*ca.* 1–6 h in capture and transit), or admissions to rehabilitation, soft hack, and falconry re-wilding (one month to four years). The effectiveness of falconry-based rewilding is presently being trialed.

CONCLUSION

In conclusion, the African Crowned Eagle is a large raptor that has successfully moved into urban landscapes in several major cities in South Africa (McPherson et al., 2021). Inevitably, the presence of such a species generates human-wildlife interactions as well as many significant risks to the birds imposed by human infrastructure and activity. We have attempted to summarize a range of issues and concerns that relate to the persistence of this species in urban areas and to provide the foundation for developing potential strategies for its management and conservation. In particular, it is hoped that this facilitates people of various socio-economic and cultural backgrounds to coexist with their urban eagles. With continued increased urbanization globally, there is a need for human-wildlife interactions, especially conflict, to be turned into coexistence (Frank et al., 2019) for species persistence in urban mosaic landscapes (Downs et al., 2021).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by the University of KwaZulu-Natal Ethics Committee.

AUTHOR CONTRIBUTIONS

SM, CD, and MB conceptualized the study and sought funding. SM, BH, BP, MB, PS, and TC collected data. SM collated and analyzed data, drafted the manuscript, and the other authors made editorial inputs. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2021.662623/full#supplementary-material

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